HJTAS
Holistic: Journal of Tropical Agriculture Sciences
HJTAS 2(1): 17-30
ISSN 3025-4272

Institute for Advanced Science,
Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Effect of cutting age and auxin concentration on growth of pinto peanut (*Arachis pintoi*)

Junaidi Muntoyib[1]*
[1] *Study Program of Agronomy and Horticulture, Graduate School, IPB University (Bogor Agricultural University), Jl. Meranti Kampus IPB Darmaga, Bogor 16880, Indonesia.*
*Correspondence: mjunaidi@apps.ipb.ac.id

ABSTRACT

Background: Pinto peanuts (*Arachis pintoi*) are known as versatile cover crops for soil conservation, biomulch, and ornamental plants. These leguminous plants rarely produce seeds, so they are commonly propagated vegetatively, resulting in low efficiency of seedling production and availability of cuttings. The aim of this study was to determine the effect of cutting age and auxin application on the growth of pinto peanut. **Methods:** This experiment used a complete randomized block factorial design. The first factor was the age of the cuttings (stolons) with three levels (young, intermediate, old). Each cutting had three nodes, with young cuttings measured from the tip, intermediate cuttings measured from the fourth node, and old cuttings measured from the seventh node. The second factor was the concentration of the commercial auxin product ROOTONE F (0 ppm, 500 ppm, 1000 ppm, 1500 ppm, 2000 ppm). **Findings:** The results showed that the difference in cutting age significantly affected the number of leaves (at 10 and 50 days after planting), plant length (at 10 to 50 days after planting), number of branches (at 30 to 50 days after planting), and canopy area. Differences in auxin concentration only significantly affected plant length from 10 to 30 days after planting. The interaction between cutting age and auxin concentration was significant only for the number of leaves at 10 to 20 days after planting and plant length at 50 days after planting. **Conclusion:** The highest values for the observed parameters were consistently obtained by intermediate cuttings followed by tip cuttings, which are therefore recommended as planting material for pinto peanut propagation. **Novelty/Originality of this article:** This study uniquely determined the effectiveness of pinto peanuts cuttings based on internode length, revealing that intermediate cuttings are the best material for its propagation, especially when treated with specific auxin concentrations, consistently outperformed tip and old cuttings in promoting optimal growth, offering a practical strategy to enhance vegetative propagation efficiency.

KEYWORDS: cover crop; forage peanuts; internode; legume; propagation; stolon

1. Introduction

Arachis pintoi, commonly known as pinto or forage peanuts, have garnered significant attention in recent years due to their diverse applications in agriculture and landscaping. This perennial legume plant originates from Brazil and had been successfully introduced to various tropical and subtropical regions worldwide (Azêvedo et al., 2016; de Sousa-Machado et al., 2018). Its adaptability to various soil types and climatic conditions makes it a valuable species for improving soil health and enhancing aesthetic value in landscapes. Pinto peanuts are particularly noted for their ability to thrive in both acidic and alkaline soils, making them highly versatile in different environmental settings. This adaptability extends to their resilience against drought conditions, which is critical in regions with irregular rainfall patterns. Additionally, their introduction has been associated with improved agricultural productivity, making them a cornerstone in sustainable farming

Cite This Article:
Muntoyib, J. (2024). Effect of cutting age and auxin concentration on growth of pinto peanut (*Arachis pintoi*). *Holistic: Journal of Tropical Agriculture Sciences, 2*(1), 17-30. https://doi.org/10.61511/hjtas.v2i1.2024.1053

practices across diverse regions (Sales et al., 2013; Suwarto & Hariyadi, 2019; Liu et al., 2024; Sousa et al., 2024).

One of the primary benefits of pinto peanuts lies in their remarkable effectiveness as ground cover. Their dense growth pattern and mat-forming capability play a crucial role in suppressing soil erosion, reducing evaporation, maintaining groundwater availability, increasing soil organic matter, and enhancing the availability of essential nutrients like nitrogen and phosphorus (Chozin et al., 2018). In addition to these benefits, as a biomulch, pinto peanuts are particularly effective at suppressing weeds, achieving up to a 58% reduction (Sumiahadi et al., 2019). A recent study has highlighted that the biomass extract of A. pintoi contains allelochemicals that are highly effective in inhibiting weed growth (Thang et al., 2023). This significant weed suppression capability greatly reduces the need for chemical herbicides, which not only leads to healthier soil but also minimizes environmental pollution. Moreover, their rapid soil coverage prevents soil compaction and improves water infiltration, thus creating a more conducive environment for the growth of other plants (Valencia et al., 2021). This multifaceted role in both preventing soil degradation and promoting sustainable weed management underscores the plant's potential in ecological farming practices.

Beyond their soil conservation benefits, *A. pintoi* is also renowned for its ornamental qualities. The plant produces attractive yellow flowers that enhance visual appeal in gardens and other landscaped areas. Moreover, as a leguminous plant, *A. pintoi* contributes to soil fertility through biological nitrogen fixation, reducing the need for chemical fertilizers and promoting sustainable agricultural practices. This natural fertilization process enhances soil health over time, supporting the growth of surrounding flora. Additionally, the low-growing nature of pinto peanuts makes them an excellent choice for preventing soil erosion on slopes and in areas with heavy rainfall (Ugrenović & Filipović, 2017). Legume plants enhance soil aggregates, increase water retention, and adapt well to adverse environments, effectively mitigating climate change impacts. Their inclusion in cropping systems boosts yields for both legumes and non-legumes, making them valuable for agriculture, forestry, and landscaping. Recognizing their benefits, the chapter explores climate change, the advantages of legume-based cropping systems, future research directions, and policy implications (Rahman et al., 2022). The plant's dual role in both enhancing aesthetic value and contributing to soil health makes it an ideal candidate for sustainable landscape management.

