

Article

Effects of Different Strip Cutting Regimes on Growth Traits, Root Morphological Plasticity, and Allocation of Nutrients and Non-Structural Carbohydrates in *Indocalamus latifolius*

Huijing Ni ^{1,2}  and Zhenya Yang ^{1,2,*}
¹ Zhejiang Academy of Forestry, Hangzhou 310023, China; nihj@zjforestry.ac.cn

² Northwest Zhejiang Bamboo Forest Ecosystem Positioning Observation and Research Station, National Forestry and Grassland Administration, Hangzhou 310023, China

* Correspondence: yangzhenya@zjforestry.ac.cn

Abstract

Strip cutting enables efficient, low-cost harvesting and regeneration of abandoned bamboo stands with minimal disturbance to the ecosystem. Nevertheless, the growth and resource allocation mechanisms of *Indocalamus latifolius* (Keng) McClure in response to varying strip cutting intensities remain unclear. In this study, abandoned *I. latifolius* stands were selected as research materials, with four gradient widths of cutting strips established (0 m, 1 m, 2 m, 3 m). This study aimed to clarify the growth and resource allocation mechanisms of *I. latifolius* in response to strip cutting by measuring organ biomass accumulation, root morphological traits, and the allocation strategies for nutrients and non-structural carbohydrates in cutting and reserved strips under different strip cutting intensities. The results showed that the 1 m strip width facilitated new ramet growth in both cutting and reserved strips, while the 2 m strip width only promoted new ramet growth in reserved strips. Both treatments suppressed fine root proliferation and increased average root diameter. Strip cutting significantly elevated nitrogen and phosphorus contents in new leaves, new stems, rhizomes, and roots, as well as soluble sugar contents in new leaves and new stems across cutting and reserved strips. By contrast, it reduced the non-structural carbohydrate content in roots, as well as nitrogen and phosphorus contents in old stems and old leaves within reserved strips. The 1 m and 2 m strip cutting treatments increased the nitrogen and phosphorus allocation ratios of new leaves, new stems, and rhizomes in reserved strips, and reduced the allocation ratios in roots, old leaves, and old stems. In conclusion, moderate-intensity strip clear-cutting facilitates new ramet sprouting within cutting strips and induces compensatory leaf growth in reserved strips. *I. latifolius* preferentially allocates nutrients and non-structural carbohydrates to new leaves, new stems, and rhizomes in reserved strips, yet this resource allocation strategy inhibits root growth.



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1. Introduction

Indocalamus latifolius (Keng) McClure belongs to the genus *Indocalamus* in the subfamily Bambusoideae of the family Poaceae [1]. It possesses large leaves that can reach a maximum length of 45 cm and a width of 9 cm. For this reason, its leaves serve as the exclusive wrapping material for zongzi, a traditional Chinese festival food consumed during the Dragon Boat Festival. This species displays strong shade tolerance and can thrive beneath

arbor and shrub canopies to construct multi-layered forest understory communities [2]. It exhibits substantial ecological application potential in sustaining community stability, ameliorating soil microenvironments, and enhancing forest carbon sequestration capacity [3]. Accordingly, *I. latifolius* represents a bamboo resource with prominent economic value and profound cultural connotations in China. At present, most stands of *I. latifolius* remain unmanaged due to the high costs of artificial cultivation. This suppresses the sprouting of new ramets and the growth of new leaves, and triggers the degradation of rhizomes and root systems. These adverse changes drastically reduce the yield of usable *I. latifolius* leaves. Therefore, cutting practices are required to regenerate and rejuvenate degraded *I. latifolius* stands.

Moderate cutting ameliorates stand microclimate including light, temperature and humidity, which provides favorable conditions for photosynthesis of post-harvest vegetation [4,5]. Furthermore, it improves soil properties by stimulating soil microbial activity and accelerating soil nutrient release [6,7]. Accordingly, appropriate cutting benefits seed germination, seedling growth, stand structural optimization and biodiversity enhancement [8]. However, determining appropriate cutting regimes matching plant functional traits remains the primary challenge of cutting. As an alternative cutting method intermediate between conventional clear-cutting and selective cutting, strip cutting arranges alternating cutting strips and reserved strips [9]. This management practice achieves stand regeneration through moderate stand disturbance while mitigating ecological risks including soil erosion and biodiversity loss [10]. Numerous studies have verified the applicability of strip cutting for coordinated timber production and ecological conservation [11,12]. Particularly for bamboo stands that produce new ramets annually, strip cutting is compatible with mechanized operations and addresses the low efficiency and high labor input of traditional selective cutting [13].

Strip width acts as the core parameter governing the regulatory effects of strip cutting [14]. Varying strip widths generate distinct microhabitat conditions including understory light, temperature, humidity, and soil aeration [15]. These factors directly regulate plant photosynthetic capacity, soil nutrient transformation and microbial community composition, and ultimately determine vegetation regeneration rate and stand recovery trajectory [16,17]. The impacts of strip width on bamboos could be far more complex. As typical clonal plants, bamboos exhibit rapid growth and reproduction as well as strong morphological plasticity [18]. More importantly, they exhibit clonal integration, through which interconnected ramets translocate nutrients, water, photosynthates, and signaling substances via underground rhizomes for resource sharing [19,20]. When some ramets within bamboo clonal systems are damaged or confined to resource-deficient patches, bamboos can adapt to heterogeneous stress via morphological plasticity and clonal integration strategies [21,22]. Thus, the growth performance of new ramets within cutting strips largely depends on clonal integration capacity and morphological plasticity. The spacer length between clonal ramets is a key factor regulating the efficiency of resource integration [23]. Accordingly, excessively wide cutting strips block resource translocation via clonal integration to ramets within harvested zones, which severely restricts new bamboo regeneration in cutting strips. Existing studies on strip cutting of bamboos predominantly focus on monopodial bamboos, with *Phyllostachys edulis* (Carrière) J. Houzeau as the main research object. Studies have shown that 8–9 m cutting strips perform significantly better than narrower or wider strips in nutrient accumulation, new ramet growth and rhizome expansion [13,17]. New shoot development of *Phyllostachys glauca* McClure is markedly suppressed under strip cutting widths greater than 10 m [24]. Clonal integration capacity varies greatly among bamboo species, leading to divergent responses to strip cutting. Compared with monopodial bamboos such as *P. edulis* and *P. glauca*, *I. latifolius* differs

substantially in spacer length, ramet size, and rhizome type [25,26]. Thus, *I. latifolius* may develop species-specific growth responses under varying strip cutting intensities. These mechanisms remain unclear, which greatly restricts the scientific tending of *I. latifolius* stands and the regulation of stand ecological stability.

This study took unmanaged natural *I. latifolius* stands as research objects. A field controlled experiment with four strip width treatments was carried out. Measurements including organ biomass, root morphology, nutrient and non-structural carbohydrate contents, and nutrient allocation ratios of *I. latifolius* were measured 1 year following strip cutting. This study aimed to elucidate how varying strip cutting intensities affect growth traits, root morphological plasticity, and nutrient and non-structural carbohydrate allocation in *I. latifolius*. Three hypotheses were proposed according to the research objective and experimental design: (1) Appropriate strip widths promote new ramet sprouting in cutting strips and induce compensatory leaf growth in reserved strips; (2) Strip cutting triggers root morphological plasticity in both cutting and reserved strips; (3) Under strip cutting treatments, *I. latifolius* preferentially allocates nutrients and non-structural carbohydrates to leaves.

