

# Auxin-Cytokinin Activity of Combined Soybean Radicle and Red Shoot Extract for Promoting Rooting and Induced Resistance in Red Dragon Fruit Cuttings

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**Abstract.** This study explored the auxin–cytokinin activity of combined soybean radicle and red shoot extracts to enhance rooting and induce resistance in red dragon fruit (*Hylocereus polyrhizus*) cuttings. A factorial randomized complete block design was used, involving nine treatment combinations of different extract concentrations. GC–MS profiling confirmed the presence of phytohormones including indole-3-acetic acid (IAA) and zeatin-type cytokinins in both extracts. The treatment combining 100% soybean radicle with 50% red shoot extract (K1P2) showed the highest root number (8.67), while 50% soybean radicle alone (K2P0) resulted in the longest root length (21.85 cm). Root biomass, both fresh and dry, was significantly increased under combined extract treatments, especially K1P2. Root Discoloration Index analysis indicated improved disease resistance, with several treatments reaching the “resistant” category. These results highlight the potential of natural, hormone-rich plant extracts as sustainable biostimulants for improving vegetative propagation and defense response in red dragon fruit cultivation.

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## 1 Introduction

Red dragon fruit (*Hylocereus polyrhizus*) has become an increasingly important horticultural commodity in Indonesia, both for domestic markets and as an export product. This plant grows widely in tropical and subtropical regions and is well known for its high nutritional content, antioxidant activity, and significant health benefits. In Indonesia, its cultivation has expanded rapidly, particularly among smallholder farmers, due to its ability to adapt to marginal soils, low input requirements, and strong market demand. This expansion has also been supported by favorable climatic and edaphic conditions in regions such as Jember, Malang, and Pasuruan, where the crop was initially introduced [1]. Despite its considerable economic potential, several challenges still constrain the optimal propagation of red dragon fruit. The main limitations in its propagation include poor rooting ability of cuttings, high susceptibility to soil-borne pathogens, and inconsistent rooting success in vegetative propagation, which often reduce overall production efficiency. These challenges highlight that efforts to improve root development remain a critical aspect that requires innovation.

Stem cutting is the most common vegetative propagation technique used in the cultivation of *H. polyrhizus*. However, rooting success in cuttings is highly dependent on endogenous hormonal regulation, particularly the presence and balance of auxins and cytokinins. Previous studies have largely focused on the application of synthetic hormones, such as auxins and cytokinins. Although effective in the short term, repeated application poses issues related to production costs, environmental impact, and long-term sustainability. These limitations have increased interest in the use of natural plant-based substances as alternatives to synthetic growth regulators, such as legume sprouts or young tissues with hormonal activity. Research findings have shown that legume sprouts and young shoots exhibit high hormonal activity, with the potential to promote adventitious root formation and enhance cutting survival [2]. In addition, several studies have demonstrated the antimicrobial potential of red shoot leaf extract. In the study by [3] reported various extracts of *S. myrtifolium*, including ethanolic, methanolic, and aqueous extracts, have shown moderate to high antibacterial activity against a range of bacterial pathogens, with inhibition zones ranging from 2 to 27.8 mm. This indicates a broad-spectrum antibacterial potential. However, such studies generally emphasize a single source of phytohormones, without combining multiple potential sources, and rarely associate their role with dual functions in plant defense induction.

The utilization of combined soybean radicle and red shoot extracts as natural phytohormone sources in the propagation of red dragon fruit remains very limited. To date, no studies have specifically evaluated how the combination of these extracts functions not only in stimulating adventitious root formation but also in activating plant defense mechanisms through induced systemic resistance. Therefore, the use of soybean radicle and red shoot extracts may represent a sustainable and multifunctional approach to improve propagation success in red dragon fruit. Furthermore, the application of exogenous compounds such as sugars and nitrogen sources has been shown to influence root architecture and development. Sucrose, glucose, and nitrate nitrogen are known to stimulate root formation and elongation, while hormonal crosstalk among auxins, cytokinins, gibberellins,

and abscisic acid regulates broader physiological responses during vegetative propagation [4,5].

Based on this background, the present study aims to evaluate the auxin–cytokinin-like activity of combined soybean radicle and red shoot extracts in supporting root development and inducing resistance in *Hylocereus polyrhizus* cuttings. Thus, this study is expected not only to provide an environmentally friendly alternative to synthetic hormones in dragon fruit propagation but also to deliver additional benefits for plant health and the sustainability of cultivation practices.