Using *A. pintoi* as a ground cover plant aligns with the growing trend towards sustainable agriculture and landscaping. The main challenge in propagating *A. pintoi* in Indonesia lies in its poor seed formation due to climatic conditions, necessitating vegetative propagation typically through cuttings. Previous research on the propagation of *A. pintoi* by Febrianto & Chozin (2014) had predominantly focused on using cuttings with a defined length in centimeters, rather than considering the specific internode length as a variable. This common practice overlooks the potential differences in rooting success and growth vigor that might arise from variations in internodal length, which could influence the cutting's physiological state and subsequent growth performance. This gap suggests a need for studies to explore whether internode-based selection can enhance propagation outcomes, potentially leading to more effective and efficient propagation techniques for *A. pintoi*. Research on cutting age based on internodes length and the use of plant growth regulators (PGRs) remains limited, making it an intriguing area for study to assess the efficiency of cutting material for propagation purposes. Understanding and overcoming these propagation challenges could significantly enhance the distribution and utilization of pinto peanuts, promoting more sustainable agricultural systems. Moreover, advancing propagation techniques could facilitate the broader adoption of *A. pintoi* in regions with similar climatic challenges, thereby expanding its benefits globally.

2. Methods

This research was conducted from March to May 2024 at the Agribusiness Techno Park, IPB University. The study focused on optimizing the propagation of pinto peanut plants through cuttings, utilizing various growth conditions and treatments. The materials employed included pinto peanut plant cuttings sourced from the IPB University coin garden, a commercially available auxin known as ROOTONE F, and a growing medium comprising soil, compost, and cocopeat. The tools utilized in the study comprised hoes, buckets, scissors, cutters, polybags, insect nets, tunnel poles, and black plastic.

The research employed a completely randomized block design (CRBD) with a factorial arrangement to assess the effects of cutting age and auxin concentration on the growth of pinto peanut plants. The first factor examined was the age of the cuttings, categorized into three levels: young cuttings (measuring three nodes from the tip), intermediate cuttings (measuring three nodes from the fourth node), and old cuttings (measuring three nodes from the seventh node). The second factor involved varying auxin concentration treatments, with levels set at 0 ppm, 500 ppm, 1000 ppm, 1500 ppm, and 2000 ppm. The experimental blocks were established based on the direction of sunlight to ensure uniform light exposure across treatments. Within each block, the polybag rows were oriented from north to south. This orientation was selected to minimize the variation in sunlight intensity and duration that could affect plant growth, thereby enhancing the reliability and accuracy of the experimental results.

The planting medium was carefully prepared by mixing soil with compost and cocopeat in a ratio of 2:1:1. This mix was chosen to provide a well-balanced medium that retains moisture while allowing adequate drainage and aeration, essential for root development. The media were moistened and incubated for seven days to stabilize the microbial activity and nutrient availability. One day prior to planting, the cuttings were soaked for 12 hours in the respective auxin solutions. The cuttings were then planted in the morning to take advantage of cooler temperatures and higher humidity, which reduce transplant shock. The insertion depth was standardized at two nodes deep to ensure uniform rooting conditions across all treatments. The planting area was covered with an insect net to protect the cuttings during the critical initial growth phase from pest attacks, minimize rainwater runoff that could dislodge the cuttings, and slightly reduce excessive sunlight, which can be detrimental to young plants.

The data collected from the experiment included several growth parameters: number of leaves, plant length (main stolon), number of branches, number of flowers, and canopy area. These parameters were selected to provide a comprehensive assessment of the plant's vegetative and reproductive growth under the different treatments. The data were first subjected to an analysis of variance (ANOVA) using the F-test at the 5% and 1% significance levels. If the F-test indicated significant differences among the treatments, a further post hoc analysis was conducted using Tukey's Honest Significant Difference (HSD) test.

3. Results and Discussion

3.1 Number of leaves

Leaves are one of the most important plant organs in the growth process, serving as the site of photosynthesis. Leaf growth can be used as an indicator of plant growth and condition (Susilo, 2015). The number of leaves in *A. pintoi* is crucial to observe because it mainly contributes to coverage potential. The effect of treatments on the number of leaves in *A. pinto*i is presented in Table 1. Leaf counting was performed periodically every 10 days. Periodic assessments reveal growth patterns over time and provide insights into how the factors influence plant development.

Based on Table 1, it indicates that the age of cuttings significantly affected the number of leaves in *A. pintoi*, particularly at 10 and 50 days after planting (DAP). Intermediate-aged cuttings consistently produced the highest number of leaves, reaching an average of 25.4 leaves at 50 DAP, which was not significantly different from the young cuttings. This suggests that intermediate cuttings might have an optimal balance of maturity and vigor, contributing to better leaf growth due to less susceptible to climate conditions such as temperature at early planting. On the other hand, old cuttings demonstrated the lowest leaf production, indicating that older plant material might be less efficient in generating new growth. This finding highlights the importance of selecting the appropriate cutting age for propagation practices, which could have long-term effects on plant establishment and yield. It also underscores the role of plant age in determining its resilience to environmental stressors, which could be crucial for optimizing agricultural practices and improving crop sustainability.