2. Materials and Methods

2.1. Experimental Setup

The experimental site was located in Baimashan Forest Farm, Suichang County, Lishui City, Zhejiang Province, China (119°09' E, 28°38' N). This region features a typical subtropical monsoon climate with a mean annual temperature of 11.6 °C, annual precipitation of 2134 mm and a frost-free period of 175 days, at an altitude of 1050 m. Clustered natural *I. latifolius* stands in the forest farm were selected as research materials. Prior to the experiment, all bamboo stands were under strict management with no harvesting, fertilization or logging activities implemented. The soil layer thickness exceeded 50 cm, and the soil was yellow soil derived from weathered volcanic rock. The soil had a pH value of 4.92. Each kilogram of dry soil contained 1.24 g total nitrogen, 11.8 g total potassium, 0.331 g total phosphorus, 102.6 mg hydrolyzable nitrogen, 105.1 mg available potassium, 6.28 mg available phosphorus, and 25.2 g soil organic matter.

In October, bamboo stands with consistent management history, slope gradient, slope aspect, soil water content, soil nutrient status and *I. latifolius* density were selected as experimental sites. A total of 16 square plots (25 m × 25 m) were established in this experiment. These plots were divided into four independent experimental blocks. Four distinct cutting treatments were applied to the four plots within each block, namely control group (CK, no cutting of *I. latifolius*), T1 (strip cutting width of 1 m), T2 (strip cutting width of 2 m), and T3 (strip cutting width of 3 m). The cutting strips and reserved strips were of equal width. The schematic diagram of strip cutting mode is shown in Figure 1. Each independent experimental block represented one biological replicate; thus, four replicates were available for each treatment. Prior to cutting, red nylon ropes were used to separate reserved strips and cutting strips. This measure prevented accidental felling of *I. latifolius* outside the cutting strips. Afterwards, all *I. latifolius* individuals in cutting strips were mown at ground level using a lawn mower. The cut bamboo materials were removed from the experimental plots. No irrigation, fertilization or other management practices were implemented in the experimental plots during the subsequent growing period. In addition, the picking of *I. latifolius* leaves was strictly prohibited.

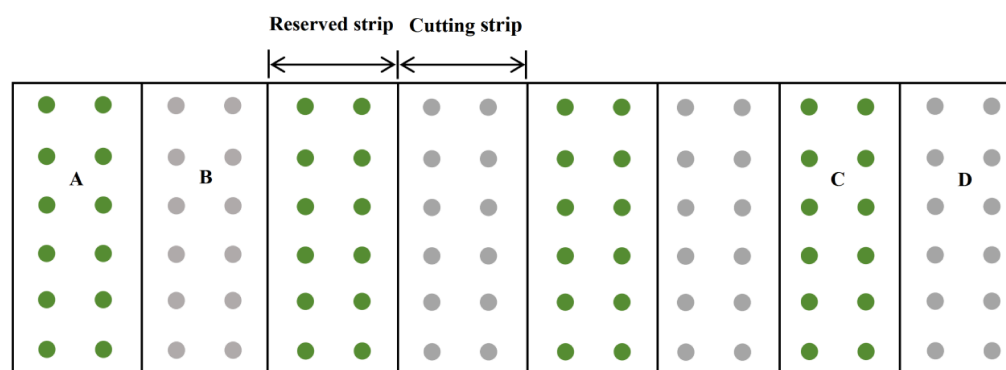


Figure 1. Schematic drawing of strip cutting. Green circles: the reserved *Indocalamus latifolius*; Gray circles: the cut *Indocalamus latifolius*. Four strip width treatments were set: 0 m (CK), 1 m (T1), 2 m (T2), 3 m (T3). The widths of cutting strips and reserved strips are identical. No sampling was conducted in the marginal strips of each plot, such as strips A, B, C, and D.

2.2. Harvest and Measurements

Sampling was carried out across the 16 bamboo plots 1 year after the cutting treatments. To eliminate edge effects induced by external factors outside the experimental plots, sampling was not performed on the two outermost groups of reserved strips and cutting strips on both sides of each plot. For example, no sampling was conducted within strips A, B, C, and D, as shown in Figure 1. Three sampling positions were randomly selected within the cutting strips and reserved strips of each plot, and one small sampling quadrat was established at each position. The longitudinal length of each small sampling quadrat was 1 m. Its transverse width equaled the cutting width of the corresponding cutting strip. Accordingly, the dimensions of small sampling quadrat for CK, T1, T2, and T3 were 1 m × 1 m, 1 m × 1 m, 1 m × 2 m, and 1 m × 3 m, respectively. This setup was designed to eliminate the influence of edge effects on the reliability of sampling data. All subsequent biomass and root morphological parameters were converted to values per 1 m² for unified comparison. Since no strip cutting was implemented in the CK plots, only three random sampling points were established without separating reserved strips and cutting strips. During sampling in reserved strips, all aboveground tissues within each small sampling quadrat were cut off at ground level. All rhizomes and roots inside the quadrat were subsequently excavated. The collected materials were then sorted into new leaves, old leaves, new stems, rhizomes, and roots. New leaves were distinguished from old leaves based on color and texture. New stems were separated from old stems according to color differences (Figure 2). Sampling procedures for cutting strips were identical to those for reserved strips, with the only difference being the absence of old leaves and old stems in cutting strips. All plant organs were transported back to the laboratory at a constant temperature of 0–2 °C.

Root samples were thoroughly rinsed with clean water and subsequently scanned using a dual-sided root scanner (Regent Instruments Inc., Quebec City, QC, Canada) to acquire root images. The root images were analyzed with WinRhizo root analysis software (version 2.0) to accurately determine root morphology parameters, including total root length, root surface area, and average root diameter. The root was partitioned into five diameter grades via the software: 0–0.5 mm, 0.5–1 mm, 1–1.5 mm, 1.5–2 mm, and >2 mm. The root length corresponding to each diameter grade was extracted. The root length ratio for each diameter grade was determined by dividing the root length of each respective diameter grade by the total root length. All plant organs were subjected to deactivation at 105 °C for 30 min, followed by oven-drying at 65 °C until constant weight was achieved. The dry mass of each organ was weighed and recorded as its biomass. Specific root length

was determined by dividing the total root length by the root dry mass. The values of biomass and root morphological indicators for each plot were the averages obtained from three small quadrats inside the plot. Each plot was treated as one biological replicate, with four replicates in total.

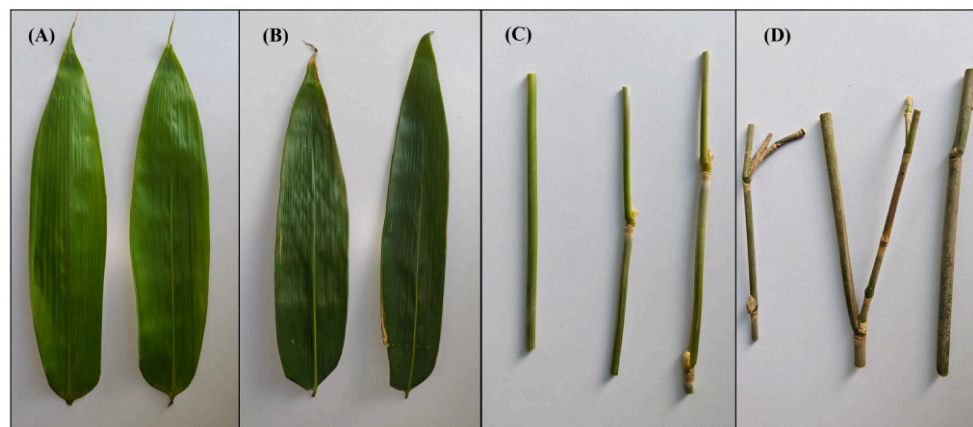


Figure 2. Images of new leaves, old leaves, new stems, and old stems of *Indocalamus latifolius*. (A): new leaves, (B): old leaves, (C): new stems, (D): old stems.