## 2 Research Methods

This research was conducted in a screenhouse located at Graha Dewata Residential Area, Dau District, Malang Regency (-7.934814, 112.574093), and at the Chemistry Laboratory of the University of Muhammadiyah Malang. The study took place over four months, from January 2025 to May 2025. During the experimental period from January to May 2025, the screenhouse in Graha Dewata, Dau–Malang, experienced average daytime temperatures ranging between 27°C and 32°C. The relative humidity varied from 65% to 85%, creating a moderately humid environment favorable for vegetative propagation. Total rainfall over the four months was approximately 900 mm, with most precipitation occurring in February and early March. The microclimatic conditions inside the screenhouse were partially controlled but still reflected typical lowland tropical weather. These environmental parameters were considered adequate for rooting studies and provided realistic conditions for evaluating the performance of the plant extract treatments.

### 2.1 Research design

The study employed a Factorial Randomized Complete Block Design (RCBD) to assess the effects of two factors: soybean radicle extract (0%, 50%, and 100%) and red shoot extract (0%, 50%, and 100%). This resulted in nine treatment combinations, each replicated three times, with stem cuttings grouped by weight into three blocks ( $\leq 160$  g,  $161–170$  g,  $\geq 171$  g) to minimize variability. The nine treatment combinations were as follows: (1) K0P0 – control (no phytohormone soaking), (2) K0P1 – soaking in 100% red shoot extract, (3) K0P2 – soaking in 50% red shoot extract, (4) K1P0 – soaking in 100% soybean radicle extract, (5) K1P1 – soaking in a combination of 100% soybean radicle and 100% red shoot extracts, (6) K1P2 – soaking in 100% soybean radicle extract combined with 50% red shoot extract, (7) K2P0 – soaking in 50% soybean radicle extract, (8) K2P1 – soaking in 50% soybean radicle extract combined with 100% red shoot extract, and (9) K2P2 – soaking in 50% soybean radicle extract combined with 50% red shoot extract. These treatments were designed to investigate the synergistic or individual effects of both natural extracts on rooting performance and potential induced resistance in red dragon fruit (*Hylocereus polyrhizus*) stem cuttings.

### 2.2 Phytohormone Profiling of Soybean Radicle and Red Shoot Extracts

Extraction was performed following [6]. Each sample (50 g of radicle and shoot) was extracted with 100 mL of distilled water (1:2), incubated for 24 hours, filtered, and then centrifuged at 3000 rpm for 5–10 minutes. The supernatant 5 mL was mixed with 5 mL of absolute methanol (1:1), vortexed, and precipitated with chilled methanol (5 mL, 4°C, 4 hours). After another centrifugation (10 minutes), the pellet was resuspended with 100  $\mu$ L of methanol and vortexed until homogeneous for GC–MS analysis.

### **2.3 Phytohormone Application Test**

All tools and materials used in the experiment were cleaned and prepared by standard laboratory protocols to ensure accuracy and minimize contamination. Soybean radicle and red shoot extracts were prepared by germinating soybean seeds for five days, after which the radicles were harvested. Red shoot samples were collected from the reddish apical tips of young leaves. Each plant material (500 g) was macerated in 1 L of distilled water (1:2 w/v ratio) and incubated for 24 hours before being filtered to obtain the crude extracts.

Treatment formulations were then prepared by adjusting concentrations to 100% (undiluted extract) and 50% (diluted 1:1 with distilled water). A total of nine treatment combinations were established from these extracts. Red dragon fruit stem cuttings, 30 cm in length, were obtained from one-year-old plants (7), weighed, and categorized into weight groups before treatment. A total of 54 cuttings were used, representing 9 treatment combinations, with 2 cuttings per treatment and 3 replications.

The planting medium consisted of a 4:1 mixture of topsoil and compost (3 kg per polybag), which was sterilized before use and placed in 30 × 30 cm polybags, each labelled accordingly. Before planting, the cuttings were soaked in their respective treatment solutions for 24 hours. Following soaking, cuttings were transplanted into the prepared polybags. Maintenance involved watering every two days or as needed based on soil moisture, manual weed control, and conditional fungicide application depending on the presence of disease symptoms.

