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Potential of Tea Pruning Litters as Key Source of Organic Matter and Major Nutrients in Tea Plantations

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Abstract

The study investigates the significance of pruning litter from tea (*Camellia sinensis* L.) plantations as a renewable source of organic matter and major nutrients. The experiment was conducted in Northeast India with three tea varieties: *Manipuri Jat*, TV1, and TV18. Sixty year old tea bushes subjected to light pruning (LP) were studied, with bush populations in a 20:30:50 blend of quality, standard, and yield varieties. Pruning litter biomass from randomly selected plants was weighed fresh and after drying segregated into leaf, twigs, and stems for nutrient analysis. Results showed that the respective total fresh and dry weight were 32.90 and 13.25 t ha^{-1}. The varietal difference in litter production, with TV18 contributing the highest total biomass per hectare due to greater bush density. Dry matter recovery rates were consistent at around 40% across the tea varieties. Moreover, nutrient analyses revealed recoverable amounts of 260 kg nitrogen ha^{-1}, 68 kg phosphorus (P_2O_5) ha^{-1}, 216 kg potassium (K_2O) ha^{-1}, 97 kg calcium ha^{-1}, 25 kg magnesium ha^{-1}, and 17 kg sulphur ha^{-1} from pruning litter. Minimal varietal differences were observed in nitrogen, phosphorus, calcium, magnesium, and sulphur, while potassium showed slightly higher variability. The findings highlight the value of integrating the recycling of pruning residue into agronomic practices to improve soil health, reduce input costs, and promote the long-term sustainability of tea agroecosystems.

Keywords: Nutrient Cycling; Pruning Litter; Sustainable Agriculture;Tea

Abbreviations

LP: Light Pruning; UP: Un-Prune; DS: Deep Skiffing; FW: Fresh Weight; DMR: Dry Matter Recovery; DW: Dry Weight; TFW: Total Fresh Weight; TDW: Total Dry Weight.

Introduction

Tea (*Camellia sinensis* L.) is a widely consumed beverage worldwide, originating from Southeast Asia. Its global popularity reflects its blend of taste, aroma, and cultural significance [1]. The signature astringency and subtle bitterness of tea are attributed to its rich polyphenol content, while the amino acid theanine promotes both relaxation and alertness, giving tea drinkers a unique sensory experience [2,3]. Tea has also been linked with the prevention of several chronic diseases, making it a potentially beneficial drink for long-term health [4].

Growing tea is a meticulous process requiring ongoing manual intervention and skill. From fertilisation and weed control to pest management and, most notably, pruning,

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each cultivation step is vital to achieving high yields and exceptional leaf quality [5]. The hallmark of tea harvesting is the selective plucking of two tender leaves and a bud, a technique that ensures consistent production of top-quality leaves throughout the growing season [6].

Pruning, among all agronomic practices, is especially crucial for maintaining the productivity and health of tea bushes [7]. As bushes mature, they can develop weak, stunted shoots known as *banjhi*, which can reduce yield [8]. By removing old, non-productive growth, pruning revitalises the plant and promotes the emergence of vigorous new shoots [9]. These effects also help explain why unpruned tea plants exhibit lower levels of beneficial catechins, underscoring the metabolic distinctions between pruned and unpruned bushes [10]. Pruning works by minimising auxin concentrations in cut areas, which in turn stimulates the production of cytokinins and gibberellins hormones that activate dormant buds and encourage robust shoot growth [11,12]. The technique also improves the overall structure of the bush, enabling more efficient light capture and air circulation, both of which are linked to higher yields and superior tea quality [13,14]. The intensity of pruning matters: heavy cuts can refresh ageing bushes but may temporarily stress the plant, whereas lighter trims allow sustained photosynthesis but may not yield maximum yield increases [15]. Beyond shoot production, pruning stimulates branching, enhances root systems, and supports greater nutrient uptake from the soil [16,17]. It also delays senescence, improves soil health, and increases overall plant biomass by accelerating the decomposition of pruned material, thereby returning organic matter to the soil [18]. Over time, pruning alters soil microbial communities, encouraging the growth of beneficial organisms that further assist tea plants [14]. Recent findings even suggest that the positive effects of pruning on yield and quality may surpass those of fertilisation, due to its influence on plant metabolism and soil biology [19].