All oven-dried samples were thoroughly ground before digestion using the hydrogen peroxide-sulfuric acid digestion method. N and P contents in different organs were measured using the H_2O_2 - H_2SO_4 digestion method and vanadomolybdate yellow colorimetric method, respectively [27]. The contents of non-structural carbohydrates (NSCs), including soluble sugars and starch, were quantified by the anthrone colorimetric assay [28].

2.3. Statistical Analysis

One-way analysis of variance (one-way ANOVA) was used to compare differences in all measured traits among the four treatments. Prior to ANOVA, Shapiro–Wilk and Levene’s tests were performed to verify the normality and homogeneity of variances in the experimental data, respectively. The significance level was set at $\alpha = 0.05$. Fisher’s least significant difference (LSD) post hoc test was conducted for pairwise multiple comparisons between treatments. All statistical analyses of measured traits across different treatments were carried out using SPSS 20.0 software (SPSS Inc., Chicago, IL, USA). Origin 9.0 software was adopted to generate all figures.

3. Results

3.1. Effects of Different Treatments on Biomass Allocation

In the reserved strips, the biomass of new leaves, new stems, and rhizomes all exhibited an initial increase followed by a decline with increasing cutting width, peaking under the T2 treatment. The biomass ranges of new leaves, new stems and rhizomes were $41.25\text{--}93.78\text{ g}\cdot\text{m}^{-2}$, $53.1\text{--}129.9\text{ g}\cdot\text{m}^{-2}$, and $148.83\text{--}214.15\text{ g}\cdot\text{m}^{-2}$, respectively. In terms of new leaf and new stem biomass, T1 and T2 were significantly higher than T3 and CK, and T2 was significantly higher than T1 ($p < 0.05$). Compared with CK, new leaf biomass under T1 and T2 increased by 41.5% and 127.3%, respectively; new stem biomass under T1 and T2 increased by 60.2% and 108.5%, respectively. Rhizome biomass under T2 was 28.9% higher than that under T1 and 43.9% higher than that under CK ($p < 0.05$). Root biomass showed a decreasing-then-increasing trend as cutting width increased, with the minimum value recorded under the T1 treatment. Root biomass under T1 and T2 decreased by 23.2% and

15.2%, respectively, relative to CK ($p < 0.05$). Strip cutting had no significant influence on biomass of aged leaves and aged stems in reserved strips (Figure 3).

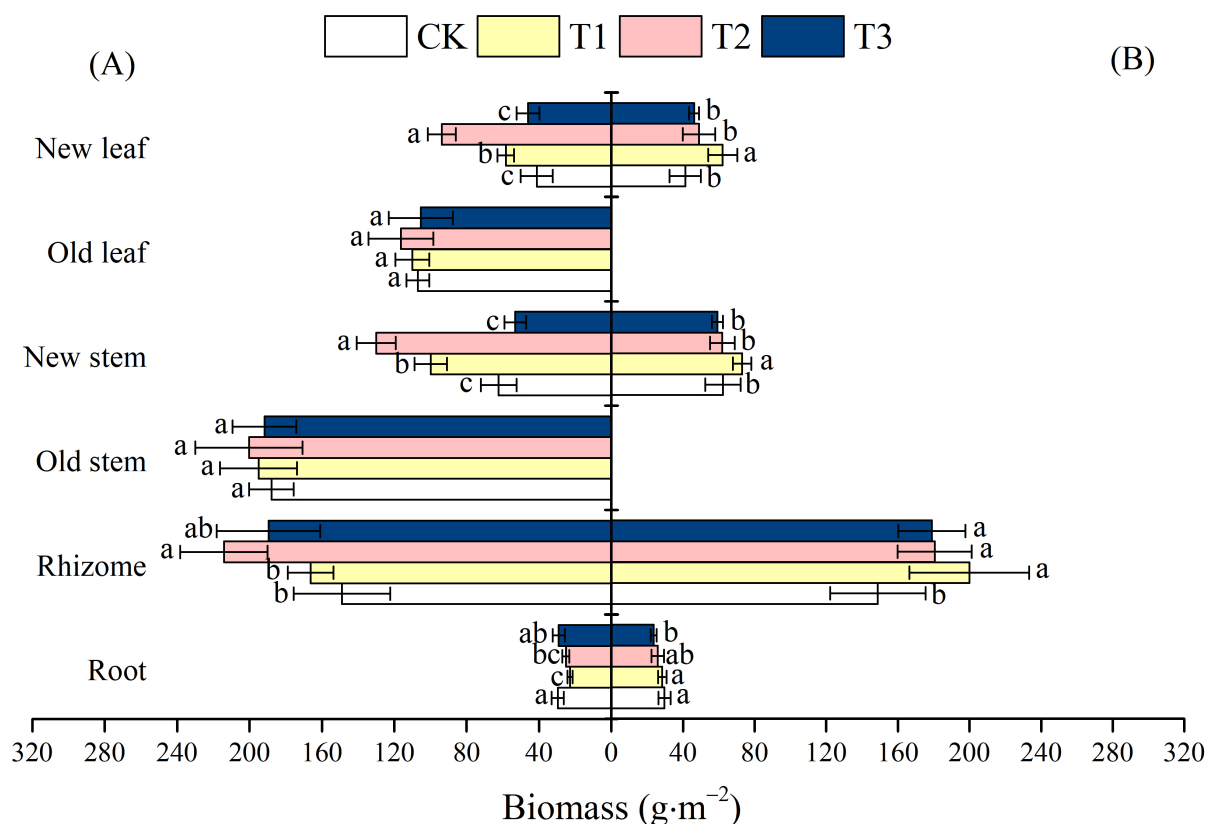


Figure 3. Biomass allocation of *Indocalamus latifolius* under different strip cutting treatments. Note: a, b, c—different letters indicate significant differences among different treatments ($p < 0.05$). The values represent means $\pm$ SE. (A): Reserved strips; (B): cutting strips. CK: no cutting of *Indocalamus latifolius*, T1: strip cutting width of 1 m, T2: strip cutting width of 2 m, T3: strip cutting width of 3 m.

In the cutting strips, biomass of new leaves, new stems, and rhizomes first increased and then decreased with increasing cutting width, reaching the maximum under the T1 treatment. Compared with CK, T2, and T3, new leaf biomass under T1 increased by 50.7%, 27.2%, and 34.7%, respectively. New stem biomass under T1 was 17.1%, 17.7%, and 23.3% higher than that under CK, T2, and T3, respectively. Rhizome biomass under T1, T2, and T3 increased by 34.3%, 21.3%, and 20.3% relative to CK ($p < 0.05$). Root biomass gradually declined as cutting width increased. Root biomass under T3 decreased by 20.3% and 16.8% compared with CK and T1, respectively ($p < 0.05$) (Figure 3).

3.2. Effects of Different Treatments on Root Morphology

In the reserved strips, the root length in reserved strips exhibited a trend of first decreasing and then increasing with the increase in cutting width. Root length under T1 and T2 decreased by 49.1% and 44.0% relative to CK, and declined by 46.6% and 41.1% compared with T3, respectively. No significant differences were detected between T1 and T2, nor between CK and T3. In the cutting strips, root length under T1, T2, and T3 was reduced by 29.9%, 20.5%, and 22.6% compared with CK ($p < 0.05$) (Figure 4).