### **2.4 Observed Variables**

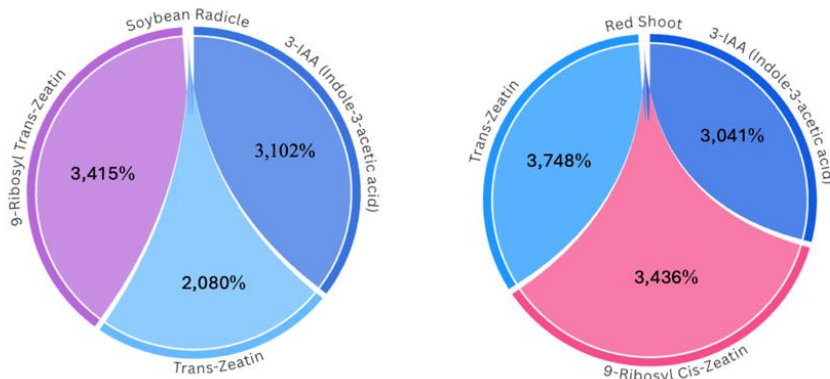
A range of morphological and physiological parameters was recorded to evaluate the effects of the treatments. Phytohormone content was identified using Gas Chromatography–Mass Spectrometry (GC–MS) to determine the presence and concentration of auxin and cytokinin-related compounds in the extracts. Days to first shoot emergence were monitored daily for each cutting, while the number of shoots (leaves) and shoot length (cm) were recorded weekly for 11 weeks. At harvest, root length and the number of roots were manually measured and counted, respectively. Biomass parameters were also assessed, including fresh and dry weights of both shoots and roots. Fresh weights were recorded immediately after harvest, whereas dry weights were measured following oven-drying at 75°C for 48 hours. These variables collectively provided insights into the rooting performance and shoot development of red dragon fruit cuttings under the influence of the plant extract treatments.

### **2.5 Data Collection and Analysis**

All data were subjected to analysis of variance at  $\alpha = 5\%$ , followed by Duncan's Multiple Range Test for post-hoc comparisons at the same significance level. Statistical analysis was conducted using R version 4.2.2. Conclusions were drawn based on the interpretation of statistical results and supported by documentation.

## **3 Result and Discussion**

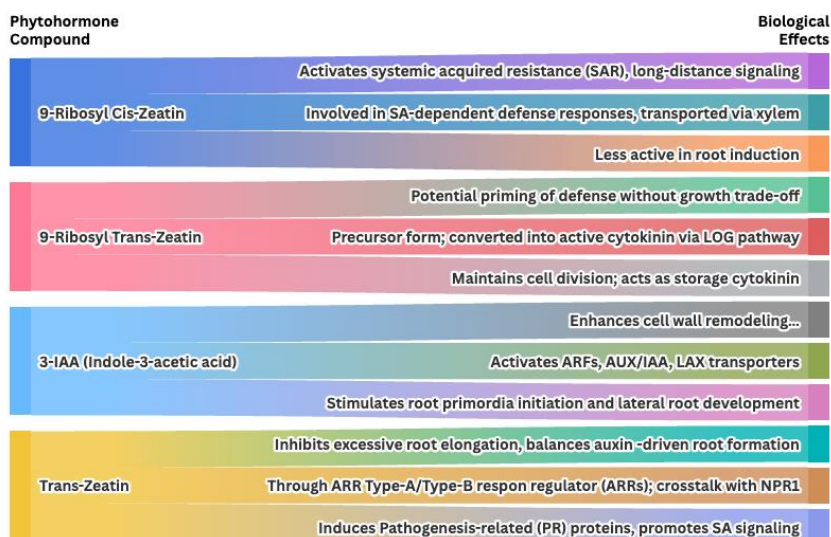
Gas Chromatography–Mass Spectrometry (GC–MS) analysis revealed the presence of key phytohormones, namely auxins and cytokinins in both soybean radicle and red shoot extracts. These hormones are critical regulators of plant growth, particularly in root initiation and shoot development.



**Fig 1.** Chord Diagram Phytohormone Content in Soybean Radicle and Red Shoot Extracts

In the soybean radicle extract, the dominant compounds identified were 9-Ribosyl/Trans-Zeatin (3.415%), 3-Indole Acetic Acid (3-IAA, 3.102%), and Trans-Zeatin (2.080%). This profile indicates a strong cytokinin presence, with 3-IAA contributing significantly to root induction and early root growth. In contrast, the red shoot extract contained Trans-Zeatin (3.748%), 9-Ribosyl Cis-Zeatin (3.436%), and 3-IAA (3.041%). Here, cytokinin activity is also predominant, particularly with a higher concentration of trans-Zeatin, which is closely associated with cell division and shoot proliferation. Despite slight variations in hormone dominance, both extracts demonstrate a balanced composition of auxins and cytokinins. The research conducted by Pérez-Pizá et al. [8] showed that the phytohormone levels between plasma treatment and the control were similar therefore, in this case the soybean roots exhibited a high IAA content.