A key goal of pruning is to keep the plucking table, the surface where shoots are harvested, at an ideal height for efficient picking. As tea bushes grow, this height gradually rises, a phenomenon called "creep," which is controlled through scheduled pruning [20,21]. Regular pruning preserves bush shape, sustains vegetative growth, and channels the plant's resources into producing high-quality leaves.

In the tea gardens of Northeast India, growers usually adopt a three- or four-year pruning cycle, adjusting their approach based on the specific climate and cultivar. This cycle typically involves light pruning (LP), un-prune (UP), and deep skiffing (DS). For example, a four-year sequence might rotate through LP-UP-DS-UP. Unpruned years leave the bushes largely intact, while DS entails cutting stems 12-15 cm above the last LP mark, resulting in moderate biomass removal. Light pruning, on the other hand, trims new shoots and leaves a margin of wood above the previous cut, with stick thickness varying by site. Because these methods produce significant amounts of pruning litter ranging from about 20 to over 60 tons per hectare, depending on the plant spacing, bush frame, stick thickness, type of pruning etc. their residues become an important resource rather than waste in terms of biomass and plant nutrients. The practice of recycling pruning residues is thus a key element of sustainable tea farming, as it returns both leaf and woody material to the ecosystem and fortifies soil fertility [22,23].

This study was conducted to determine the biomass and nutrient contribution of pruning residues from different tea varieties by measuring both their fresh and dry weights. By doing so, it sharpens the focus on pruning litter recycling as a key factor in sustainable tea production and soil health for future generations of growers.

Materials and Methods

Details of the Experiment Include the Site, Planting Pattern, Bush Pattern, Bush Population, and Pruning Style

In the Experimental Tea Estate at Borbhetta, Jorhat, Assam, India; Section No. 24 (26°43′05.72″ N and 94°12′08.38″ E) had been selected for the study to quantify the volume of tea pruning litter. This section features a diverse plantation established in 1961 that includes *Manipuri Jat* (a quality tea variety), TV1 (a standard clone), and TV18 (a yield clone). The planting design follows a double hedge system with a ratio of 20% quality clones, 50% standard clones, and 30% yield clones, arranged with a spacing of 4' × 3' × 3'. The bush populations for each tea variety are as follows: TV1 had 4600 plants, TV18 had 2760 plants, and *Manipuri Jat* had 1840 plants, for a total of 9200 plants per hectare. The section underwent a light prune (LP) operation in the year 2025 (Figure 1a).

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Figure 1: Field operations associated with pruning operation in tea. (a) Light pruning (LP) operations conducted in the experimental plot to regulate bush frame and promote rejuvenation. (b) Collection and weighing of freshly cut pruning litter to quantify biomass and assess nutrient recycling potential.

Procedure for Collecting Weights of Fresh and Dry Pruning Litter

To ensure homogeneity in the weight of the pruning litter, ten randomly selected tea bushes were labelled in each variety. Following the pruning operation, meticulously recorded the weight of the fresh pruning litter collected from each of the selected plants using GLUN® Electronic Portable Digital LED Screen Weighing Scale (50 kg/110 Lb), as illustrated in Figure 1b. The fresh pruning litter was then spread out to dry under the sun for a duration of approximately 30 to 40 days. After the samples had dried completely, again measured their weight to document the dry weight of each individual samples.

Using these measurements, the fresh and dry pruning litter biomass generated per hectare was calculated utilizing the formulas outlined below.

TFPLW (kg ha^{-1}) = (Mean FPLW of TV1 × TV1 population) + (Mean FPLW of TV18 × TV18 population) + (Mean FPLW of *Manipuri Jat* × *Manipuri Jat* population)

TDPLW (kg ha^{-1}) = (Mean DPLW of TV1 × TV1 population) + (Mean DPLW of TV18 × TV18 population) + (Mean DPLW of *Manipuri Jat* × *Manipuri Jat* population)

Where; TFPLW and TDPLW are total fresh pruning litter weight and total dry pruning litter weight, respectively, and FPLW and DPLW are fresh pruning litter weight and dry pruning litter weight, respectively.