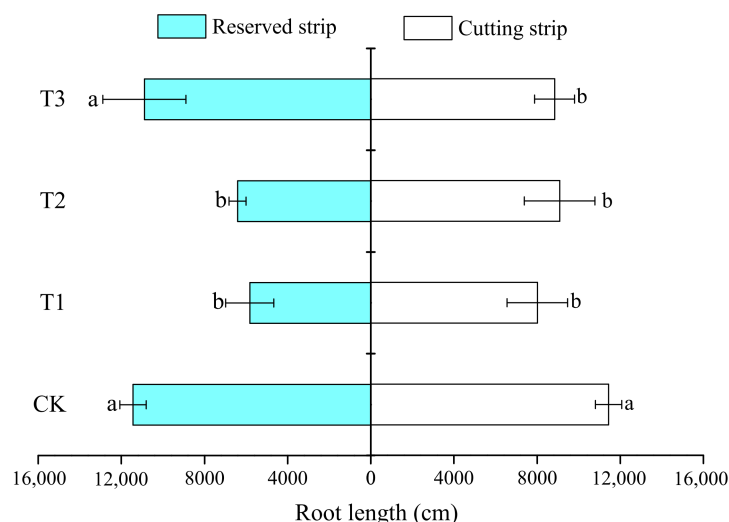


Figure 4. Root length of *Indocalamus latifolius* under different strip cutting treatments. Note: a, b—different letters indicate significant differences among different treatments ($p < 0.05$). The values represent means $\pm$ SE. CK: no cutting of *Indocalamus latifolius*, T1: strip cutting width of 1 m, T2: strip cutting width of 2 m, T3: strip cutting width of 3 m.

In the reserved strips, the root surface area exhibited a trend of first decreasing and then increasing with the increase in cutting width. Root surface area under T1 and T2 decreased by 38.5% and 34.1% relative to CK, and declined by 36.6% and 32.2% compared with T3, respectively. In the cutting strips, root length under T1, T2, and T3 was reduced by 15.5%, 16.6%, and 19.9% compared with CK ($p < 0.05$) (Figure 5).

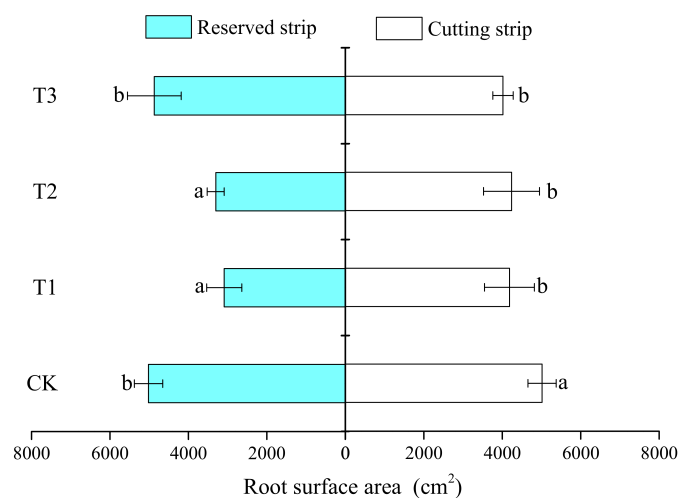


Figure 5. Root surface area of *Indocalamus latifolius* under different strip cutting treatments. Note: a, b—different letters indicate significant differences among different treatments ($p < 0.05$). The values represent means $\pm$ SE. CK: no cutting of *Indocalamus latifolius*, T1: strip cutting width of 1 m, T2: strip cutting width of 2 m, T3: strip cutting width of 3 m.

With the increase in cutting width, the average root diameter in both reserved strips and cutting strips increased first and then decreased, with the maximum value observed under the T1 treatment. In the reserved strips, average root diameter under T1 and T2 increased by 22.0% and 17.5% relative to CK, and decreased by 19.0% and 14.6% compared with T3, respectively ($p < 0.05$). In cutting strips, the average root diameter under T1 and T2 was 19.4% and 6.7% higher than that under CK, respectively. The average root diameter under T1 was 12.0% greater than that under T2 (Figure 6).

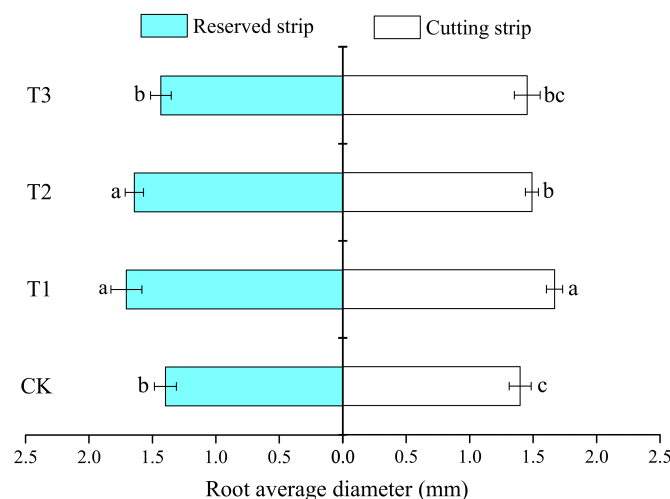


Figure 6. Root average diameter of *Indocalamus latifolius* under different strip cutting treatments. Note: a, b, c—different letters indicate significant differences among different treatments ($p < 0.05$). The values represent means $\pm$ SE. CK: no cutting of *Indocalamus latifolius*, T1: strip cutting width of 1 m, T2: strip cutting width of 2 m, T3: strip cutting width of 3 m.

Specific root length in reserved strips and cutting strips showed a decreasing-then-increasing trend as cutting width increased, reaching the minimum under the T1 treatment. In reserved strips, specific root length under T1 and T2 decreased by 34.7% and 34.3% relative to CK, and declined by 36.9% and 36.5% compared with T3, respectively ($p < 0.05$). In the cutting strips, specific root length under T1 was reduced by 27.8%, 19.7%, and 25.6% compared with CK, T2, and T3, respectively ($p < 0.05$) (Figure 7).

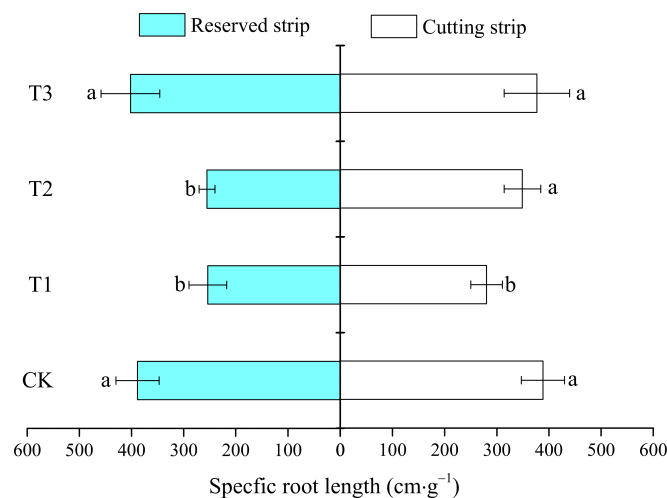


Figure 7. Root specific length of *Indocalamus latifolius* under different strip cutting treatments. Note: a, b—different letters indicate significant differences among different treatments ($p < 0.05$). The values represent means $\pm$ SE. CK: no cutting of *Indocalamus latifolius*, T1: strip cutting width of 1 m, T2: strip cutting width of 2 m, T3: strip cutting width of 3 m.