Tabel 1. The number of leaves of *A. pintoi* at 10 – 50 days after planting (DAP)

Treatments	Number of leaves				
	10 DAP	20 DAP	30 DAP	40 DAP	50 DAP
Cutting age					
Young	2.45 b	6.05	8.65	11.70	22.35 ab
Intermediate	3.20 a	6.70	9.25	10.05	25.40 a
Old	2.80 ab	6.10	9.00	10.60	18.05 b
F-test	*	ns	ns	ns	*
P-value	0.037	0.259	0.635	0.306	0.049
Auxin concentration					
0 ppm	2.67	5.67	8.75	11.17	21.67
500 ppm	2.83	6.33	9.08	10.25	18.33
1000 ppm	2.75	6.00	8.67	9.67	20.75
1500 ppm	2.75	6.50	9.58	11.75	22.92
2000 ppm	3.08	6.92	8.75	11.08	26.25
F-test	ns	ns	ns	ns	ns
P-value	0.814	0.233	0.812	0.597	0.325
Interaction	*	**	ns	ns	ns
P-value	0.013	0.004	0.883	0.395	0.396

Notes: Numbers followed by the same letter in the same column do not differ according to Tukey's HSD test, DAP (days after planting), * (significant at p≤0.05), ** (significant at p≤0.01), ns (not significant)

In contrast, the application of auxin concentration did not show a significant independent effect on the number of leaves at any plant age. This finding is somewhat unexpected given that auxins are known to stimulate both cell division and cell elongation, which are crucial for leaf development. By promoting these processes, auxins can increase the rate at which new leaves are formed (Sauer, 2013). One possible explanation could be that the inherent growth capacity of *A. pintoi* is not significantly enhanced by external auxin applications, or that the concentrations used in this study were not optimal for stimulating leaf growth in this species. Recent studies have indicated that auxin responses can be highly species-specific and dependent on the developmental stage of the plant, which might explain the lack of a significant effect in *A. pintoi* (Zhang et al., 2023). Furthermore, environmental factors and the interaction with other hormones such as cytokinins could also play a crucial role in modulating the plant's response to auxin application (Sosnowski et al., 2023). These results suggest that a more nuanced approach might be required when applying auxins to different plant species, considering their unique physiological and developmental contexts. This knowledge can guide future research aimed at fine-tuning hormone applications to achieve desired growth outcomes in various plant species.

Interestingly, there was a significant interaction between cutting age and auxin concentration at 10 and 20 DAP (Table 2). At 10 DAP, intermediate cuttings generally produced the most leaves, particularly at 0 ppm (3.75 leaves) and 2000 ppm (4.00 leaves), indicating their early vigor. By 20 DAP, the trend continued, with intermediate cuttings showing the highest leaf count at 0 ppm (7.50 leaves) and 2000 ppm (7.75 leaves), while old cuttings also performed well at higher auxin concentrations, particularly at 1500 ppm (8.00 leaves). This indicates that intermediate cuttings are consistently effective across different auxin concentrations, with the highest leaf production observed at both early and later stages of growth. These findings imply that intermediate-aged cuttings might have a broader hormonal sensitivity range, making them more adaptable to varying conditions and treatments. Understanding this interaction is vital for optimizing propagation techniques, especially in horticulture, where maximizing leaf production can directly impact plant establishment and overall yield.

Table 2. Interaction of treatments on the number of leaves at 10 and 20 DAP

Cutting age	Auxin concentration				
	0 ppm	500 ppm	1000 ppm	1500 ppm	2000 ppm
10 DAP					
Young	2.50	2.25	2.50	2.25	2.75
Intermediate	3.75	2.50	3.25	2.50	4.00
Old	1.75	3.75	2.50	3.50	2.50
20 DAP					
Young	5.75	5.50	6.00	6.00	7.00
Intermediate	7.50	6.25	6.50	5.50	7.75
Old	3.75	7.25	5.50	8.00	6.00

This interaction suggests that the effect of auxin on leaf growth may be dependent on the physiological state of the cutting, with younger and more vigorous cuttings benefiting more from higher auxin concentrations. This could be due to the increased responsiveness of younger tissues to hormonal signals compared to older tissues. According to Zhang et al. (2022a) and Ćosić & Raspor (2022), this increased responsiveness can be attributed to the higher metabolic activity and greater number of auxin receptors present in younger tissues, making them more efficient in utilizing the hormone for growth processes. This phenomenon is primarily due to the active division and differentiation occurring in younger tissues, which require a constant supply of auxin to support rapid cell expansion and elongation. Additionally, the elevated metabolic activity in these tissues enhances the production and transport of auxin, further amplifying their growth response.

The abundance of auxin receptors in younger tissues ensures that even small concentrations of the hormone can trigger significant growth responses, optimizing the plant's developmental processes during its early stages. These insights could be leveraged in plant breeding and propagation strategies, where manipulating auxin levels at specific growth stages might enhance overall plant performance. By targeting the most responsive tissues, it might be possible to achieve more efficient growth regulation, ultimately improving crop yields and resilience. These insights could be leveraged in plant breeding and propagation strategies, where manipulating auxin levels at specific growth stages might enhance overall plant performance. By targeting the most responsive tissues, it might be possible to achieve more efficient growth regulation, ultimately improving crop yields and resilience.

3.2 Plant length (main stolon)

The length of the plant reflects the level of vegetative growth rate, it serves as a key indicator of vegetative growth and is influenced by factors like nutrient uptake, environmental conditions, and hormonal balance. The effect of treatments on the length of *A. pintoi* main stolon is presented in Table 3. The main stolon was observed for the first sprouted shoot from intermediate and old aged cuttings. This measurement is critical as stolon length can also influence the plant's ability to spread and establish itself in a given area, directly impacting its competitive advantage and ecological success. Understanding the factors that drive stolon growth can therefore be vital for both agricultural and environmental management practices.

Tabel 3. The plant length / main stolon length of *A. pintoi* at 10 – 50 DAP

Treatments	Length (cm)				
	10 DAP	*20 DAP*	*30 DAP*	*40 DAP*	*50 DAP*
Cutting age					
Young	10.83a	15.70a	17.08a	19.92a	30.95b
Intermediate	8.20b	13.32b	13.43b	14.50b	36.45a
Old	6.43b	11.42b	12.58b	14.03b	30.85b
F-test	***	**	**	**	**
P-value	0.000	0.000	0.001	0.000	0.004
Auxin concentration					
0 ppm	7.32b	11.98b	14.13ab	16.58	29.33
500 ppm	7.83ab	12.86ab	14.46ab	16.17	32.00
1000 ppm	7.25b	12.68ab	11.54b	12.83	33.00
1500 ppm	9.96a	15.01a	15.33a	17.13	35.17
2000 ppm	10.06a	14.86a	16.33a	18.04	34.25
F-test	*	*	*	ns	ns
P-value	0.029	0.047	0.032	0.225	0.123
Interaction	ns	ns	ns	ns	*
P-value	0.359	0.487	0.083	0.119	0.041

Notes: Numbers followed by the same letter in the same column do not differ according to Tukey's HSD test, DAP (days after planting), * (significant at p≤0.05), ** (significant at p≤0.01), ns (not significant).

