RESEARCH ARTICLE

# The effects of different cultivation modes on the growth traits of vegetative branches of cut roses

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**As one of the world's four major cut flowers, cut rose boasts both remarkable ornamental appeal and commercial potential with its industry advancement being vital to bolstering the floral economy. The growth of vegetative shoots directly dictates the yield and quality of cut roses, while cultivation modes serve as the core lever for regulating this growth. In current practices, conventional soil cultivation often triggers continuous cropping issues, compromising vegetative shoot development. Yet, systematic comparative validation of the efficacy of substrate cultivation and soil-improved cultivation remains insufficient. This study explored the effects of different cultivation modes on the disease incidence, growth and development, and flower traits of vegetative branches of cut roses, evaluated the advantages and disadvantages of the three modes, and provided a scientific basis for selecting efficient cultivation modes for cut roses. Three treatments were set up as substrate cultivation (T1), soil improvement cultivation (T2), and conventional soil cultivation (T3). The diseased plant rate and disease index were determined, while the cutting survival rate, plant height, stem diameter, number of branches, and number of leaves of roses were counted. After layering the vegetative branches, the flower diameter, number of flowers, and number of petals of the first batch of cut flowers that met the cut flower standards were measured. Correlation analysis and principal component analysis (PCA) were used to comprehensively evaluate the differences in rose growth traits. The results showed that different cultivation modes had significant effects on the related indices of vegetative branches. The diseased plant rate of T2 was significantly lower than that of T1 and T3. The cutting survival rate showed an order of T2 > T1 > T3 with T1 and T2 increasing by 4.68% and 8%, respectively, compared with T3. Among the growth indices of vegetative branches, plant height, stem diameter, and number of leaves all followed the order of T2 > T1 > T3. T2 performed the best in terms of number of flowers, number of petals, and flower diameter, and the indices of T2 were 34.62%, 27.22%, and 44.69% higher than those of T3, respectively. Correlation analysis showed that plant height, stem diameter, and number of leaves had an extremely significant positive correlation with the number of flowers, number of petals, and flower diameter. The comprehensive score ranking of PCA was T2 > T1 > T3. The three cultivation modes had significant effects on the disease incidence, growth and development, and flower traits of vegetative branches. T2 was the optimal cultivation mode as it improved the growth status of vegetative branches of cut roses, reduced disease incidence, and enhanced the quality of cut flowers. T1 ranked second, while T3 was the worst. The results of this study provided a scientific basis for the selection of efficient cultivation modes for cut roses and had important practical guiding significance for promoting the sustainable development of the flower industry.**

**Keywords:** cultivation mode; cut roses; vegetative branches; growth traits.

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## Introduction

*Rosa hybrida*, renowned for its prolonged blooming period and diverse flower colors, holds significant ornamental and commercial value, ranking among the world's four most important cut flowers [1]. In recent years, with continuous expansion of market demand, enhancing the yield and quality of cut roses has become a critical objective for the sustainable development of the floriculture industry [2]. As vegetative branches are pivotal in determining plant value, their quantity and vigor directly influence branching capacity and cut-flower yield, fundamentally dictating the grade and market value of fresh-cut flowers [3]. During the cultivation of vegetative branches in cut roses, the properties of the growth medium constitute a decisive factor affecting their development. An optimal medium creates a loose, well-aerated, nutrient-balanced environment for root systems [4], while providing structural support to ensure robust stem thickness and fullness, thereby preventing weak growth and diminished branching potential caused by suboptimal substrates [5]. Given that the status and abundance of vegetative branches profoundly impact overall plant vigor, productivity, and floral quality [6]. Investigating the growth characteristics of vegetative branches under different cultivation media including substrate-based systems, soil-improvement practices, and conventional field soil holds substantial research significance.

It has been established that vegetative branches are core determinants of yield and quality in cut roses with studies demonstrating that enhancing their quantity and quality constitutes an effective approach to improving overall productivity [7, 8]. The growth of these branches is influenced by multiple interacting factors [9]. Ye *et al*. reported positive correlations between changes in the number of vegetative branches and plant height, stem diameter, fresh weight, and dry matter accumulation [10]. Existing research predominantly focuses on single cultivation systems, which is either substrate-based or conventional soil farming, while comprehensive comparative analyses among substrate culture, soil-improvement practices, and traditional field cultivation remain limited. Moreover, investigations into vegetative branch development have primarily focused on pruning frequency and height management, leaving the effects of growth medium conditions on branch formation and cultivation underexplored.