In reserved strips, T1 and T2 treatments significantly reduced root length across all five root diameter grades when compared with CK and T3 ($p < 0.05$) (Figure 8A). The maximum root length for all five diameter grades was recorded under CK. Relative to CK, root length under T1 decreased by 55.8% (0–0.5 mm), 50.0% (0.5–1 mm), 51.6% (1–1.5 mm), 53.0% (1.5–2 mm), and 27.8% (>2 mm), respectively. Compared with CK, root length under T2 declined by 51.5% (0–0.5 mm), 41.7% (0.5–1 mm), 37.9% (1–1.5 mm), 54.1% (1.5–2 mm), and 26.5% (>2 mm), respectively ($p < 0.05$). In the cutting strips, T1 significantly decreased root

length in the 0–0.5 cm, 0.5–1 cm, and 1.5–2 cm diameter grades by 38.0%, 38.6%, and 54.2%, respectively, relative to CK ($p < 0.05$). T2 induced significant reductions in root length for the 0–0.5 cm, 1–1.5 cm and 1.5–2 cm grades, with decreases of 22.9%, 35.2% and 47.0% compared with CK ($p < 0.05$). T3 significantly reduced the root length in 0–0.5 cm, 0.5–1 cm, 1.5–2 cm, and >2 cm diameter grades by 24.4%, 19.3%, 45.9%, and 13.5%, respectively ($p < 0.05$) (Figure 8B).

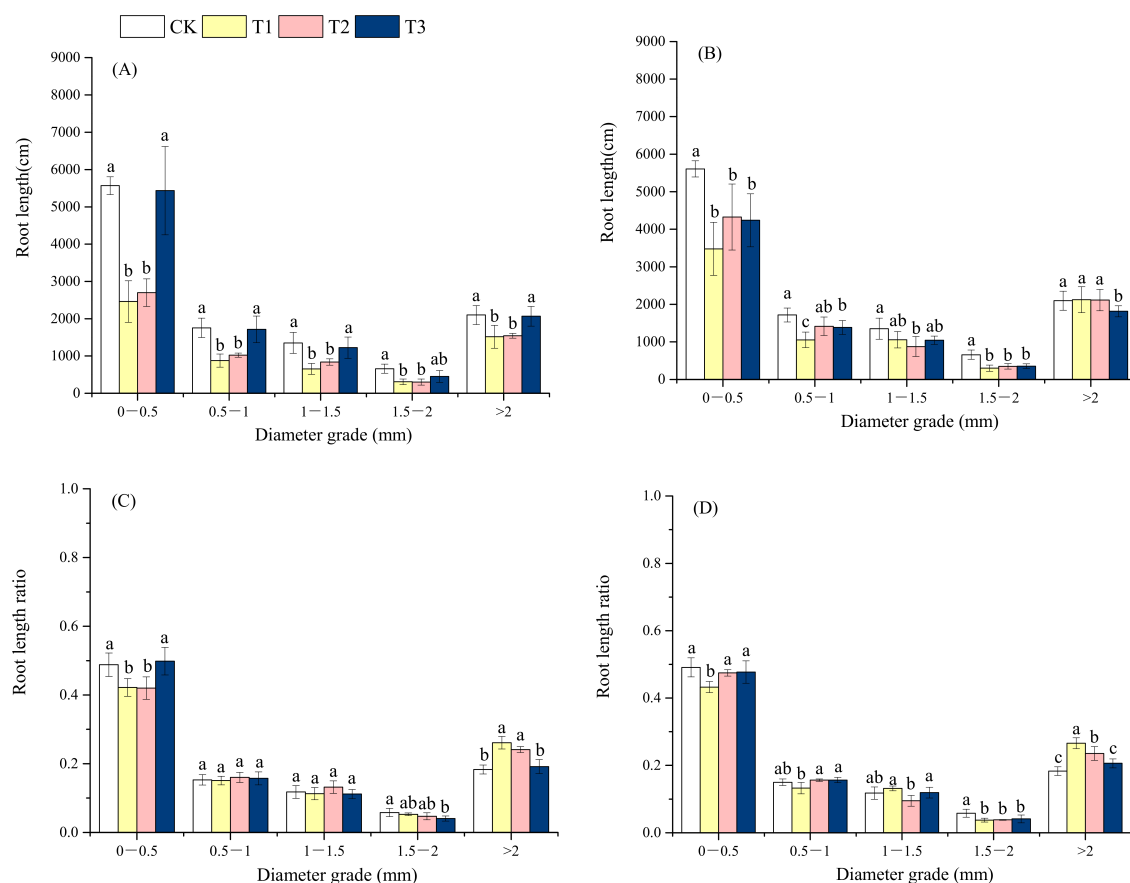


Figure 8. Root length and root length ratio across different diameter grades of *Indocalamus latifolius* under different strip cutting treatments. Note: a, b, c—different letters indicate significant differences among different treatments ($p < 0.05$). The values represent means $\pm$ SE. (A): root length of reserved strips; (B): root length of cutting strips; (C): root length ratio of reserved strips; (D): root length ratio of cutting strips. CK: no cutting of *Indocalamus latifolius*, T1: strip cutting width of 1 m, T2: strip cutting width of 2 m, T3: strip cutting width of 3 m.

In the reserved strips, compared with CK, T1 and T2 reduced the root length ratio of the 0–0.5 cm diameter grade by 13.5% and 13.9%, respectively, and increased the root length ratio of the >2 cm grade by 42.5% and 31.7%, respectively ($p < 0.05$). Relative to T3, T1 and T2 decreased the root length ratio of the 0–0.5 cm grade by 15.3% and 15.7%, while significantly elevating that of the >2 cm grade by 36.2% and 25.8%, respectively ($p < 0.05$) (Figure 8C). In cutting strips, the root length ratio in 0–0.5 cm grade under T1 was significantly lower than that under the other three treatments. T1 and T2 presented a significantly higher root length ratio in >2 cm grade than CK and T3 (Figure 8D). Compared with CK, the root length ratio of the 0–0.5 cm grade under T1 declined by 20.0%, and the root length ratio of the >2 cm grade under T1 and T2 increased by 45.2% and 28.5%, respectively.

3.3. Effects of Different Treatments on the Allocation of Nutrient Elements in *Indocalamus latifolius*

In the reserved strips, all three strip cutting treatments significantly increased the nitrogen content of new leaves, rhizomes, and roots compared with CK. T2 and T3 significantly elevated the nitrogen content of new stems ($p < 0.05$). The maximum nitrogen contents of new leaves, new stems, and roots were observed under T2, which were 20.9%, 26.6%, and 28.7% higher than CK, respectively. Rhizomes reached the highest nitrogen content under T3, representing a 47.0% increase relative to CK. All three strip cutting treatments significantly reduced the nitrogen content of old leaves relative to CK, and T2 and T3 significantly lowered the nitrogen content of old stems ($p < 0.05$). The minimum nitrogen contents of old leaves and old stems occurred under T2, decreasing by 20.8% and 12.1% compared with CK, respectively. In the cutting strips, the three strip cutting treatments significantly increased nitrogen contents in new leaves, new stems, rhizomes, and roots (Table 1). The maximum nitrogen contents of new leaves, new stems, rhizomes, and roots were found under T3, with increases of 21.4%, 37.1%, 28.6%, and 20.4% relative to CK, respectively.

Table 1. Nitrogen contents of *Indocalamus latifolius* under different treatments.