Based on Table 3, it can be seen that the age of cuttings has a significant effect on plant length at all observation intervals (10 – 50 DAP). Young cuttings produced greater plant length at all time intervals except at 50 DAP, where intermediate-aged cuttings showed the highest growth (36.45 cm). Auxin concentration also significantly affected plant length from 10 to 30 DAP. Auxin concentrations of 1500 ppm and 2000 ppm resulted in the highest plant length at 10 DAP, 20 DAP, and 30 DAP. The interaction between the age of cuttings and auxin concentration showed a significant effect at 50 DAP. Intermediate cuttings treated with 1000 ppm and 1500 ppm of auxin produced the longest plants, with lengths of 40.25 cm and 39.25 cm, respectively, indicating that this combination is most effective for growth (Table 4). Young and old cuttings had variable responses to auxin, with young cuttings generally showing reduced growth at higher auxin concentrations, except for 0 ppm and 1500 ppm, where growth was comparable to intermediate cuttings. This suggests that the relationship between auxin concentration and cutting age is complex and may require further investigation to fully understand the underlying mechanisms. Optimizing this relationship could lead to improved strategies for enhancing vegetative growth in A. pintoi and other similar species.

Table 4. Interaction of treatments on the plant length (cm^2) at 50 DAP

Cutting age	Auxin concentration				
	0 ppm	500 ppm	1000 ppm	1500 ppm	2000 ppm
Young	34.25	28.25	25.00	34.00	33.25
Intermediate	28.25	38.00	40.25	39.25	36.50
Old	25.50	29.75	33.75	32.25	33.00

These results support the theory that auxin can stimulate plant length growth by increasing the rate of cell elongation at optimal concentrations. However, the effect of auxin depends on the age of the cuttings, with younger cuttings being more responsive to auxin application compared to older cuttings. These findings align with previous studies that have shown that young cuttings have a better ability to respond to hormonal regulation for early growth (Taiz & Zeiger, 2010; Hartmann et al., 2011). Research has shown that the response of plant cuttings to growth-promoting conditions varies with age, with younger cuttings generally exhibiting more vigorous growth due to better metabolic activity (Goh et al., 2012; Rademacher, 2015). This highlights the importance of selecting appropriate propagation materials to optimize plant performance and growth outcomes. Additionally, the physiological state of the cuttings, including factors like carbohydrate reserves and hormonal balance, can significantly influence their responsiveness to auxin. This phenomenon has been observed in other plant species were young tissues, rich in meristematic cells, exhibit a higher capacity for cell division and elongation in response to auxin, compared to older tissues that may have reduced metabolic activity (Davis et al., 1989; Leakey, 2004). Moreover, studies have suggested that the sensitivity of cuttings to auxin can decline with age due to changes in the expression of auxin-responsive genes, which are crucial for promoting growth and development (Gaspar et al., 2003). These findings underscore the intricate relationship between plant physiology and hormone signaling, highlighting the need for an integrated approach that considers both internal and external factors when applying growth regulators. Such an approach can lead to more sustainable and effective horticultural practices.

Auxin concentrations that are too high or too low can yield suboptimal results, indicating an optimal range of auxin concentrations for maximal growth (Davies, 2010). Auxins play a role in maintaining apical dominance, which is the phenomenon where the main central stem of the plant grows more vigorously than the side stems. Intermediate-aged cuttings might have proportional total auxin that caused the apical dominance can be reinforced (Spaepen, 2015). These results emphasize the importance of considering physiological factors such as the age of cuttings and hormone concentration in efforts to optimize the growth of *A. pintoi*. This finding highlights the nuanced role of auxins in plant development, illustrating that careful management of hormone application can significantly enhance growth outcomes. The findings provide valuable insights for plant management, suggesting that tailored hormone treatments based on plant age and development stage could lead to better control over growth patterns. This could be particularly useful in both agricultural and landscape contexts, where plant form and vigor are critical considerations.

3.3 Number of branches (stolons)

The number of branches is calculated by summing all primary, secondary, and tertiary branches (all stolons) of *A. pintoi*. The number of branches is important to observe as an integral part of the vegetative growth indicators of the plant, it reflects the plant's ability to produce new growth points and support future development. Increased branching is often associated with enhanced photosynthetic capacity and biomass production, as more branches can support additional leaves and, consequently, greater photosynthetic surface area (Weiner et al., 2009). Furthermore, the branching pattern can influence the plant's overall architecture, affecting its ability to compete for light and resources. A well-branched plant may also have a better capacity to recover from damage caused by herbivores or mechanical disturbances, ensuring its survival and continued growth in various environments. A higher number of branches can improve the plant's resilience to environmental stress and contribute to a more robust and stable growth habit, facilitating better adaptation to varying conditions (Müller & Leyser, 2011). The effect of treatments on the number of branches is presented in Table 5.

The treatment that significantly affected the number of branches was only the age of cuttings independently at 30 – 50 DAP. Meanwhile, the auxin concentration treatment and its interaction with the age of cuttings did not have a significant effect. The number of branches at 10 – 20 DAP did not yet show treatment differences as it is still in the early growth stage where the number of branches in all treatments is relatively the same. The highest number of branches was consistently shown by the intermediate-aged cuttings treatment at 30 – 50 DAP with values of 3.30, 4.10, and 5.50, respectively. This consistent performance of intermediate-aged cuttings suggests that they might be at an ideal developmental stage for branching, having enough maturity to support robust growth while still maintaining high metabolic activity.