This study aimed to elucidate how different cultivation models affected disease incidence, growth dynamics, and developmental variations in vegetative branches of cut roses to objectively assess their relative merits by systematically evaluating multidimensional impacts across various cultivation modes. The cut rose cultivar “Sweetheart Story” was selected for this research with three cultivation modes established as substrate cultivation, soil-improved cultivation, and conventional soil cultivation. By investigating the incidence and disease index of powdery mildew as well as the survival rate of cuttings under different modes and assessing agronomic growth traits of vegetative shoots including plant height, stem diameter, branch number, leaf count, and soil and plant analysis development (SPAD) value, this study analyzed flower traits including diameter, number, and petal count of the first flush of cut flowers following vegetative branch layering. Furthermore, correlation analysis and principal component analysis were employed to explore the intrinsic relationship between vegetative shoot growth traits and flower traits, thereby comprehensively evaluating the application efficacy of the three cultivation modes. The results of this research provided empirical evidence for selecting high-efficiency cultivation strategies and offered practical guidance to advance sustainable floriculture industry development.

## Materials and methods

### Plant resource and planting modes

The rose cuttings of “Sweetheart Story” rose cultivar with 30 days seedling age obtained from

Kunming Jinyuan Flower Industry Co., Ltd. (Kunming, Yunnan, China) were employed in this research. The cultivation trials were conducted in the greenhouse facility of Academician Chen Wenfu's Workstation located at Xiangshi Village, Anning City, Yunnan, China with the geographic coordinates of 24°93’74” N and 102°54’05” E, altitude of 1,860 m. The soil type was loamy with neutral pH, good water retention, adequate irrigation infrastructure, abundant water resources, and efficient drainage conditions. Three planting modes were established with substrate-based cultivation mode (T1) utilizing a substrate mixture composed of coconut coir:perlite:ceramsite as 60%:15%:25%, soil improvement cultivation mode (T2) involving deep plowing amendment with 7.5 kg/m² bio-organic fertilizer containing 30% Zhaotong humic acid, 30% chrysanthemum residue, 30% tobacco dust, and 10% supplementary blend comprising distillers' grains, fish protein, rapeseed cake, potassium fulvate, tobacco-derived potassium at pH 7.28 prior to planting, and conventional soil cultivation mode (T3) as control without any pre-treatment. Uniformly grown rose cuttings were transplanted by using single-ridge double-row configuration at 15 cm plant spacing × 30 cm row spacing. Each treatment was implemented with 300 cuttings, and the experiment was replicated three times with 100 cuttings per replication. All cultivation systems received identical standardized irrigation and fertilization protocols throughout the experimental period. The assessments were performed after 90 days of vegetative branch development preceding cane bending.

### Disease investigation and disease index calculation

A five-point sampling method was employed to assess the incidence of major rose diseases (powdery mildew) [11]. Two plants were randomly selected at each point with all leaves per plant being examined. Each treatment was replicated three times. The diseased plant rate and disease index for the rose cultivar under the three cultivation modes were statistically analyzed by using the disease identification grading standards with the lesion areas less than 5%, 5.1 – 10%, 10.1 to 25%, 25.1 to 50%, and larger than 50% as scales 0, 3, 5, 7, and 9, respectively [12]. The disease incidence rate (DIR) and disease index (DI) were calculated as follows.

$$\text{DIR} = \frac{\text{Number of Infected Plants}}{\text{Total Number of Plants Sampled}} \times 100\ \%$$

$$\text{DI} = \Sigma \frac{(\text{No. of diseased leaves at each scale} \times \text{representative value of each scale})}{(\text{Total No. of diseased leaves} \times 9)} \times 100$$

### Measurement of growth traits

By the 90th day of vegetative branch development, when rose cuttings met the cane-bending standard for vegetative branches, survival rates, plant height, stem diameter, number of branches, SPAD values (relative chlorophyll content), and leaf count were recorded across different cultivation treatments. Following cane bending, first-flush flowers conforming to harvest standards were evaluated for flower diameter, floral abundance, and petal quantity [13].