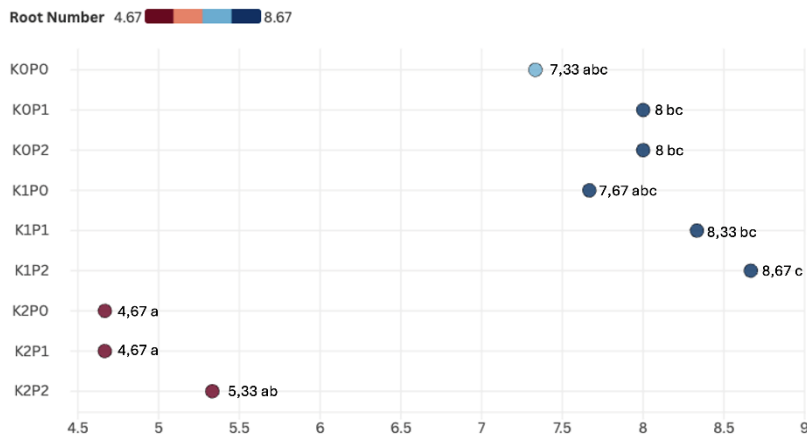
This balance is essential for synergistic root and shoot development, where auxin-rich conditions promote rooting, while cytokinin-rich conditions encourage shoot growth. The combination of soybean radicle and red shoot extracts thus offers a promising dual-function bio-stimulant, capable of enhancing rooting while potentially improving physiological resilience in red dragon fruit cuttings. These results are supported by the study of [9], who demonstrated that auxin hormones are capable of stimulating new root tip formation in stem cuttings of dragon fruit plants.



**Fig. 2.** Sankey diagram illustrating the biological effects of identified phytohormones (3-IAA, Trans-Zeatin, 9-Ribosyl Trans-Zeatin, and 9-Ribosyl Cis-Zeatin) involved in growth regulation and defense responses in red dragon fruit cuttings.

The Sankey diagram illustrates the diverse biological roles of the phytohormones identified in the soybean radicle and red shoot extracts, highlighting their contribution to both growth regulation and defense signaling. 3-IAA (Indole-3-acetic acid) is primarily responsible for activating key transcription factors such as ARFs and AUX/IAA, which are essential for root primordia initiation and lateral root development. This auxin-driven process is balanced by Trans-Zeatin, which prevents excessive root elongation and ensures optimal shoot-root coordination through the ARR signaling pathway. Furthermore, Trans-Zeatin also promotes the expression of pathogenesis-related proteins via salicylic acid (SA) signaling, linking growth regulation with induced resistance.

The cytokinin 9-Ribosyl Trans-Zeatin acts as a precursor that is enzymatically converted into active forms through the LOG pathway, functioning in cell division and serving as a cytokinin reservoir (10). Meanwhile, 9-Ribosyl Cis-Zeatin plays a more specialized role in systemic acquired resistance (SAR), enhancing SA-dependent long-distance defense signaling while being less active in direct root induction (11). Its involvement in xylem-based transport further supports its systemic function. In the study by Grobkinsky et al., (2013), the comparison of the effects of cis-zeatin and trans-zeatin in the plant defense system against pathogen attacks showed that cis-zeatin exhibits a specific immunomodulatory effect, although its overall activity is generally lower than that of trans-zeatin. Collectively, the hormonal profile suggests a synergistic potential between auxins and cytokinins not only in promoting root and shoot development but also in priming defense responses without compromising growth. This dual role is particularly valuable for improving the resilience and vigor of red dragon fruit cuttings during propagation.

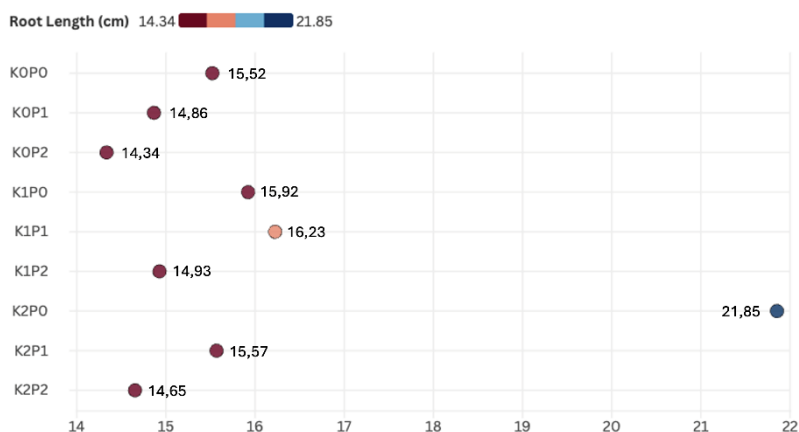


**Fig. 3.** Root Number Analysis of Red Dragon Fruit Cuttings Treated with Soybean Radicle and Red Shoot Extracts. Note (1) KOP0 – control (no phytohormone soaking), (2) KOP1 – soaking in 100% red shoot extract, (3) KOP2 – soaking in 50% red shoot extract, (4) K1P0 – soaking in 100% soybean radicle extract, (5) K1P1 – soaking in a combination of 100% soybean radicle and 100% red shoot extracts, (6) K1P2 – soaking in 100% soybean radicle extract combined with 50% red shoot extract, (7) K2P0 – soaking in 50% soybean radicle extract, (8) K2P1 – soaking in 50% soybean radicle extract combined with 100% red shoot extract, and (9) K2P2 – soaking in 50% soybean radicle extract combined with 50% red shoot extract.