Tabel 5. The number of branches (stolons) of *A. pintoi* at 10 – 50 DAP

Treatments	Number of branches (stolons)				
	10 DAP	20 DAP	30 DAP	40 DAP	50 DAP
Cutting age					
Young	0.10	1.60	2.40b	2.75b	3.65b
Intermediate	0.05	1.60	3.30a	4.10a	5.50a
Old	0.05	1.45	2.50b	3.05ab	4.15b
F-test	ns	ns	*	*	**
P-value	0.784	0.690	0.011	0.011	0.003
Auxin concentration					
0 ppm	0.00	1.50	2.42	2.92	3.92
500 ppm	0.00	1.33	2.42	3.00	4.17
1000 ppm	0.08	1.42	2.58	2.83	3.92
1500 ppm	0.17	1.67	2.83	3.42	4.42
2000 ppm	0.08	1.83	3.42	4.33	5.75
F-test	ns	ns	ns	ns	ns
P-value	0.499	0.322	0.088	0.074	0.056
Interaction	ns	ns	ns	ns	ns
P-value	0.561	0.414	0.613	0.565	0.675

Notes: Numbers followed by the same letter in the same column do not differ according to Tukey's HSD test, DAP (days after planting), * (significant at p≤0.05), ** (significant at p≤0.01), ns (not significant).

According to Beyl & Trigiano (2016), intermediate-aged cuttings show optimal growth potential due to their more physiologically active tissues. This optimal growth can be attributed to several physiological factors inherent to non-apical cuttings. Non-apical cuttings, taken from the middle sections of the parent plant, often contain a higher concentration of stored nutrients and growth hormones compared to apical cuttings, which provides the necessary energy for the development of multiple branches. Additionally, non-apical cuttings have more dormant buds along their stems, which can be activated to form branches when conditions are favorable. This balance between root and shoot growth ensures that the developing branches receive adequate water and nutrients from the newly established root system, leading to a higher branching potential in non-apical cuttings. These characteristics make non-apical cuttings particularly valuable in propagation efforts, where maximizing the growth and health of new plants is critical. By selecting cuttings with higher nutrient reserves and dormant buds, propagators can improve the success rate and overall vigor of new plants, leading to better yields and more resilient crops.

In contrast, Blythe et al. (2007) mentioned that basal cuttings (old-aged cuttings) generally showed poorer performance due to several factors, including lower physiological activity and reduced levels of growth hormones. de Klerk et al. (2011) indicated that the biochemical differences in cutting positions suggest that the lower part of the stem may contain inhibitory compounds that affect growth. These findings highlight the importance of selecting the appropriate part of the plant for cuttings, as the presence of inhibitory compounds or lower hormone levels in basal cuttings could significantly hinder growth. Understanding these biochemical differences can help in refining propagation techniques, ensuring that the most vigorous and productive parts of the plant are used for new growth.

3.4 Number of flowers

Based on Table 6, the treatments of cutting age and auxin concentration, as well as their interactions, did not show a significant effect on the number of flowers. This is in line with the research by Andianingsih et al. (2021) which found that auxin treatment only affected plant height and did not affect the number and age of flowering. Flowers are a product of the generative phase of the plant, endogenously induced by the hormone florigen, which plays a crucial role in inducing flowering through its accumulation in the shoot apical meristem (SAM) and triggering the conversion to flower meristem (Hujiser & Schmid, 2011; Lee et al., 2023). This suggests that the timing and conditions for floral induction may be more closely linked to endogenous signals rather than external hormone applications. Understanding the precise mechanisms of florigen's role could provide deeper insights into optimizing flowering in various crop species, potentially leading to improved yields and better management of flowering cycles.

Tabel 6. The number of flowers and canopy area of *A. pintoi* at 10 – 50 DAP

Treatments	Number of flowers	Canopy area (cm^2)
Cutting age		
Young	0.85	222.20ab
Intermediate	0.90	239.85a
Old	0.85	178.15b
F-test	ns	*
P-value	0.988	0.042
Auxin concentration		
0 ppm	0.83	210.83
500 ppm	0.50	181.58
1000 ppm	0.92	239.33
1500 ppm	0.92	187.92
2000 ppm	1.17	247.33
F-test	ns	ns
P-value	0.732	0.151
Interaction	ns	ns
P-value	0.768	0.754

Notes: Numbers followed by the same letter in the same column do not differ according to Tukey's HSD test, DAP (days after planting), * (significant at $p \leq 0.05$), ** (significant at $p \leq 0.01$), ns (not significant).

While auxins are well-known for their role in cell elongation and plant growth, their impact on flowering is more complex and less direct. According to Taiz & Zeiger (2010), auxins can influence flowering indirectly by affecting the transport and distribution of other hormones like gibberellins and cytokinins, which are more directly involved in the flowering process. Recent studies have further explored the nuanced role of auxins in flowering, highlighting that their effect is often context-dependent. For example, Zhang et al. (2022b) reported that the exogenous application of auxin in certain plant species did not significantly alter flowering time or the number of flowers produced. Instead, they found that auxins might play a more supportive role by facilitating nutrient allocation and shoot architecture, which can indirectly influence flowering. In contrast, some research suggests that the interaction of auxins with other phytohormones can lead to the suppression of flowering-promoting genes, inhibiting the flowering process under certain conditions. For example, in Arabidopsis thaliana, it has been observed that auxin can regulate the timing of floral initiation by influencing the expression of key regulatory genes, including those involved in the floral transition. This regulatory mechanism often involves the interaction between auxin and gibberellins (GA), where auxin can modulate GA signaling pathways to delay flowering (McSteen, 2010; Benjamins & Scheres, 2008).