### Determination of leaf SPAD values

During active growth phases of reproductive shoots, the widest midpoint region of the fourth fully expanded compound leaf below the apical meristem was selected [14]. Chlorophyll content (SPAD index) was measured by using a SPAD-TYS-A SPAD meter (Beijing Zhongke Weihe Technology Development Co., Ltd., Beijing, China) across fifteen representative leaves per treatment with mean values calculated as relative SPAD concentrations.

### Data processing and analysis

Data compilation was performed in Microsoft Excel 2021 (Microsoft, Redmond, WA, USA). The statistical analyses were conducted by using SPSS Statistics 26 (IBM, Armonk, NY, USA). The data visualizations were generated by using OriginPro 2025 software (Origin Lab Corporation, Northampton, MA, USA). Duncan’s test was employed to analyze the difference significance with $P$ value less than 0.05 as statistically significant.

**Table 1.** Investigation on diseases of roses under different cultivation modes.

| Date | Treatment | Total number of plants surveyed | Diseased plant rate (%) | Disease index |
|---|---|---|---|---|
| 90 d | T1 | 30 | 12.66 ± 1.53$^{b}$ | 2.5 ± 0.11$^{b}$ |
| | T2 | | 10.33 ± 0.58$^{c}$ | 2.47 ± 0.16$^{b}$ |
| | T3 | | 16.33 ± 1.15$^{a}$ | 4.64 ± 0.62$^{a}$ |

**Note:** The data were expressed as mean ± standard deviation (n = 3). Different lowercase letters in the same column indicated significant differences between different treatments ($P < 0.05$).

## Results

### Effects of different cultivation modes on disease incidence in vegetative branches

The results showed that the cultivation mode significantly affected the incidence rate of diseased plants ($P < 0.05$). Among the three treatments, the disease incidence was markedly lower under T2 than under T1 or T3, indicating that both T2 and T1 effectively reduced disease occurrence with T2 demonstrating superior performance in controlling infected plant numbers. The highest disease incidence occurred under T3, suggesting this system predisposed roses to greater susceptibility. Significant differences were also observed in disease index across modes ($P < 0.05$). Both T1 and T2 exhibited substantially lower disease severity indices compared to T3, while no significant difference existed between T1 and T2, implying equivalent efficacy in mitigating pathogenic damage. Notably, T3 not only showed maximum infection frequency but also induced severe symptom expression (Table 1). Overall, soil-improved cultivation (T2) proved optimal for minimizing both disease prevalence and pathological impact.

### Effects of different cultivation modes on survival rate of rose

The significant differences were observed in survival rates among treatments T1, T2, and T3 ($P < 0.05$). The overall trend of rose survival rate under the three cultivation modes was T2 > T1 > T3. Compared to T3, survival rates increased by 4.68% and 8% for T1 and T2, respectively. No significant difference was found between T1 and T2, while a significant difference existed between T2 and T3. Survival rate under T2 treatment was 2.98% higher than that under T1 and 8% higher than that under T3, indicating that T2 treatment was more conducive to improving plant survival rate, whereas T3 showed relatively poor performance in maintaining survival rate (Figure 1).

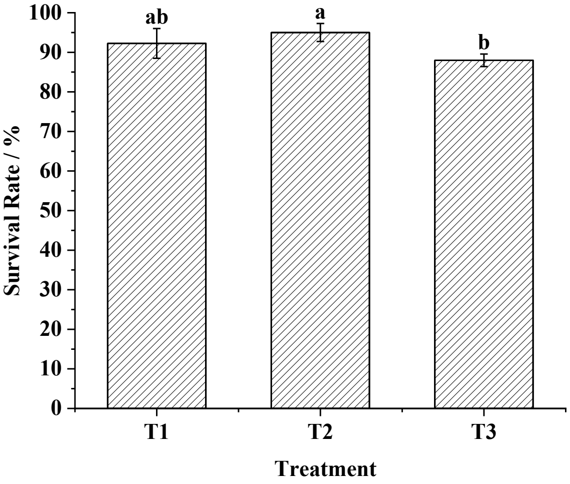

**Figure 1.** Effects of different cultivation modes on cutting survival rate of roses. The different lowercase letters in the same column indicated significant difference between different treatments ($P < 0.05$).