The number of roots formed in red dragon fruit cuttings varied significantly across treatment combinations. Treatments containing 100% soybean radicle extract (K1) exhibited the highest root numbers, particularly the K1P2 (100% soybean radicle + 50% red shoot) treatment, which was significantly higher than most other treatments of 8.67 roots. This supports the strong auxin–cytokinin synergy when both extracts are optimally combined. Followed by K1P1 (8.33) and K1P0 (8.00). These results highlight the strong root-inducing potential of soybean radicle extract, likely due to its high auxin (3-IAA) content that stimulates root primordia and lateral root development. This is supported by a study by Yu et al. (2025) (13), who stated that the expression profiles of ARF and YUC genes, which are actively expressed in soybean radicles, can synthesize local IAA, thereby serving as a hormonal source that triggers the initiation of lateral roots.

In contrast, treatments with 50% soybean radicle extract (K2) produced the lowest root numbers, with K2P0 and K2P1 both showing only 4.67 roots, and K2P2 yielding 5.33. This indicates that a reduced concentration of soybean radicle extract alone or in combination with red shoot extract may not be sufficient to enhance root initiation.

Interestingly, moderate root numbers were observed in treatments using only red shoot extract (KOP1 and KOP2), with root numbers ranging from 7.33 to 8.00, suggesting that red shoot extract may also contribute to rooting through its cytokinin content, albeit less effectively than soybean radicle. These findings suggest that the synergistic application of 100% soybean radicle extract with moderate red shoot extract (K1P2) is the most effective combination for promoting root formation in red dragon fruit cuttings.

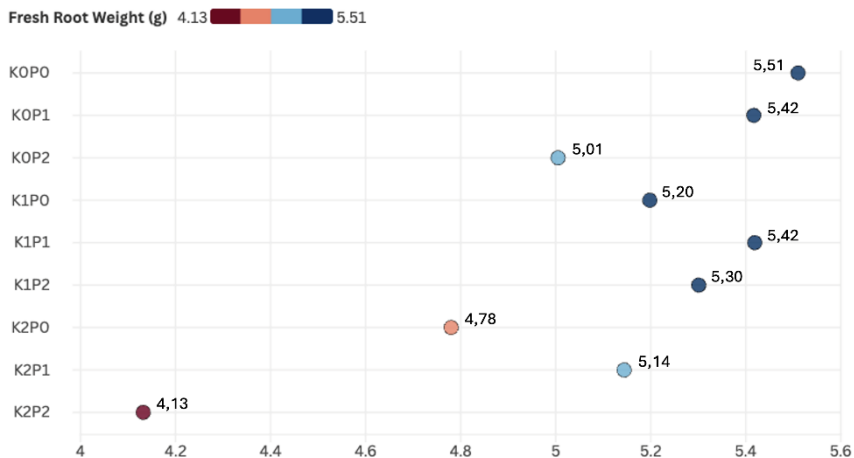


**Fig. 4.** Root Length Response of Red Dragon Fruit Cuttings to Soybean Radicle and Red Shoot Extracts Treatments Note (1) K0P0 – control (no phytohormone soaking), (2) K0P1 – soaking in 100% red shoot extract, (3) K0P2 – soaking in 50% red shoot extract, (4) K1P0 – soaking in 100% soybean radicle extract, (5) K1P1 – soaking in a combination of 100% soybean radicle and 100% red shoot extracts, (6) K1P2 – soaking in 100% soybean radicle extract combined with 50% red shoot extract, (7) K2P0 – soaking in 50% soybean radicle extract, (8) K2P1 – soaking in 50% soybean radicle extract combined with 100% red shoot extract, and (9) K2P2 – soaking in 50% soybean radicle extract combined with 50% red shoot extract.

The root length of red dragon fruit cuttings varied considerably depending on the combination of soybean radicle and red shoot extracts. The longest root length, measured at 21.85 cm, was observed in the K2P0 treatment (50% soybean radicle extract without red shoot extract), suggesting a distinct effect of moderate auxin concentration in promoting root elongation over initiation. On the other hand, most other treatments resulted in shorter root lengths, ranging between 14.34 cm (K0P2) and 16.23 cm (K1P1). Treatments with 100% soybean radicle extract (K1) combined with red shoot extract (P1 or P2) showed relatively moderate lengths (15.92–16.23 cm), indicating a balance between root induction and elongation processes.