Strips	Treatments	Nitrogen Content (mg·g ⁻¹)					
		New Leaves	Old Leaves	New Stems	Old Stems	Rhizome	Roots
Reserved strips	CK	9.77 ± 0.60 b	10.43 ± 0.37 a	4.29 ± 0.22 b	4.67 ± 0.11 a	5.11 ± 0.22 b	7.73 ± 0.47 b
	T1	11.14 ± 0.49 a	9.44 ± 0.28 b	4.50 ± 0.27 b	4.30 ± 0.18 ab	6.61 ± 0.56 a	9.06 ± 0.46 a
	T2	11.81 ± 0.93 a	8.26 ± 0.66 b	5.43 ± 0.40 a	4.10 ± 0.22 b	7.39 ± 0.49 a	9.95 ± 0.58 a
	T3	11.38 ± 0.51 a	8.89 ± 0.56 b	5.13 ± 0.42 a	4.24 ± 0.14 b	7.51 ± 0.70 a	9.43 ± 0.57 a
Cutting strips	CK	9.77 ± 0.60 b	—	4.29 ± 0.22 c	—	5.11 ± 0.22 c	7.73 ± 0.47 c
	T1	11.07 ± 0.63 a	—	4.93 ± 0.26 b	—	5.75 ± 0.39 b	8.38 ± 0.73 bc
	T2	11.24 ± 0.58 a	—	5.35 ± 0.40 ab	—	5.60 ± 0.19 b	8.72 ± 0.29 b
	T3	11.84 ± 0.36 a	—	5.88 ± 0.28 a	—	6.57 ± 0.27 a	9.31 ± 0.31 a

Note: a, b, c—different letters indicate significant differences among different treatments ($p < 0.05$). The values represent means ± SE. CK: no cutting of *Indocalamus latifolius*, T1: strip cutting width of 1 m, T2: strip cutting width of 2 m, T3: strip cutting width of 3 m.

In the reserved strips, all three strip cutting treatments significantly increased the phosphorus content of new leaves, new stems, rhizomes, and roots compared with CK ($p < 0.05$). The phosphorus contents of these organs showed an increasing-then-decreasing trend with the increase in cutting width and peaked under T2. Relative to CK, the phosphorus contents of new leaves, new stems, rhizomes and roots under T2 increased by 42.8%, 38.7%, 82.1% and 76.2%, respectively. Compared with CK, T1 and T2 significantly reduced the phosphorus content of old leaves by 11.5% and 9.6%, respectively ($p < 0.05$). In the cutting strips, all three strip cutting treatments significantly increased the phosphorus content of new leaves, new stems, and roots relative to CK, while T1 and T2 increased the phosphorus content of rhizomes. The maximum phosphorus contents of new leaves, new stems, and rhizomes were observed under T1, which were 23.2%, 26.5%, and 25.6% higher than CK, respectively. The phosphorus content of roots peaked under T2, with a 21.4% increase compared with CK (Table 2).

Table 2. Phosphorus contents of *Indocalamus latifolius* under different treatments.

Strips	Treatments	Phosphorus Content (mg·g ⁻¹)					
		New Leaves	Old Leaves	New Stems	Old Stems	Rhizome	Roots
Reserved strips	CK	0.56 ± 0.02 b	0.52 ± 0.02 a	0.49 ± 0.03 b	0.48 ± 0.03 a	0.39 ± 0.03 c	0.42 ± 0.03 c
	T1	0.80 ± 0.05 a	0.46 ± 0.03 b	0.65 ± 0.05 a	0.46 ± 0.02 a	0.65 ± 0.03 ab	0.60 ± 0.04 b
	T2	0.80 ± 0.04 a	0.47 ± 0.02 b	0.68 ± 0.04 a	0.47 ± 0.02 a	0.71 ± 0.05 a	0.74 ± 0.06 a
	T3	0.74 ± 0.06 a	0.48 ± 0.03 ab	0.65 ± 0.03 a	0.46 ± 0.02 a	0.52 ± 0.04 b	0.56 ± 0.02 b
Cutting strips	CK	0.56 ± 0.02 b	—	0.49 ± 0.03 c	—	0.39 ± 0.03 b	0.42 ± 0.03 b
	T1	0.69 ± 0.03 a	—	0.62 ± 0.04 a	—	0.49 ± 0.03 a	0.48 ± 0.02 a
	T2	0.64 ± 0.03 a	—	0.59 ± 0.05 ab	—	0.47 ± 0.02 a	0.51 ± 0.03 a
	T3	0.64 ± 0.02 a	—	0.54 ± 0.03 b	—	0.42 ± 0.03 b	0.49 ± 0.02 a

Note: a, b, c—different letters indicate significant differences among different treatments ($p < 0.05$). The values represent means $\pm$ SE. CK: no cutting of *Indocalamus latifolius*, T1: strip cutting width of 1 m, T2: strip cutting width of 2 m, T3: strip cutting width of 3 m.

In the reserved strips, the nitrogen allocation ratios of new leaves and new stems exhibited an initial increase followed by a decrease with the increase in cutting width, with both parameters peaking under the T2 treatment. Relative to CK, the nitrogen allocation ratios of new leaves and new stems under T2 increased by 86.3% and 78.5%, respectively ($p < 0.05$). In contrast, the nitrogen allocation ratios of old leaves, old stems, and roots showed an initial decline followed by an elevation as cutting strip width increased, and all reached their minimum values under the T2 treatment. Relative to CK, the nitrogen allocation ratios of old leaves, old stems, and roots under T2 decreased by 42.4%, 37.4%, and 25.8%, respectively. The nitrogen allocation ratios of rhizomes continuously increased with the increase in cutting width. Relative to CK, the nitrogen allocation ratios of rhizomes under T1, T2, and T3 treatments increased by 23.5%, 40.5%, and 61.5%, respectively ($p < 0.05$) (Figure 9A). In the cutting strips, the nitrogen allocation ratios of new leaves, new stems, and rhizomes showed no significant differences among the four treatments. Relative to CK, the nitrogen allocation ratios of roots were significantly reduced under T1, T2, and T3 treatments, with reduction magnitudes of 29.3%, 23.0%, and 30.6%, respectively ($p < 0.05$) (Figure 9B).

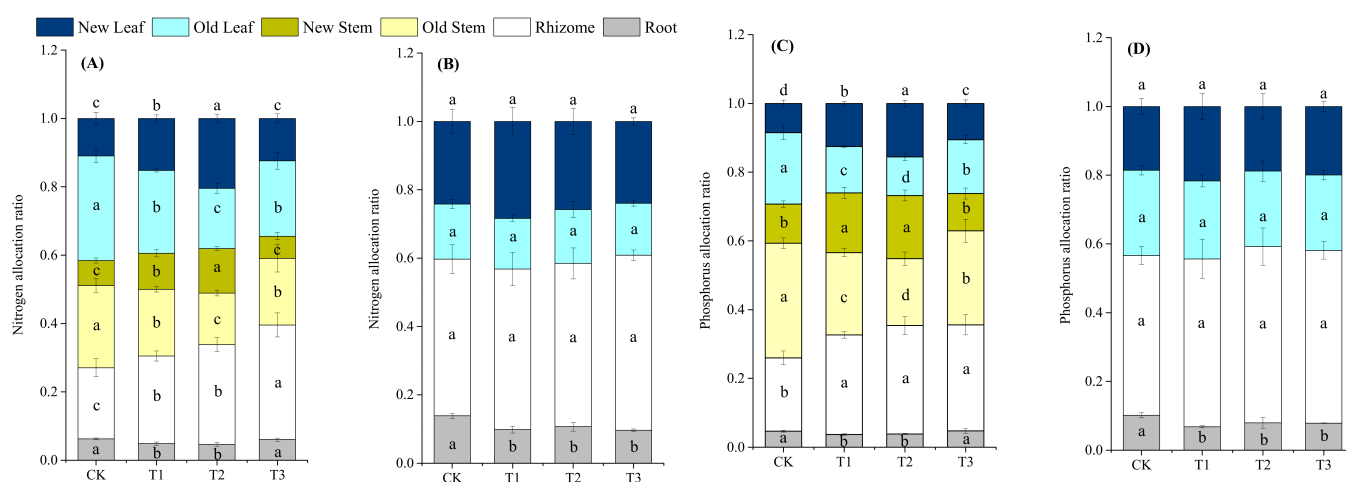


Figure 9. Nitrogen and phosphorus allocation ratio of *Indocalamus latifolius* under different strip cutting treatments. Note: a, b, c—different letters indicate significant differences among different treatments ($p < 0.05$). The values represent means $\pm$ SE. (A): nitrogen accumulation ratio of reserved strips; (B): nitrogen accumulation ratio of cutting strips; (C): phosphorus accumulation ratio of reserved strips; (D): phosphorus accumulation ratio of cutting strips. CK: no cutting of *Indocalamus latifolius*, T1: strip cutting width of 1 m, T2: strip cutting width of 2 m, T3: strip cutting width of 3 m.