### Effects of different cultivation modes on agronomic trait development of vegetative branches

The diverse cultivation modes exerted significant impacts on the vegetative growth traits including plant height, stem diameter, branch number, and leaf count of cut roses ($P < 0.05$). Across all metrics, the general pattern ranked as T2 > T1 > T3. Specifically, under the T2 treatment, plant height, stem diameter, and leaf count increased by 17.18%, 13.83%, and 29.63%, respectively, over T3, while T1 and T2 both showed a 29.41% increase in branch number. Notably, T2 showed

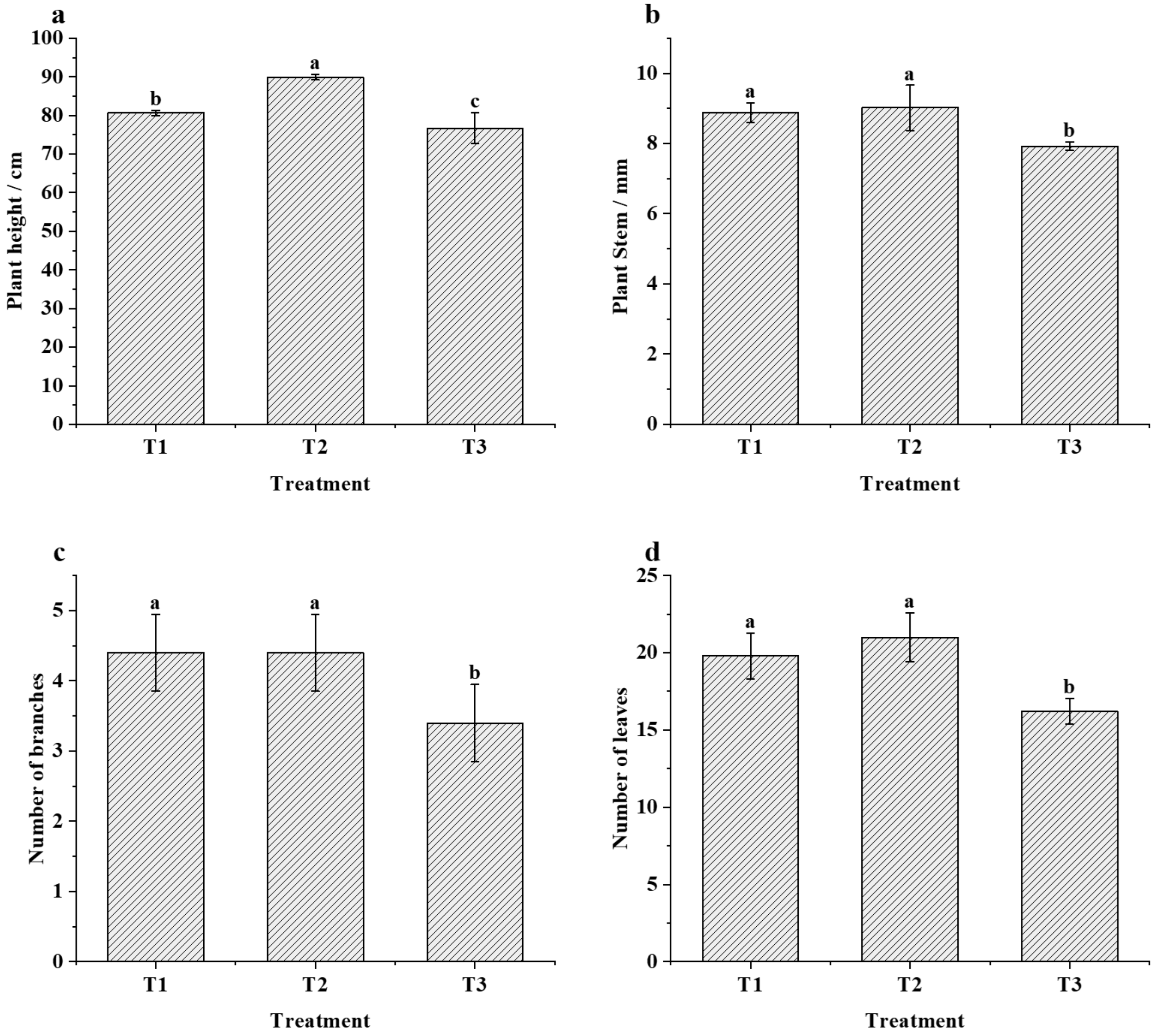

**Figure 2.** Effect of diverse cultivation modes on the growth of agronomic traits in vegetative shoots. **a.** plant height. **b.** plant stem. **c.** number of branches. **d.** number of leaves. The different lowercase letters in the same column indicated significant difference between different treatments (*P* < 0.05).