Treatments using only red shoot extract (K0) or with a combination of 50% soybean and red shoot extracts (K2P1, K2P2) generally resulted in shorter root lengths, clustered between 14.34–15.57 cm, potentially due to the dominance of cytokinin content, which may inhibit excessive root elongation while promoting other developmental traits. Pernisova et al. (2016) (14) also stated that cytokinins reduce root meristem size and suppress the elongation of differentiating root cells, resulting in an overall reduction in root length.

Interestingly, the highest root number observed in K1P2 did not correspond with the longest root length, suggesting a trade-off between root proliferation and elongation under different hormonal compositions. This implies that while high auxin levels (from K1) promote more root primordia, moderate concentrations (as in K2P0) may favor elongation instead. This is supported by the statement of Jan et al. (2024) (15), who explained that the interaction between auxin and cytokinin regulates root meristem size by controlling the transition from cell proliferation to the cell elongation phase.

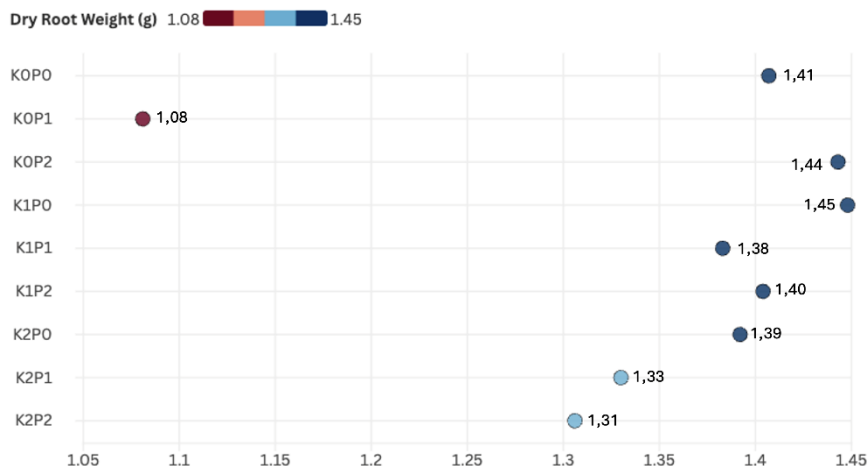


**Fig. 5.** Effect of Soybean Radicle and Red Shoot Extracts on Fresh Root Wight in Red Dragon Fruit Cuttings Note (1) KOP0 – control (no phytohormone soaking), (2) KOP1 – soaking in 100% red shoot extract, (3) KOP2 – soaking in 50% red shoot extract, (4) K1P0 – soaking in 100% soybean radicle extract, (5) K1P1 – soaking in a combination of 100% soybean radicle and 100% red shoot extracts, (6) K1P2 – soaking in 100% soybean radicle extract combined with 50% red shoot extract, (7) K2P0 – soaking in 50% soybean radicle extract, (8) K2P1 – soaking in 50% soybean radicle extract combined with 100% red shoot extract, and (9) K2P2 – soaking in 50% soybean radicle extract combined with 50% red shoot extract.

The fresh root weight of red dragon fruit cuttings showed a clear response to the combinations of soybean radicle (auxin source) and red shoot (cytokinin source) extracts. The highest fresh root weight was recorded in the K1P2 treatment (100% soybean radicle extract + 100% red shoot extract), reaching 5.51 g, indicating a synergistic effect of high auxin and cytokinin content on root biomass accumulation. Vaseva et al. (2024) (16) reported that the combination of auxin and cytokinin can work synergistically to develop a strong root system and increase root biomass accumulation, even when the plant is under stress conditions.

Following this were K1P1 and KOP2, both with 5.42 g, suggesting that a single full-dose of either extract (particularly high cytokinin from red shoot in KOP2) can significantly contribute to root weight when combined with moderate or no auxin levels. Treatments K1P0 and K2P1 also performed well, with fresh root weights between 5.01–5.30 g, reinforcing the positive role of auxin in root biomass development.

In contrast, the lowest fresh root weight was observed in the K2P2 treatment (4.13 g), where both extracts were at half concentration. This suggests that suboptimal hormone concentrations may not be sufficient to trigger effective root biomass formation. The pattern highlights that optimal or balanced hormone combinations particularly higher levels of auxin (IAA) from soybean radicle and active cytokinin (zeatin-type) from red shoot are crucial for maximizing root development, not just in number or length, but also in biomass accumulation. According to Jan et al. (2024) (15), an imbalance between auxin and cytokinin either a deficiency or an excess can result in suboptimal root quality, both in terms of root number and biomass.