In addition, auxins can act antagonistically with cytokinin, another hormone known to promote flowering, further complicating the hormonal balance required for flower development (Chandler, 2009). These findings highlight the multifaceted role of auxins in plant development, showing that their effects on flowering are highly context-dependent and can vary across different plant species and environmental conditions (Ellis et al., 2005; Ding et al., 2012; Estornell et al., 2013). This antagonistic relationship between auxins and cytokinins underscores the delicate balance required for successful flowering. Manipulating this balance could provide new avenues for controlling flowering in agricultural settings, allowing for more precise timing and potentially enhancing crop productivity by aligning flowering periods with optimal environmental conditions..

3.5 Canopy area

Canopy area was significantly affected by the age of cuttings, while the treatment of auxin concentration and its interaction with cutting age did not show an effect (Table 6). The highest canopy area was obtained in the intermediate-aged cuttings treatment with an average value of 239.85 cm, not significantly different from young cuttings (222.20 cm) but significantly different from old cuttings (178.15 cm). The findings highlight the significant impact of cutting age on canopy area, suggesting that intermediate-aged cuttings are optimal for maximizing canopy development. This observation aligns with the notion that intermediate-aged cuttings possess a balanced combination of maturity and vigor, facilitating better growth performance. The average canopy area recorded for intermediate-aged cuttings underscores their potential in promoting extensive canopy spread, which is crucial for effective ground coverage. In contrast, older cuttings exhibited a notably reduced canopy area, likely due to diminished regenerative capacity and lower metabolic activity, as reported by other studies on plant cutting age and growth vigor (Sachs, 1991; Druege et al., 2016).

Fig. 1. Representative results from the treatment with 0 ppm auxin concentration at second repetition: (a) young cutting, (b) intermediate cutting, (c) old cutting.

Moreover, the positive correlation between canopy area and other growth parameters such as the number of leaves, plant length, and number of branches emphasizes the integrated nature of plant development. A larger number of leaves contributes to a greater photosynthetic capacity, supporting overall plant growth and biomass accumulation. Similarly, increased plant length and branching enhance the structural framework, allowing for a more extensive canopy. These findings resonate with previous research demonstrating the interdependence of growth parameters in contributing to overall plant vigor and productivity (Poorter et al., 2019).

Furthermore, the consistency of these results with the research by Febrianto & Chozin (2014) reinforces the reliability of the observed trends. Its study on the effectiveness of different cutting types in achieving rapid ground cover corroborates the advantage of using tip, middle, and bottom cuttings, which align with the intermediate-aged cuttings in this study. This parallel suggests that selecting appropriate cutting age and type can strategically enhance canopy development and ground coverage, benefiting agricultural and horticultural practices aimed at maximizing plant productivity and soil protection.

4. Conclusions

Based on the results and discussion, the cutting ages independently affected the number of leaves at 10 and 50 days after planting, plant length on all frequently observed days, the number of branches at 30 to 50 days after planting, and canopy area. It didn't affect the number of flowers. The auxin concentrations only independently affected the plant length at 10 to 30 days after planting. The interaction between cutting ages and auxin concentrations showed significant effect on the number of leaves at 10 to 20 days after planting and plant length on 50 days after planting. The highest values for the parameters were consistently obtained from the intermediate cutting age treatment, followed by young/tip cuttings, with the lowest values observed in old cuttings. Generally, the auxin concentration treatment independently did not have a significant effect on most parameters. From these results, it can be recommended that the best planting material for pinto peanuts cuttings are intermediate followed by young cuttings (tip cuttings) with a length of three nodes.

Acknowledgement

The author wishes to express gratitude to the lecturers of the Advanced Agronomy course in the Agronomy and Horticulture Department at IPB University for their guidance in conducting this research.

Author Contribution

The author contributed to the research, as well as the drafting and revision of the manuscript.

Funding

This research received no external funding.

Ethical Review Board Statement

Not available.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Primary data is based on requests due to confidentiality or ethical constraints.

Conflicts of Interest

The author declares no conflict of interest.

Open Access

References

Aloni, R., Aloni, E., Langhans, M., & Ullrich, C. I. (2006). Role of auxin in regulating *Arabidopsis* flower development. *Planta, 223*(2), 315-328. https://doi.org/10.1007/s00425-005-0088-9

Andianingsih, N., Rosmala, A., & Mubarok, S. (2021). The effect of auxin and giberellin on the growth of tomato (*Solanum lycopersicum* L.) var. Aichi First on medium plain. *Agroscript*, *3*(1), 48-56. https://doi.org/10.36423/agroscript.v3i1.531

Azêvedo, H. S., Sousa, A. C., Martins, K., Oliveira, J. C., Yomura, R. B., Silva, L. M., Valls, J. F., Assis, G. M., & Campos, T. (2016). Genetic diversity of the forage peanut in the Jequitinhonha, São Francisco, and Paranã River valleys of Brazil. *Genetics and Molecular Research: GMR, 15*(3). https://doi.org/10.4238/gmr.15038601

Benjamins, R., & Scheres, B. (2008). Auxin: The looping star in plant development. *Annual Review of Plant Biology, 59*, 443-465. https://doi.org/10.1146/annurev.arplant.58.032806.103805

Beyl, C. A., & Trigiano, R. N. (2016). *Plant propagation concepts and laboratory exercises* (3rd ed.). CRC Press.