a more pronounced boost, indicating both soil-improved and substrate cultivation outperformed conventional soil with T2 being optimal (Figure 2).

### Effects of different cultivation modes on SPAD value in vegetative branches

Significant differences were observed in leaf SPAD value among different treatments of T1, T2, and T3 ($P < 0.05$). Under the three cultivation modes, the overall trend for rose SPAD value was T1 > T2 > T3. Compared to T3, SPAD value increased by 10.47% and 5.87% under T1 and T2 treatments, respectively. No significant difference was found between T1 and T2, nor between T2 and T3, while a significant difference existed between T1 and T3. SPAD value under T1 treatment was 4.34% higher than that under T2 and 10.47% higher than that under T3, indicating that both T1 and T2 were conducive to promoting SPAD value accumulation compared with T3, while T1 treatment exhibited a more pronounced effect (Figure 3).

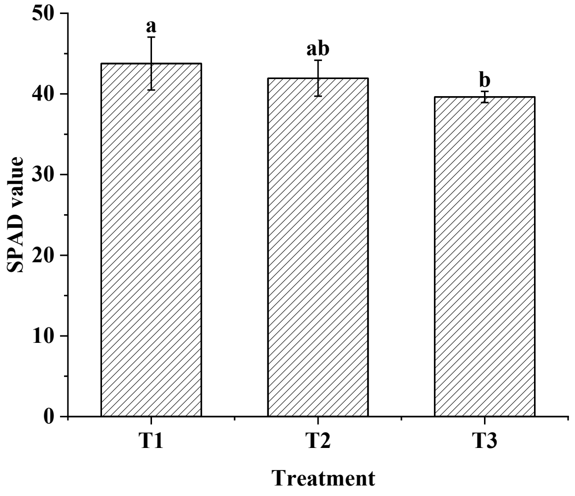

**Figure 3.** Effects of different cultivation modes on SPAD value of Roses. The different lowercase letters in the same column indicated significant difference between different treatments ($P < 0.05$).

## Effects of different cultivation modes on flower traits

Significant differences were observed in flower traits among different treatments of T1, T2, and T3 ($P < 0.05$). Under the three cultivation modes, the overall trends for rose flower number, petal number, and flower diameter were T2 > T1 > T3. Specifically, compared to T3, flower number increased by 19.23% and 34.62% under T1 and T2 treatments, respectively, while petal number increased by 13.33% and 27.22%, respectively, and flower diameter increased by 22.27% and 44.69%, respectively. Flower number under T2 treatment was 12.9% higher than that under T1 and 34.62% higher than that under T3. Petal number under T2 was 12.25% higher than that under T1 and 27.22% higher than that under T3. Flower diameter under T2 was 18.35% higher than that under T1 and 44.69% higher than that under T3 (Figure 4). These results indicated that both T1 and T2 treatments significantly promoted flowering traits compared with T3 treatment, while T2 treatment was more conducive to increasing flower number, petal quantity, and flower diameter, demonstrating a more pronounced effect on improving rose flower quality.