**Fig. 6.** Dry Root Biomass Accumulation in Response to Auxin–Cytokinin Extract Treatments, Note (1) K0P0 – control (no phytohormone soaking), (2) K0P1 – soaking in 100% red shoot extract, (3) K0P2 – soaking in 50% red shoot extract, (4) K1P0 – soaking in 100% soybean radicle extract, (5) K1P1 – soaking in a combination of 100% soybean radicle and 100% red shoot extracts, (6) K1P2 – soaking in 100% soybean radicle extract combined with 50% red shoot extract, (7) K2P0 – soaking in 50% soybean radicle extract, (8) K2P1 – soaking in 50% soybean radicle extract combined with 100% red shoot extract, and (9) K2P2 – soaking in 50% soybean radicle extract combined with 50% red shoot extract.

The dry root weight data further confirms the positive influence of soybean radicle and red shoot extract combinations on root development in red dragon fruit cuttings. The highest dry root weight was observed in the K1P2 treatment (100% soybean radicle + 100% red shoot), reaching 1.45 g, followed closely by K1P0 (1.44 g) and K0P2 (1.41 g). These results indicate that either high auxin or high cytokinin alone can enhance dry biomass accumulation, but their combination maximizes the effect.

Other treatments with high performance include K1P1, K1P2, and K2P1, all above 1.38 g, suggesting that a range of moderately high hormone doses also support effective root biomass formation. The lowest dry weight was recorded in K0P1 (1.08 g), where no soybean radicle extract was applied, indicating the critical role of auxin in supporting biomass development and lignification processes in roots. This pattern aligns with fresh weight trends, reinforcing the importance of hormonal balance between auxin and cytokinin. Notably, treatments with higher IAA (from soybean radicle) and active zeatin-type cytokinins (from red shoot) contributed significantly to the dry matter of roots, which is essential for the structural development and stress resilience of the plant. Tiwari et al., 2023 reported that an optimal combination of auxin and cytokinin is crucial for establishing a robust root architecture and enhancing root biomass accumulation when plants are exposed to low-temperature stress.

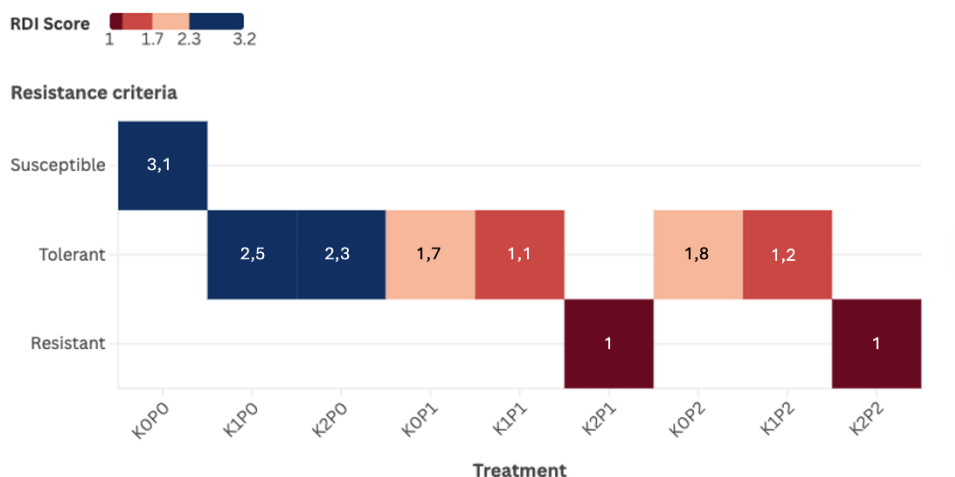


**Fig. 7.** Root Development in Response to Auxin–Cytokinin Combinations. Note (1) K0P0 – control (no phytohormone soaking), (2) K0P1 – soaking in 100% red shoot extract, (3) K0P2 – soaking in 50% red shoot extract, (4) K1P0 – soaking in 100% soybean radicle extract, (5) K1P1 – soaking in a combination of 100% soybean radicle and 100% red shoot extracts, (6) K1P2 – soaking in 100% soybean radicle extract combined with 50% red shoot extract, (7) K2P0 – soaking in 50% soybean radicle extract, (8) K2P1 – soaking in 50% soybean radicle extract combined with 100% red shoot extract, and (9) K2P2 – soaking in 50% soybean radicle extract combined with 50% red shoot extract.