Blythe, E. K., Sibley, J. L., Tilt, K. M., & Ruter, J. M. (2007). Methods of auxin application in cutting propagation: A review of 70 years of scientific discovery and commercial practice. *Journal of Environmental Horticulture, 25*(3), 166-185. https://doi.org/10.24266/0738-2898-25.3.166

Chandler, J. W. (2009). Local auxin production: A small contribution to a big field. *BioEssays, 31*(1), 60-70. https://doi.org/10.1002/bies.080146

Chozin, M. A., Nuryana, F. I., Guntoro, D., Sumiahadi, A., Badriyah, R. N., & Wibowo, A. P. (2018). Potency of *Arachis pintoi* Krap. & Greg. as biomulch in the tropical upland agriculture. *IOP Conference Series: Earth and Environmental Science, 196*(1), 012011. https://doi.org/10.1088/1755-1315/196/1/012011

Ćosić, T., & Raspor, M. (2022). The role of auxin and cytokinin signaling components in *de novo* shoot organogenesis. In Aftab, T. (Ed.), *Auxins, cytokinins and gibberellins signaling in plants*. Signaling and Communication in Plants. Springer, Cham. https://doi.org/10.1007/978-3-031-05427-3_3

Davies, P.J. (2010). The Plant Hormones: Their Nature, Occurrence, and Functions. In Davies, P.J. (eds) *Plant Hormones*. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-2686-7_1

Davis, T. D., Haissig, B. E., & Sankhla, N. (Eds.). (1989). Adventitious root formation in cuttings. Advances in Plant Science Series, Volume 2. *Tree Physiology*, 5(3), 401–401. https://doi.org/10.1093/treephys/5.3.401

de Klerk, G. J., Guan, H., Huisman, P., & Marinov, S. (2011). Effects of phenolic compounds on adventitious root formation and oxidative decarboxylation of applied indoleacetic acid in *Malus* 'Jork 9'. *Plant Growth Regulation, 63*, 175-185. https://doi.org/10.1007/s10725-010-9555-9

de Sousa-Machado, I. B., Felippe, T., Garcia, R., Pacheco, G., Moreira, D., & Mansur, E. (2018). Total phenolics, resveratrol content and antioxidant activity of seeds and calluses of pinto peanut (*Arachis pintoi* Krapov. & W.C. Greg.). *Plant Cell, Tissue and Organ Culture, 134*, 491-502. https://doi.org/10.1007/s11240-018-1438-1

Ding, Z., Wang, B., Moreno, I., Duplakova, N., Simon, S., Carraro, N., Reemmer, J., Pěnčík, A., Chen, X., Tejos, R., Skupa, P., Pollmann, S., Friml, J., Rolcik, J., & Ljung, K. (2012). ER-localized auxin transporter PIN8 regulates auxin homeostasis and male gametophyte development in *Arabidopsis*. *Nature Communications, 3*, 941. https://doi.org/10.1038/ncomms1941

Druege, U., Franken, P., & Hajirezaei, M. R. (2016). Plant Hormone Homeostasis, Signaling, and Function during Adventitious Root Formation in Cuttings. *Frontiers in Plant Science*, 7. https://doi.org/10.3389/fpls.2016.00381

Ellis, C. M., Nagpal, P., Young, J. C., Hagen, G., Guilfoyle, T. J., & Reed, J. W. (2005). Auxin response factor1 and auxin response factor2 regulate senescence and floral organ abscission in *Arabidopsis thaliana*. *Development, 132*(20), 4563-4574. https://doi.org/10.1242/dev.02012

Estornell, L. H., Agustí, J., Merelo, P., Talón, M., & Tadeo, F. R. (2013). Elucidating mechanisms underlying organ abscission. *Plant Science, 199-200*, 48-60. https://doi.org/10.1016/j.plantsci.2012.10.008

Febrianto, Y., & Chozin, M. A. (2014). Effect of density and type of cutting on the coverage of *Arachis pintoi* as biomulch on tomatoes cultivation. *Bul. Agrohorti, 2*(1), 37-41. https://doi.org/10.29244/agrob.2.1.37-41

Gaspar, T., Kevers, C., Faivre-Rampant, O., Crèvecoeur, M., Penel, C., Greppin, H., & Dommes, J. (2003). Changing concepts in plant hormone action. *In Vitro Cellular & Developmental Biology. Plant, 39*(2), 85-106. http://www.jstor.org/stable/4293578

Goh, C. H., Ko, S. M., Koh, S., Kim, Y. J., & Bae, H. J. (2012). Photosynthesis and environments: Photoinhibition and repair mechanisms in plants. *Journal of Plant Biology, 55*, 93-100. https://doi.org/10.1007/s12374-011-9195-2

Hartmann, H. T., Kester, D. E., Davies, F. T., & Geneve, R. L. (2011). *Plant propagation: Principles and practices* (8th ed.). Prentice Hall.

Hujiser, P., & Schmid, M. (2011). The control of developmental phase transitions in plants. *Development, 138*(19), 4117-4129. https://doi.org/10.1242/dev.063511

Leakey, R. R. B. (2004). Physiology of vegetative reproduction. In J. Burley, J. Evans, & J. A. Youngquist (Eds.), *Encyclopaedia of forest sciences* (pp. 1655-1668). Academic Press.

Lee, Z., Kim, S., Choi, S. J., Joung, E., Kwon, M., Park, H. J., & Shim, J. S. (2023). Regulation of flowering time by environmental factors in plants. *Plants, 12*(3680). https://doi.org/10.3390/plants12213680

Liu, Y., Lan, X., Hou, H., Ji, J., Liu, X., & Lv, Z. (2024). Multifaceted ability of organic fertilizers to improve crop productivity and abiotic stress tolerance: Review and perspectives. *Agronomy, 14*(6), 1141. https://doi.org/10.3390/agronomy14061141

McSteen, P. (2010). Auxin and monocot development. *Cold Spring Harbor Perspectives in Biology, 2*(3), a001479. https://doi.org/10.1101/cshperspect.a001479

Müller, D., & Leyser, O. (2011). Auxin, cytokinin and the control of shoot branching. *Annals of Botany, 107*(7), 1203-1212. https://doi.org/10.1093/aob/mcr069

Poorter, H., Niinemets, Ü., Poorter, L., Wright, I. J., & Villar, R. (2009). Causes and consequences of variation in leaf mass per area (LMA): A meta-analysis. *New Phytologist, 182*(3), 565-588. https://doi.org/10.1111/j.1469-8137.2009.02830.x