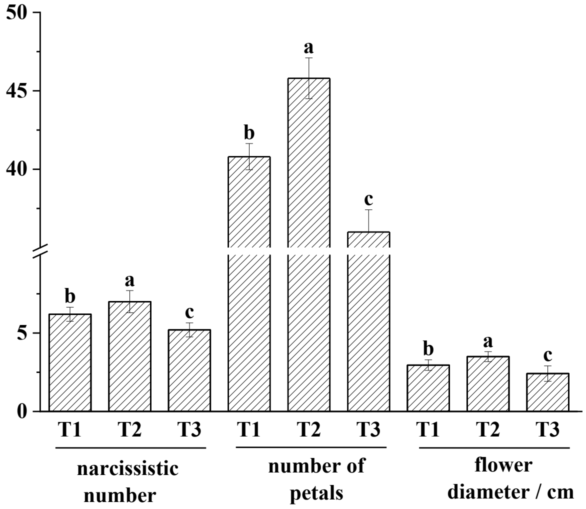

**Figure 4.** Effects of different cultivation modes on Rose flowering traits. The different lowercase letters in the same column indicated significant difference between different treatments ($P < 0.05$).

## Correlation analysis of growth indicators in roses under different cultivation modes

Pearson correlation analysis revealed varying inter-indicator relationships among growth traits across cultivation modes. Petal numbers exhibited a highly significant positive correlation with flower diameter. Vegetative branch height demonstrated highly significant positive correlations with leaf count and cut-flower branch abundance, while weak non-significant positive correlations were observed between plant height and SPAD values, as well as between stem diameter and SPAD. Overall, key vegetative growth metrics including height, stem thickness, leaf quantity showed highly significant positive associations with quality parameters of reproductive structures including floral abundance, petal quantity, bloom diameter, whereas SPAD values displayed weak and non-significant correlations with most other indicators (Figure 5). These findings indicated that the developmental status of vegetative branches positively influenced floral quality characteristics, while chlorophyll content showed limited predictive value for comprehensive growth performance.

## Comprehensive evaluation of rose traits under different cultivation modes

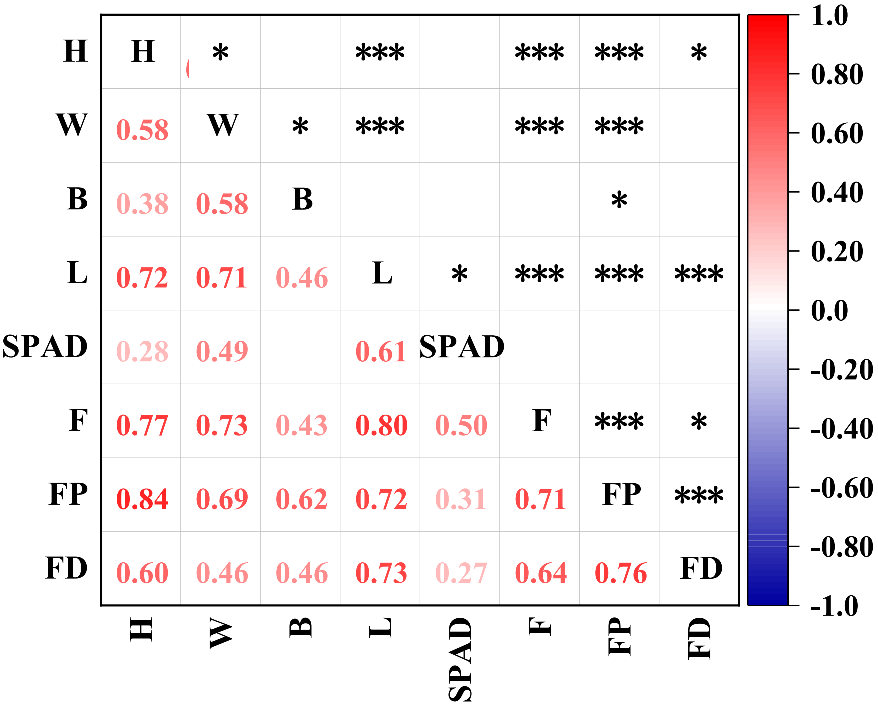

**Figure 5.** Correlation analysis of growth indicators of Roses under different cultivation modes. **H:** plant height. **W:** stem diameter. **B:** number of branches. **L:** number of leaves. **F:** number of flowers. **FP:** number of petals. **FD:** flower diameter. *****: $P \leq 0.05$. *******: $P \leq 0.001$.