The visual image aligns well with the quantitative data regarding root development in red dragon fruit cuttings treated with combinations of soybean radicle extract (auxin source) and red shoot extract (cytokinin source). The K1P2 treatment (100% soybean radicle and 100% red shoot) clearly exhibits the most optimal root growth, both visually and numerically. The roots appear dense, long, and well-branched, which corresponds with the highest recorded values for root number (8.67), root length (16.23 cm), fresh weight (5.51 g), and dry weight (1.45 g).

Treatments K1P0 and K1P1 also display well-developed root systems, with thick and branched roots, supporting their high measurements in root length and biomass. In contrast, K0P2 (0% soybean radicle and 100% red shoot) shows a relatively high number of roots (8.00), but the root system appears less robust and less branched, suggesting that a cytokinin-dominant treatment promotes lateral shoot formation rather than root development. This statement is supported by the study of Jing et al. (2019) (18), who reported that cytokinin can disrupt polar auxin transport and inhibit the expression of PIN genes, which are essential for lateral root and root meristem development. As a result, cytokinin dominance enhances the formation of lateral root primordia without strengthening the primary root system.

Meanwhile, treatments K0P1 and K2P0 demonstrate the weakest root growth, both in terms of quantity and visual appearance, with small, thin, and unbranched roots. Although K2P2 appears moderately developed in the images, its quantitative results show relatively high fresh and dry weights, indicating a synergistic effect of moderate doses of both extracts. Overall, the morphological visualization supports the quantitative findings, confirming that an optimal combination of auxin and cytokinin significantly enhances root induction and development in red dragon fruit cuttings.



**Fig. 8.** Root Discoloration Index (RDI) and Resistance Response by Treatment Note (1) K0P0 – control (no phytohormone soaking), (2) K0P1 – soaking in 100% red shoot extract, (3) K0P2 – soaking in 50% red shoot extract, (4) K1P0 – soaking in 100% soybean radicle extract, (5) K1P1 – soaking in a combination of 100% soybean radicle and 100% red shoot extracts, (6) K1P2 – soaking in 100% soybean radicle extract combined with 50% red shoot extract, (7) K2P0 – soaking in 50% soybean radicle extract, (8) K2P1 – soaking in 50% soybean radicle extract combined with 100% red shoot extract, and (9) K2P2 – soaking in 50% soybean radicle extract combined with 50% red shoot extract.

The Root Discoloration Index (RDI) was used to qualitatively estimate the severity of root or basal stem rot symptoms in dragon fruit stem cuttings across different treatments (K0P0–K2P2). Based on the Disease Severity Index (DSI) classification, treatments were categorized into four resistance levels: resistant (RDI = 1), tolerant (RDI = 1.1–3.0), susceptible (RDI = 3.1–5.0), and very vulnerable (RDI = 5.1–8.0) (19).

The untreated control (K0P0) exhibited the highest RDI score of 3.1, falling into the susceptible category, indicating severe root discoloration and the presence of basal stem rot symptoms. Treatments K1P0 (2.5) and K2P0 (2.3) were categorized as tolerant, suggesting partial reduction of disease symptoms with the application of either extract alone. Furthermore, treatments K0P1 (1.7), K0P2 (1.8), K1P1 (1.1), and K1P2 (1.2) also showed tolerant responses, indicating that even moderate levels of soybean radicle and red shoot extract can mitigate symptom development. Notably, the K2P1 and K2P2 treatments, which combined the highest levels of both extracts, achieved the lowest RDI score of 1.0, classifying them as resistant.

These results suggest a synergistic effect between the bioactive compounds present in both the soybean radicle and red shoot extracts, effectively enhancing the plant's defense response and reducing disease severity. This is further supported by the study of Kim et al. (2022) (19), which reported that the compounds daidzein and coumestrol found in soybean roots are capable of enhancing the activity of defense-related enzymes such as PAL (phenylalanine ammonia-lyase) and PPO (polyphenol oxidase), which play a crucial role in strengthening the plant's defense system against pathogens and oxidative stress.

## 4 Conclusion

The combined application of soybean radicle and red shoot extracts significantly enhanced root development and induced resistance in *Hylocereus polyrhizus* cuttings. The presence of

auxin (IAA) and cytokinins in both extracts promoted synergistic effects on root initiation, elongation, and biomass accumulation. The K1P2 treatment (100% soybean radicle + 50% red shoot extract) consistently yielded the best results across multiple parameters. Moreover, the application of these natural extracts reduced root discoloration, indicating their role in triggering induced systemic resistance. Therefore, these findings support the use of soybean radicle and red shoot extracts as eco-friendly alternatives to synthetic growth regulators in sustainable horticultural practices.

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