In the reserved strips, the phosphorus allocation ratios of new leaves and new stems increased first and then decreased with the increase in cutting width, and both peaked under the T2 treatment. Compared with CK, the phosphorus allocation ratios of new leaves and new stems under T2 increased by 81.1% and 61.6%, respectively. In contrast, the phosphorus allocation ratios of old leaves, old stems, and roots declined initially and then rose as cutting strip width increased, all reaching their minimum values under T2. Relative to CK, the phosphorus allocation ratios of old leaves, old stems, and roots under T2 decreased by 46.1%, 41.6%, and 17.3%, respectively. The phosphorus allocation ratio of rhizomes exhibited a gradual upward trend with increasing cutting strip width. Compared with CK, rhizome phosphorus allocation ratios under T1, T2, and T3 rose by 35.6%, 47.8%, and 44.6%, respectively ($p < 0.05$) (Figure 9C). In the cutting strips, there were no significant differences in phosphorus allocation ratios of new leaves, new stems, and rhizomes across the four treatments. Compared with CK, T1, T2, and T3 significantly reduced the phosphorus allocation ratios of roots, with reduction rates of 32.9%, 21.9%, and 22.6%, respectively ($p < 0.05$) (Figure 9D).

3.4. Effects of Different Treatments on Non-Structural Carbohydrate Allocation in *Indocalamus latifolius*

In the reserved strips, no significant differences in starch contents of old leaves, old stems, new stems, and rhizomes were detected among all treatments. Compared with CK, T2 increased the starch content of new leaves by 17.2% and reduced that of roots by 10.9% ($p < 0.05$). In the cutting strips, the starch content of new leaves exhibited an increasing-then-decreasing trend with the increase in cutting width and peaked under T1. Compared with CK, T1 increased the starch content of new leaves by 11.5%. The starch contents of rhizomes and roots under T3 were significantly lower than those under CK and T1 ($p < 0.05$). Relative to CK, the starch contents of rhizomes and roots under T3 decreased by 9.3% and 16.0%, respectively (Table 3).

Table 3. Starch contents of *Indocalamus latifolius* under different treatments.

Strips	Treatments	Starch Content (%)					
		New Leaves	Old Leaves	New Stems	Old Stems	Rhizome	Roots
Reserved strips	CK	6.96 ± 0.29 b	6.28 ± 0.30 a	5.05 ± 0.40 a	5.71 ± 0.28 a	7.22 ± 0.45 a	7.96 ± 0.32 a
	T1	7.53 ± 0.24 ab	6.12 ± 0.34 a	5.11 ± 0.47 a	5.39 ± 0.39 a	7.31 ± 0.40 a	7.48 ± 0.38 ab
	T2	8.16 ± 0.56 a	5.94 ± 0.21 a	5.23 ± 0.30 a	5.28 ± 0.44 a	7.46 ± 0.26 a	7.09 ± 0.19 b
	T3	7.49 ± 0.45 ab	6.32 ± 0.45 a	5.16 ± 0.26 a	5.48 ± 0.32 a	7.38 ± 0.11 a	7.70 ± 0.88 ab
Cutting strips	CK	6.96 ± 0.29 b	—	5.05 ± 0.40 a	—	7.22 ± 0.45 a	7.96 ± 0.32 a
	T1	7.76 ± 0.45 a	—	5.32 ± 0.24 a	—	7.37 ± 0.47 a	8.23 ± 0.57 a
	T2	7.14 ± 0.38 ab	—	5.08 ± 0.33 a	—	7.21 ± 0.70 ab	7.31 ± 0.81 ab
	T3	6.80 ± 0.22 b	—	5.12 ± 0.35 a	—	6.55 ± 0.39 b	6.69 ± 0.61 b

Note: a, b—different letters indicate significant differences among different treatments ($p < 0.05$). The values represent means ± SE. CK: no cutting of *Indocalamus latifolius*, T1: strip cutting width of 1 m, T2: strip cutting width of 2 m, T3: strip cutting width of 3 m.

In the reserved strips, compared with CK, T1 and T2 increased the soluble sugar content of new leaves by 13.8% and 22.7%, respectively, while reducing that of roots by 30.9% and 22.3%, respectively ($p < 0.05$). Relative to CK, T2 significantly increased the soluble sugar content of new stems and rhizomes by 26.9% and 17.5%, respectively ($p < 0.05$). In the cutting strips, the soluble sugar contents of new leaves, new stems, and roots gradually decreased with increasing cutting width. The soluble sugar contents of new leaves and roots under all three cutting treatments were significantly lower than those under CK, and the soluble sugar content of new stems under T3 was significantly lower

than that under CK. Compared with CK, the soluble sugar contents of new leaves, new stems, and roots under T3 decreased by 16.0%, 16.4%, and 30.9%, respectively ($p < 0.05$) (Table 4).

Table 4. Soluble sugar contents of *Indocalamus latifolius* under different treatments.

Strips	Treatments	Soluble Sugar Content (%)					
		New Leaves	Old Leaves	New Stems	Old Stems	Rhizome	Roots
Reserved strips	CK	1.81 ± 0.07 b	2.02 ± 0.13 a	0.67 ± 0.04 b	0.80 ± 0.07 a	1.37 ± 0.08 b	0.94 ± 0.13 a
	T1	2.06 ± 0.11 a	2.01 ± 0.12 a	0.78 ± 0.08 ab	0.77 ± 0.04 a	1.48 ± 0.07 b	0.65 ± 0.06 c
	T2	2.22 ± 0.16 a	1.93 ± 0.11 a	0.85 ± 0.06 a	0.77 ± 0.06 a	1.61 ± 0.09 a	0.73 ± 0.05 b
	T3	1.88 ± 0.10 b	1.97 ± 0.09 a	0.71 ± 0.06 b	0.78 ± 0.04 a	1.35 ± 0.11 b	0.82 ± 0.09 ab
Cutting strips	CK	1.81 ± 0.07 a	—	0.67 ± 0.04 a	—	1.37 ± 0.08 a	0.94 ± 0.13 a
	T1	1.58 ± 0.12 b	—	0.65 ± 0.06 ab	—	1.43 ± 0.09 a	0.80 ± 0.09 b
	T2	1.56 ± 0.14 b	—	0.60 ± 0.05 ab	—	1.41 ± 0.08 a	0.76 ± 0.07 b
	T3	1.52 ± 0.10 b	—	0.56 ± 0.04 b	—	1.38 ± 0.06 a	0.65 ± 0.03 c

Note: a, b, c—different letters indicate significant differences among different treatments ($p < 0.05$). The values represent means ± SE. CK: no cutting of *Indocalamus latifolius*, T1: strip cutting width of 1 m, T2: strip cutting width of 2 m, T3: strip cutting width of 3 m.