Rademacher, W. (2015). Plant growth regulators: Backgrounds and uses in plant production. *Journal of Plant Growth Regulation, 34*(4), 845-872. https://doi.org/10.1007/s00344-015-9541-6

Rahman, M. M., Alam, M. S., Islam, M. M., Kamal, M. Z. U., Rahman, G. K. M. M., Haque, M. M., Miah, M. G., & Biswas, J. C. (2022). Potential of legume-based cropping systems for climate change adaptation and mitigation. In Meena, R. S., & Kumar, S. (Eds.), *Advances in legumes for sustainable intensification* (pp. 381-402). https://doi.org/10.1016/B978-0-323-85797-0.00030-6

Sachs, T. (1991). *Pattern Formation in Plant Tissues*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511574535

Sales, R. M. P., Fries, D. D., Bonomo, P., Pires, A. J. V., Campos, C. N., Brito, P. H. R., Pereira, I. S., & Santos, J. da S. (2013). Effect of water stress on the growth of *Arachis pintoi* plants under different nitrogen levels. *Revista Brasileira De Zootecnia*, *42*(3), 149–154. https://doi.org/10.1590/S1516-35982013000300001

Sauer, M., Robert, S., & Kleine-Vehn, J. (2013). Auxin: Simply complicated. *Journal of Experimental Botany, 64*(9), 2565-2577. https://doi.org/10.1093/jxb/ert139

Sosnowski, J., Truba, M., & Vasileva, V. (2023). The impact of auxin and cytokinin on the growth and development of selected crops. *Agriculture*, *13*(3), 724. https://doi.org/10.3390/agriculture13030724

Sousa, I., Garcia, R., Valls, J., Pacheco, G., & Mansur, E. (2024). *Arachis pintoi* Krapov. & W.C. Greg.–A multifunctional legume. *Grass and Forage Science*, *79*(3), 343-352. https://doi.org/10.1111/gfs.12674

Spaepen, S. (2015). Plant hormones produced by microbes. In Lugtenberg, B. (Ed.), *Principles of plant-microbe interactions*. Springer, Cham. https://doi.org/10.1007/978-3-319-08575-3_26

Sumiahadi, A., Chozin, M. A., & Guntoro, D. (2019). Effectiveness of *Arachis pintoi* Karp. & Greg. as biomulch to control weeds on maize cultivation. *International Journal of Innovative Approach in Agricultural Research, 3*(4), 680-689. https://doi.org/10.29329/ijiaar.2019.217.14

Susilo, D. E. H. (2015). Identification of constanta value of leaf shape for leaf area measurement using length cross width of leaf of horticulture plant in peat soil. *Anterior Jurnal, 14*(2), 139-146. https://doi.org/10.33084/anterior.v14i2.178

Suwarto, & Hariyadi, A. (2020). Growth and fruit panicle responses of shrub pepper (*Piper nigrum* L.) to bio-mulch. *IOP Conference Series: Earth and Environmental Science*, 418(1), 012050. https://doi.org/10.1088/1755-1315/418/1/012050

Taiz, L., & Zeiger, E. (2010). *Plant physiology* (5th ed.). Sinauer Associates.

Thang, P. T., Vien, N. V., Anh, L. H., Xuan, T. D., Duong, V. X., Nhung, N. T., Trung, K. H., Quan, N. T., Nguyen, C. C., Loan, L. T. K., Khanh, T. D., & Ha, T. T. T. (2023). Assessment of allelopathic activity of *Arachis pintoi* Krapov. & W.C. Greg as a potential source of natural herbicide for paddy rice. *Applied Sciences, 13*(8268). http://dx.doi.org/10.3390/app13148268

Ugrenović, V., & Filipović, V. (2017). Cover crops: Achievement of sustainability in the ecological systems of agriculture. In A. Jean Vasile & D. Nicolò (Eds.), *Sustainable entrepreneurship and investments in the green economy* (pp. 257-281). IGI Global. https://doi.org/10.4018/978-1-5225-2075-7.ch009

Valencia, K. J. E., Castillo, Á. R., Ruden, D. A., & Burkart, S. (2021). Risk reduction and productivity increase through integrating *Arachis pintoi* in cattle production systems in the Colombian Orinoquía. *Frontiers in Sustainable Food Systems, 5*(666604). https://doi.org/10.3389/fsufs.2021.666604

Weiner, J., Andersen, S. B., Wille, W. K., Griepentrog, H. W., & Olsen, J. M. (2009). Evolutionary agroecology: The potential for cooperative, high density, weed-suppressing cereals. *Evolutionary Applications, 3*(5-6), 473-479. https://doi.org/10.1111/j.1752-4571.2010.00144.x

Zhang, Q., Gong, M., Xu, X., Li, H., & Deng, W. (2022b). Roles of auxin in the growth, development, and stress tolerance of horticultural plants. *Cells, 11*(17), 2761. https://doi.org/10.3390/cells11172761

Zhang, Y., Yu, J., Xu, X., Wang, R., Liu, Y., Huang, S., Wei, H., & Wei, Z. (2022a). Molecular mechanisms of diverse auxin responses during plant growth and development. *International Journal of Molecular Sciences, 23*(20), 12495. https://doi.org/10.3390/ijms232012495

Zhang, Y., Han, S., Lin, Y., Qiao, J., Han, N., Li, Y., Feng, Y., Li, D., & Qi, Y. (2023). Auxin transporter OsPIN1b, a novel regulator of leaf inclination in rice (*Oryza sativa* L.). *Plants, 12*(2), 409. https://doi.org/10.3390/plants12020409

Biographies of Author

Junaidi Muntoyib, Graduate student, Study Program of Agronomy and Horticulture, Graduate School, IPB University (Bogor Agricultural University), Jl. Meranti Kampus IPB Darmaga, Bogor 16880, Indonesia.

- Email: mjunaidi@apps.ipb.ac.id
- ORCID: 0009-0008-5467-0129
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A