Processing and Nutrient Analysis of the Different Parts of the Pruning Litters

Pruning litter samples were systematically classified into three distinct categories: leaf, twigs, and stems. Each category was carefully separated and ovendried at a controlled temperature to remove residual moisture, thereby facilitating uniform processing. The dried materials were subsequently ground to a fine powder using a laboratory sample grinder to ensure homogeneity. The finely ground samples were subjected to tri-acid (HNO_3:H_2SO_4: $HClO_4$ ≡ 9:1:4) and di-acid (HNO_3:$HClO_4$ ≡ 9:4) digestions in accordance with established analytical protocols, thereby releasing bound nutrients into solution. The digested extracts were then analysed using standard procedures to determine nutrient composition, as outlined in [24]. The nitrogen was estimated using Kjeldahl method, phosphorus by Vanadomolybdate method using spectrophotometer (Model: Varian; 50 Bio), potassium by flame photometer (Systronics Model 130), calcium and magnesium by EDTA method and sulphur by turbidimetry method using spectrophotometer (Model: Varian; 50 Bio).

Statistical Analysis

Statistical analyses of the important parameters were done by following the appropriate methodologies [25]. The data of the major chemical properties of soils were performed in Excel.

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Result

Pruning Litter Production and Dry Matter Recovery among Tea Clones

The detailed data for individual bushes of three tea varieties *Manipuri Jat*, TV1, and TV18 are presented in Table 1. The analysis highlights clear variability among varieties in fresh and dry pruning litter production as well as dry matter recovery.

Table 1: Fresh and dry weight of pruning litter with the recovery of dry matter from three distinct tea varieties.

Bush No.	*Manipuri Jat*			TV1			TV18		
	FW (kg)	DW (kg)	DMR (%)	FW (kg)	DW (kg)	DMR (%)	FW (kg)	DW (kg)	DMR (%)
Bush-1	3.80	1.65	43.42	3.68	1.36	37.01	4.05	1.53	37.83
Bush-2	6.40	2.75	42.97	2.70	1.12	41.48	4.45	1.75	39.33
Bush-3	0.88	0.35	40.00	1.40	0.55	39.29	7.50	3.13	41.67
Bush-4	1.35	0.55	41.04	2.40	1.05	43.75	6.70	2.79	41.64
Bush-5	1.68	0.65	38.81	2.50	1.12	44.80	3.50	1.35	38.57
Bush-6	8.00	3.25	40.63	3.90	1.56	40.00	4.30	1.52	35.35
Bush-7	5.05	2.10	41.58	1.10	0.45	40.91	5.50	2.17	39.45
Bush-8	6.80	2.75	40.44	2.00	0.79	39.50	3.20	1.28	40.00
Bush-9	12.20	4.69	38.44	1.23	0.45	36.73	3.40	1.21	35.59
Bush-10	5.50	2.32	42.18	1.80	0.74	41.11	4.30	1.89	43.95
Mean	5.16	2.11	40.95	2.27	0.919	40.46	4.69	1.86	39.34
Range	0.88-12.20	0.35-4.69	38.44-43.42	1.10-3.90	0.45-1.56	36.73-44.80	3.20-6.70	1.21-3.13	37.83-43.95
On account of bush population (t ha-1) ± Sd (Standard deviation)	9.51±2.02	3.88±0.79	40.95±0.52	10.45±1.41	4.23±0.56	40.46±0.81	12.94±1.26	5.14±0.57	39.34± 0.85
TFW: 32.90±1.80, TDW: 13.25±0.63									

FW: Fresh weight, DW: Dry weight, DMR: Dry matter recovery, TFW: Total fresh weight, TDW: Total dry weight.

In *Manipuri Jat*, the fresh weight (FW) of pruning litter per bush ranged from 0.88 to 12.20 kg, with a mean of 5.16 kg. The corresponding dry weight (DW) ranged from 0.35 to 4.69 kg, averaging 2.11 kg per bush. The dry matter recovery (DMR), calculated as the percentage of dry weight from fresh weight, averaged 40.95%, with individual bushes ranging from 38.44% to 43.42%. In case of TV1 tea variety, the fresh pruning litter per bush ranged from 1.10 to 3.90 kg (mean: 2.27 kg), and dry weight ranged from 0.45 to 1.56 kg (mean: 0.92 kg). The DMR for TV1 was similar to *Manipuri Jat*, averaging 40.46%, with a range from 36.73% to 44.80%. Moreover, the TV18 tea clone showed fresh pruning litter per bush between 3.20 and 6.70 kg (mean: 4.69 kg), and dry weights ranging from 1.21 to 3.13 kg (mean: 1.86 kg). The average DMR for TV18 was slightly lower at 39.34%, with a range of 35.35% to 43.95%. When scaled up to the hectare level, accounting for bush population, TV18 clone contributed the highest total fresh and dry pruning litter: 12.94 t ha^{-1} fresh and 5.14 t ha^{-1} dry, followed by TV1 (10.45 t ha^{-1} fresh, 4.23 t ha^{-1} dry) and *Manipuri Jat* (9.51 t ha^{-1} fresh, 3.88 t ha^{-1} dry). The overall mean dry matter recovery for all clones was approximately 40.25%.