4. Discussion

4.1. Biomass Allocation Strategies

In this study, both the 1 m and 2 m cutting strips exerted positive effects on new bamboo growth within reserved strips. Such compensatory growth in reserved strips may represent a form of clonal integration known as clonal division of labor in clonal plants [29]. When resource acquisition of some ramets within a clonal system is constrained, other ramets often develop compensatory growth to mitigate the risk of mortality induced by heterogeneous environmental stress [30]. Alternatively, this compensatory growth may also stem from elevated light availability in reserved strips following strip clear-cutting. A study has revealed that strip clear-cutting creates a light gradient increasing from the interior toward the edges of reserved strips. Consequently, new seedlings growing closer to strip edges within reserved strips display superior growth performance [31]. In studies concerning *P. edulis*, strip cutting boosts new bamboo sprouting within cutting strips yet suppresses new ramet growth in reserved strips [32]. This indicates that the adaptive strategy of compensatory growth observed in *I. latifolius* is absent in moso bamboo. Nevertheless, new moso bamboo ramets within reserved strips display leaf–stem allometric growth, with leaves growing considerably faster than stems [17]. Cutting treatments exert minimal impacts on the growth of old bamboo. This may be attributed to the fact that old ramets have lower annual growth rates and weaker morphological plasticity compared with young ramets [2].

The 2-meter-wide cutting strip treatment yielded substantially stronger facilitative effects on new ramets in reserved strips compared with the 1 m treatment. A plausible explanation is that, despite its narrower cutting width, the 1 m strip setup entails narrower reserved strips and a higher density of cutting zones. Consequently, bamboo ramets in reserved strips suffer more intensive resource extraction from adjacent cutting strips. When strip width is expanded to 3 m, new ramet development inside cutting strips is constrained, accompanied by the disappearance of compensatory growth in reserved strips. This may also occur when the inter-ramet distance reaches the threshold for clonal integration, restricting both signal transduction and resource translocation [33]. For instance, studies on *P. glauca* have identified the maximum transmission distance of clonal integration as 2.8 m [34]. For *I. latifolius*, which features smaller ramets and shorter spacers, this critical

distance is likely even shorter. Although moderate widths of reserved strips facilitate the growth of new ramets, such a biomass allocation strategy suppresses root development. The canopy cutting impairs the carbon-fixing capacity of the clonal system far more severely than its nutrient absorption capacity. Accordingly, clonal systems tend to allocate greater biomass to photosynthetic leaves.

In this study, the 1 m cutting strip generated the optimal growing conditions for new ramets within the cutting zone. The canopy gaps created by cutting alleviated interspecific light competition. Elevated understory light intensity following strip cutting substantially boosts the growth of heliophytic vegetation [35]. Meanwhile, the increased surface temperature after cutting accelerates litter decomposition, which elevates soil nutrient availability and further facilitates vegetation regeneration [36]. Conversely, research on coniferous plantations has drawn contradictory conclusions, reporting that clear-cutting fails to promote understory species regeneration [37]. Such divergent results may be related to species-specific light requirements, recovery duration, and forest types [16]. Non-clonal plants without clonal integration traits may require a longer recovery period [13]. Although excessively wide cutting strips provide ample growing space, the excessive inter-ramet distance disrupts resource translocation via clonal integration and thereby suppresses the growth of new ramets. Most existing studies focus primarily on vegetation regeneration within cutting strips while overlooking the growth performance of reserved strips. For *I. latifolius*, whose young leaves are harvested annually, reserved strips contribute a larger share of yield and thus merit greater research attention. Overall, the 2 m cutting strip yields the maximum production of new leaves, whereas the 1 m cutting strip delivers superior regeneration and recovery within harvested zones. One limitation of this study is that post-harvest soil properties and microclimatic conditions were not monitored. This gap hinders our full understanding of the adaptive mechanisms of *I. latifolius*.

4.2. Root Morphological Plasticity

In this study, strip clear-cutting inhibited root elongation within reserved strips. This phenomenon may arise because limited resources are preferentially allocated to leaves, reducing root proliferation. This represents a morphological plasticity strategy whereby clonal plants simplify their tissue structures under resource scarcity [38]. Nevertheless, the morphological plastic responses of bamboo species to cutting vary considerably. For example, research on *P. edulis* has shown that strip cutting exerts weak impacts on root systems and reduces leaf area within cutting strips [4]. Excessively wide cutting strips eliminate compensatory aboveground growth, while root length within reserved strips remains nearly unchanged. However, this leads to much stronger growth suppression of ramets and roots in cutting strips that rely on resource supply from reserved strips. Notably, while root growth was suppressed in this experiment, root diameter increased. This is mainly driven by a reduced ratio of finer roots and an increased ratio of coarse roots. Previous studies have also confirmed that fine root growth is the first to be suppressed under resource limitation [39]. For non-clonal tree species incapable of clonal integration, cutting imposes an even stronger inhibitory effect on fine roots. For instance, fine root biomass in oak stands under cutting treatments dropped to merely 22% of that in uncut plots [40]. Such impacts on fine root development also depend on cutting intensity. Existing research reports accelerated fine root decomposition with rising cutting intensity [41]. Overall, strip cutting restrains root proliferation and may trigger root system degradation over time. To achieve sustainable management, root-promoting practices such as phosphorus fertilization and soil tillage can be implemented alongside harvesting. The upward allocation of resources did not suppress rhizome growth. This indicates that under resource scarcity, rhizomes responsible for ramet propagation take priority over absorption roots.

4.3. Nutrients and Photosynthate Allocation

Strip clear-cutting increased the nitrogen content of new bamboo and belowground tissues. This may be because strip clear-cutting curtails nutrient consumption in aboveground tissues, resulting in a relatively nutrient-sufficient internal status within the plant [16]. Additionally, the accelerated return of nutrients to the soil following cutting may also contribute to this pattern. Previous research on moso bamboo forests has reported significant increases in soil available nitrogen and available phosphorus under 12 m and 15 m cutting strip widths [13]. Such nutrient elevation is most pronounced in the early post-harvest stage [32]. Notably, nutrient contents in old leaves and stems decreased significantly. This trend was especially evident under treatments T1 and T2, which produced greater biomass of new leaves and stems. This suggests that under nutrient deficiency, *I. latifolius* activates nutrient resorption mechanisms, whereby nutrients are remobilized from mature tissues to nourish newly formed tissues. Nutrient resorption is a functional strategy that alleviates resource limitation induced by adverse conditions such as drought and shading [2,42].

In terms of non-structural carbohydrate (NSC) allocation, *I. latifolius* under strip cutting allocated more photosynthates to newly formed leaves and stems. The reduction in root soluble sugars was the primary factor restricting root growth. Earlier studies have likewise confirmed that root NSC contents are key regulators of root growth and root morphology [43,44]. Su et al. observed a universal decline in soluble sugar concentrations across all organs of moso bamboo under strip cutting, with more severe impacts on large-culm individuals [45].

5. Conclusions

In conclusion, the findings of this study fully validate the three initial hypotheses proposed. First, the 2-meter-wide cutting strips yield the greatest production of new leaves, while the 1-meter-wide cutting strips facilitate superior regeneration and recovery of *I. latifolius* within cutting strips. Both the cutting intensities trigger compensatory growth of new leaves and stems in reserved strips, which validates Hypothesis 1. Second, the 1 m and 2 m strip cutting treatments suppress finer root proliferation and thicken root systems in reserved strips. This phenomenon demonstrates the root morphological plasticity of *I. latifolius* under strip cutting disturbance, thereby confirming Hypothesis 2. Under strip cutting regimes, *I. latifolius* preferentially allocates nutrients and non-structural carbohydrates to rhizomes and newly formed leaves and stems in reserved strips, supporting Hypothesis 3. The results fill the research gap regarding strip cutting of dwarf bamboo species, and provide theoretical references for population regeneration and rational cutting management of *I. latifolius* in natural habitats.

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