**Table 2.** Principal component analysis of 8 growth traits under different cultivation modes.

| Index | Growth index | PC1 | PC2 | PC3 |
|---|---|---|---|---|
| Eigenvector | Plant height | 0.164 | -0.076 | -0.498 |
| | Stem diameter | 0.162 | 0.055 | 0.618 |
| | Leaf number | 0.121 | -0.527 | 0.688 |
| | Branch number | 0.178 | 0.182 | -0.051 |
| | SPAD | 0.103 | 0.714 | 0.278 |
| | Flower count | 0.175 | 0.13 | -0.078 |
| | Petal quantity | 0.178 | -0.213 | -0.179 |
| | Bloom diameter | 0.155 | -0.151 | -0.487 |
| Eigenvalue | | 5.10 | 1.09 | 0.69 |
| Contribution rate (%) | | 63.697 | 13.667 | 8.572 |
| Cumulative contribution rate (%) | | 63.697 | 77.364 | 85.936 |

Principal component analysis (PCA) was performed on growth traits across cultivation systems. Three principal components were extracted, accounting for 85.94% of total variance. Eigenvalues for the three components reached 5.10, 1.09, and 0.69, respectively. The first principal component (PC1), contributing 63.70% of variance, primarily correlated with branch number and petal count. PC2 explained 13.67% variation, mainly associated with leaf quantity and SPAD values. PC3 accounted for 8.57% of variance, predominantly linked to stem diameter and leaf number (Table 2). Higher composite scores indicated superior growth

**Table 3.** Comprehensive evaluation scores of each treatment.

| Treatment | Principal component factor score | | | General score | Rank |
|---|---|---|---|---|---|
| | F1 | F2 | F3 | | |
| T1 | 0.22 | 0.38 | 0.22 | 0.21 | 2 |
| T2 | 1.03 | -0.38 | -0.64 | 0.55 | 1 |
| T3 | -1.25 | 0.00 | -0.28 | -0.82 | 3 |

performance. By using variance contribution rates as weights, the comprehensive score was calculated as follows.

$$F = 0.64 \times PC1 + 0.14 \times PC2 + 0.08 \times PC3$$

The ranking order was T2 > T1 > T3. Overall, both substrate-based (T1) and soil-improved (T2) cultivation significantly enhanced plant vigor compared to conventional soil farming (T3) with T2 demonstrating optimal outcomes (Table 3).

## Discussion

Significant differences were observed in disease incidence and severity index of vegetative branches across cultivation modes. The results demonstrated that soil-improved cultivation (T2) exhibited the lowest diseased plant rate and pathological index, significantly outperforming conventional soil farming (T3), while showing no significant difference from substrate-based cultivation (T1). Survival rates followed the order of T2 > T1 > T3, indicating soil-improvement as the optimal strategy for disease suppression and propagation success. This study revealed pronounced effects of cultivation systems on vegetative growth parameters including plant height, stem diameter, branch number, leaf count, and SPAD values with T2 demonstrating superior performance in all metrics except SPAD, while T1 showed marginal advantage. These findings aligned with previous research [15, 16], establishing that robust vegetative structures enhanced cut-flower quality through increased assimilate supply to reproductive shoots [17]. Notably, floral traits including bloom quantity, petal abundance, and flower diameter followed the sequence of T2 > T1 > T3 with T2 significantly surpassing T1, suggesting that optimized vegetative development under soil-improved conditions maximized cut-flower quality. This phenomenon aligned with the findings of Xu *et al*. who observed dry matter accumulation in the vegetative organs of cotton [18]. Pearson correlation analysis confirmed highly significant positive associations between vegetative metrics of height, stem thickness, leaf number and floral characteristics, which was corroborated by the reports of Liu *et al*. who found phenotypic correlations in *Astragalus polycladus* [19]. Weak non-significant correlations were detected between SPAD values and other indicators. Principal component analysis extracted three components accounting for 85.94% total variance with comprehensive rankings confirming T2's superiority. The enhanced vegetative vigor observed in T2 characterized by greater stem girth corresponding to improved fruiting traits was the similar to the findings about jujube productivity [20]. These advantages likely stemmed from the improvements in soil physicochemical properties brought about by organic fertilizers [21]. Collectively, this systematic evaluation demonstrated that soil-improved cultivation (T2) optimally enhanced vegetative branch development and subsequent cut-flower quality, establishing a positive correlation between vegetative growth and floral excellence. These insights provided scientific foundations for efficient rose production protocols with substantial implications for industrial advancement.

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