The total fresh pruning litter (TFW) produced by all clones was 32.90 t ha^{-1}, and the total dry pruning litter (TDW) was 13.25 t ha^{-1}. These findings indicate that while *Manipuri Jat* bushes yielded the highest litter weights on a per-plant basis, the higher bush density of TV18 resulted in the greatest overall contribution of pruning litter per hectare. Dry matter recovery was relatively consistent across all varieties, with small differences. The results demonstrated a significant variation in both litter production and dry matter recovery among the tea varieties studied, underscoring the importance of varietal selection for optimizing organic matter management and nutrient cycling in tea plantations.

The Nutrient Content In Leaf, Twigs, and Stems in the Pruning Litter

Nitrogen (N): Analysis of N content variation in leaf, twigs, and stems among different tea varieties (Figure 2a) shows nearly identical levels across all three clones. In leaf, N content was 3.62% in *Manipuri Jat*, 3.63% in TV 1, and 3.58% in TV 18. In twigs, values were 1.38% in *Manipuri Jat*, 1.40% in TV 1, and 1.35% in TV 18. Stems also showed comparable

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N content: 0.89% in *Manipuri Jat*, 0.92% in TV 1, and 0.89% in TV 18.

Phosphorus (P): Variation in P content in leaf, twigs, and stems among tea varieties (Figure 2b) showed a similar pattern. Leaf P content was 0.90% in *Manipuri Jat*, 0.87% in TV 1, and 0.89% in TV 18. Twigs contained 0.61% in *Manipuri Jat*, 0.59% in TV 1, and 0.56% in TV 18. Stem P content was 0.07% in *Manipuri Jat*, 0.06% in TV 1, and 0.08% in TV 18. Overall, phosphorus content varied little among varieties across all plant parts.

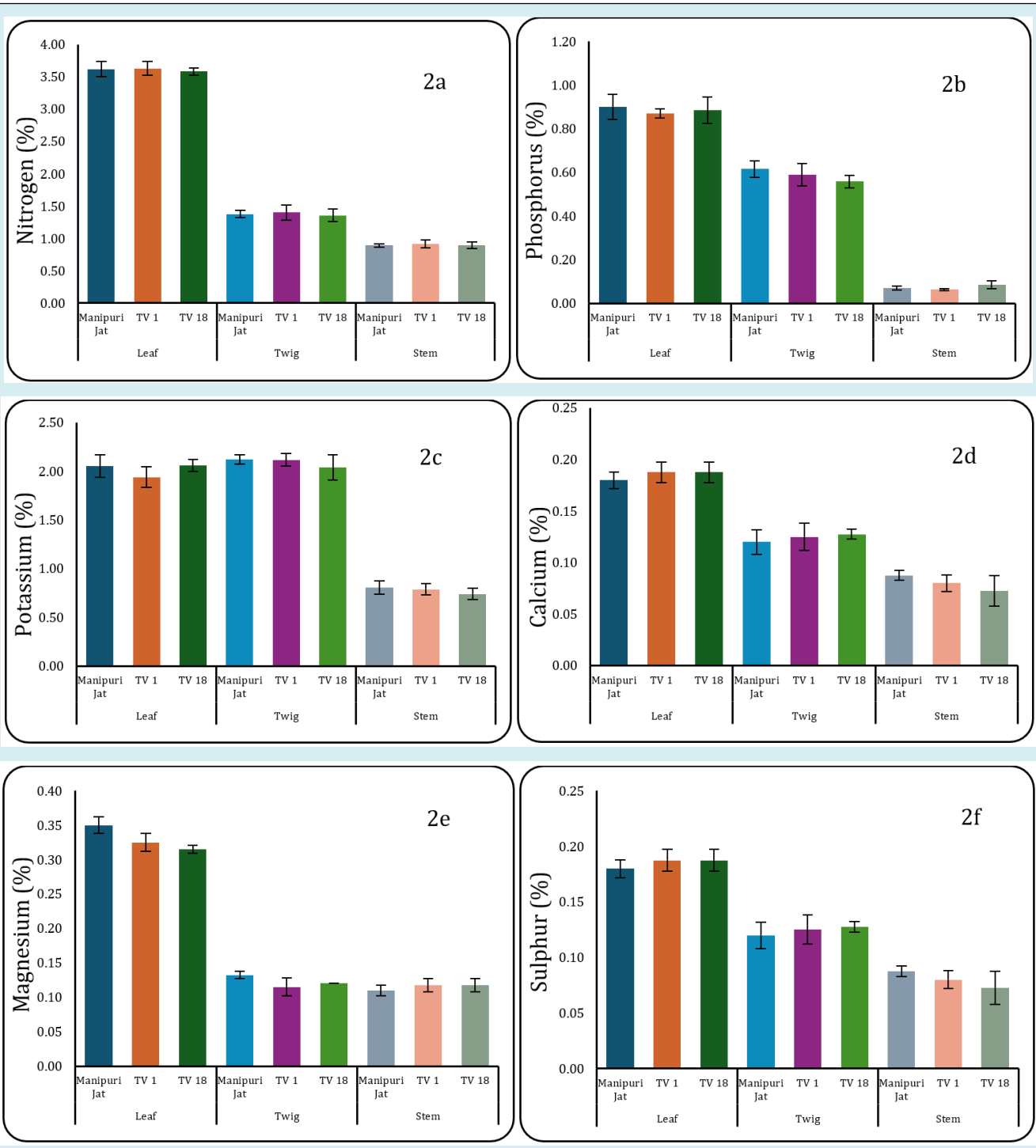

Figure 2: Nutrient contents in leaf, twigs, and stems in the pruning litter.

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Potassium (K): The K content varied more among varieties (Figure 2c). In leaf, *Manipuri Jat* (2.05%) and TV 18 (2.06%) had higher K content than TV 1 (1.94%). Twigs showed similar K content in *Manipuri Jat* and TV 1 (2.12%), while TV 18 was slightly lower (2.04%). In stems, *Manipuri Jat* (0.80%) and TV 1 (0.79%) had similar values, with TV 18 lower at 0.74%. These results suggest that potassium content, unlike N and P, exhibits greater varietal difference, particularly in leaf and stems.

Calcium (Ca) and Magnesium (Mg): The Ca and Mg contents in leaf, twigs, and stems (Figures 2d & 2e) were consistent across all tea varieties. Leaf Ca was 1.42% in *Manipuri Jat*, 1.34% in TV 1, and 1.25% in TV 18, while Mg content was 0.35% in *Manipuri Jat*, 0.33% in TV 1, and 0.31% in TV 18. In twigs, Ca ranged from 0.48% to 0.52% and Mg from 0.11% to 0.13%. Similarly, stems had Ca content between 0.35% and 0.41% and Mg between 0.11% and 0.12%, confirming minimal varietal differences.

Sulphur (S): The S content in leaf, twigs, and stems among the tea varieties (Figure 2f) was consistent. Leaf S content ranged from 0.18% to 0.19%. In twigs, S content was 0.12% to 0.13%, and in stems, 0.07% to 0.09%. This consistency indicates that varietal difference has little or no effect on sulphur content in any plant part.

Discussion

The present study demonstrates that tea pruning litter represents a substantial and valuable source of organic matter and essential nutrients in tea plantations. Quantification of fresh and dry pruning litter across three prominent varieties-*Manipuri Jat*, TV1, and TV18 not only show variability among tea genotypes but also the significant potential of pruning residues as a sustainable input for nutrient cycling and soil health.

The observed differences in pruning litter production and dry matter recovery among varieties underscore the importance of genotype in shaping the contribution of pruning residues to plantation nutrient budgets. While *Manipuri Jat* yielded the highest pruning litter per bush, the greater planting density of TV18 resulted in the highest total litter yield per hectare. This finding is consistent with previous research emphasising the influence of bush density and varietal characteristics on total biomass production and nutrient return [22]. The relatively consistent dry matter recovery rate across varieties (approximately 40%) further supports the feasibility of using variety-agnostic estimates for litter-based nutrient management, as also noted in studies of other perennial crops [23].

In case of nutrient contents of leaf, twigs, and stems showed minimal varietal difference in nitrogen, phosphorus, calcium, magnesium, and sulphur concentrations. This suggests that pruning litter recycling can be broadly implemented across tea varieties without major concern for differences in nutrient return quality. Potassium content showed slightly greater variability between varieties, indicating that targeted varietal selection could modestly enhance potassium cycling where needed. These results align with previous findings that nutrient concentrations in tea litter are relatively stable, particularly for nitrogen and phosphorus, which are critical for plant growth and soil fertility [10,26]. Notably, leaf contributed most of the nutrients in the analysed pruning litter samples, except for potassium, which was highest in the twigs. In the TV1 clone, different plant parts varied in nutrient content, whereas in TV18, leaves alone contributed the majority of measured nutrients, with stems contributing the least. Retaining pruning litter *in situ* can thus add significant quantities of essential nutrients to tea-growing soils, helping to reduce fertiliser costs a major advantage during the rising cost of synthetic inputs.

This study quantified overall nutrients recoverable from pruning litter, illustrated in Figure 3 showed that approximately 260 kg ha^{-1} of nitrogen (N), 68 kg ha^{-1} of phosphorus (P_2O_5), 216 kg ha^{-1} of potassium (K_2O), about 97 kg ha^{-1} of calcium (Ca), 25 kg ha^{-1} of magnesium (Mg), and 17 kg ha^{-1} of sulphur (S) can be recovered from the pruning litter of the three studied tea varieties.

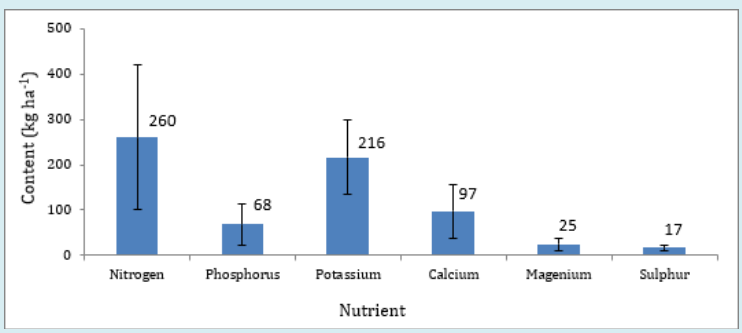

Figure 3: Overall nutrient recovery from pruning litter.

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The ecological and agronomic benefits of recycling pruning litter *in situ* are well documented. Decomposition of this organic material contributes to soil organic matter, enhances microbial activity, improves soil structure, and increases the water-holding capacity of soils [23]. In the context of Northeast India, where tea plantations often face declining soil fertility and rising input costs, maximising the use of on-site organic resources, such as pruning litter, is both economically and environmentally prudent [5].

Furthermore, sustainable litter management aligns with broader goals of reducing reliance on synthetic fertilisers, lowering production costs, and mitigating environmental impacts associated with intensive tea cultivation [1,4]. As pruning is already an integral part of routine tea management for yield and quality enhancement [7,9], the additional practice of deliberate litter recycling offers a low-cost, high-impact strategy for nutrient management.

Conclusion

Pruning operations of tea bushes generate a huge volume of litters consisting of both leaves and stems. These pruning litters when retained *in situ*, can add organic matter to the soil which improves the physico-chemical and biological properties of soils leading to higher tea production. Pruning litters lock good amount plant nutrients in the cells and tissues which can be released again in the soil upon decomposition by various microbial and enzymatic activities. The present study concluded that the pruning litters can on an average add 40% of dry matter irrespective of tea varieties and plant parts. The study also quantified the nutrient recovery from the pruning litters when retained in the fields. It was also concluded that these pruning litters can be utilized for recovering the plant nutrients in soil for future plant uptake which can economize the tea production by saving the cost on fertilizers.

Conflict of Interest

The authors declare no competing interests.

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Author Contributions

Jintu Dutta: conceptualization, original draft, review, editing and Harisadhan Malakar: conceptualization, original draft, review, editing.

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