Effect of Gibberellic Acid on Sprouting of Arrowroot (*Colocasia esculenta* L.) Rhizomes in Different Media

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Abstract

Arrowroot [*Colocasia esculenta* (L.) Schott] is traditionally propagated through headsets or suckers. However, initiating an arrowroot crop remains a challenge due to shortages of propagation materials. This study investigated the potential of nodal cuttings derived from rhizomes produced by arrowroot corms to develop into plantlets suitable for propagation. Potted arrowroot mother plants were treated with varying concentrations of gibberellic acid (GA_3): 100, 250, 500, and 750 parts per million (ppm), leading to the development of corm-rhizomes. A pot experiment was conducted using a split-plot design nested within a completely randomized design (CRD) framework, with four replications to ensure statistical rigor. The sprouting media constituted the main plot, while the application of GA_3 (gibberellic acid) was assigned to the sub-plots. The resulting rhizomes from the GA_3 treatment were sliced into two-node cuttings and sown in either river sand or sawdust-filled pots. The pots were then placed in controlled sprouting chamber with ideal temperature and humidity conditions. The highest sprouting percentage of 96% was recorded for nodal cuttings propagated in river sand and treated with 500 ppm GA_3, 250 ppm (81%), 750 ppm (79%), while 100 ppm yielded the lowest rate at 79%, with same GA_3 concentrations in the sawdust demonstrating varying lower percentages. The interactions between GA3, Media and time were highly significant. Therefore, river sand emerged as the superior medium for initial growth. These findings underscore the potential of this propagation method, but further research into single-node cuttings and the evaluation of the resulting plantlets under field conditions is essential to evaluate the scalability and yield performance for arrowroot production.

Keywords: arrowroot; gibberellic acid; nodal-cutting; rhizome

1. Introduction

Arrowroot (*Colocasia esculenta* L.) is a globally recognized root crop (Mongi & Chove, 2020). It is cultivated mainly in Africa, Oceania, and the Orient (Tumuhimbise et al., 2009) for its diverse culinary and nutritional uses (Gerrano *et al*., 2019). Nigeria is the largest producer, contributing over 25% of the world's arrowroot production (Oladimeji *et al*., 2022). In many rural African communities, arrowroot is vital for food security, serving as a subsistence crop and providing income for small-scale farmers (Tumuhimbise, 2015). Known as "Nduma" in Kenya (Sagoe *et al*., 2018) and taro in Uganda (Talwana *et al*., 2010), it thrives in wetlands and riverbanks (Akwee *et al*., 2015).

Arrowroot is a significant yet underutilized crop in policy and research, compared to other root and tuber crops. Its cultivation is primarily informal and often lacks proper agronomic practices, which negatively impacts growth and yields (Bentley *et al*., 2018). Plant growth regulators (PGRs) can enhance arrowroot development, similar to other crops (Lolael *et al*., 2013). Gibberellic acid (GA_3) is a key hormone for root and shoot elongation, but its effectiveness depends on correct concentration and timing (Saini *et al*., 2021). Studies have shown that GA_3 can enhance various growth processes and significantly increase yields in crops such as Indian mustard and Red Fescue (Szczepanek *et al.,* 2021). Research on plant growth regulators (PGRs) has shown significant benefits for various crops. For instance, the GA_3 application in potatoes increased tuber yield but caused some damage (Chindi & Tsegaw, 2019). Similarly, GA_3 increased productivity in plantain bananas without harming the mother plant (Swennen *et al.,* 2014). These findings highlight the positive role of PGRs in enhancing the rapid multiplication of vegetatively propagated crops (Khangjarakpam *et al*., 2019), which is essential for food security (Wamalwa *et al*., 2022).

In Kenya, arrowroot production relies on traditional methods, with quality planting material being crucial for optimal yields. Standard propagules include headsets and suckers, but both often vary in size and maturity, complicating harvesting. Challenges in sourcing quality materials hinder large-scale production, as arrowroot has a low multiplication rate and limited farmland. While headset propagation is preferred for its uniformity, it is typically only available at harvest time. This study examines the impact of GA_3 on sprouting nodal cuttings from rhizomes, aiming to develop a new propagation protocol for arrowroot.

2. Materials and Methods

2.1 Study area

A pot experiment was conducted at the Egerton University, Kenya, Department of Crops, Horticulture, and Soils, Teaching and Research Field Station, located at the Njoro Campus, at an altitude of 2,267 m above sea level. The soils are classified as mollic phaeozems in Agro-ecological Zone III of Kenya (Jaetzold *et al*., 2010). They are red-brown, well-drained, and receive annual rainfall between 950 and 1,500 mm in a bimodal pattern. Average temperatures range from 8°C to 23°C.

2.2 Experimental design and treatment application

The experiment utilized a split-plot design within a completely randomized design (CRD) with four replicates, focusing on the local arrowroot cultivar Girigaca. This dasheen type was evaluated for sprouting from nodal cuttings and rooting in various media, with the type of sprouting media as the main plot and gibberellic acid (GA_3) application in sub-plots. Wooden rooting chambers (1.2m x 3m x 1m) were created, covered with a 1000-gauge polythene sheet and a black agro-shade net to protect the young plants. One hundred plastic bags filled with fresh sawdust or river sand were prepared for each treatment using rhizomes harvested from potted plants pre-treated with GA_3. The rhizomes were carefully washed and sorted according to four GA_3 treatment levels: T1 (100 ppm), T2 (250 ppm), T3 (500 ppm), and T4 (750 ppm). Apical meristems were removed with a sterile blade, and 100 two-node rhizome cuttings per treatment were dipped in a fungicide solution (Ridomil Gold®) before planting at a depth of 5 cm in polythene bags. The sprouting experiment lasted four months, with watering every week to maintain humidity. Data were measured bi-weekly based on visible shoot protrusions.

2.3 Data collection and statistical analysis

Data were recorded periodically, noting the days until sprouting. The number of sprouted nodal cuttings was evaluated 14 days post-sprouting, calculated as follows: Percentage sprouted = (Number of sprouted cuttings / Total cuttings) × 100. Plantlet height was measured from the sprouting medium to the leaf attachment point of the tallest leaf. Stem girth was recorded at the base using a Digital Vernier Caliper, while root length was measured from the plant crown to the longest root tip. Leaf area was determined using leaf length and width based on method used by Biradar *et al*. (1978). Data were analyzed for normality and homogeneity using SAS Software version 9.4, with ANOVA conducted at $p \leq 0.05$, followed by Tukey's post-hoc analysis.

3. Results and Discussion

3.1 Effects of GA_3 and sprouting media on sprout counts of rhizome nodal cutting

The average number of nodal cutting sprouts counted on various days after sowing is presented in Table 1. Figure 1 shows the sprouting percentages of rhizome nodal cuttings pre-treated with different gibberellic acid concentrations and sown in different sprouting media. The 500-ppm treatment had the highest sprouting rate at 96%, despite a decrease on day 28 after sowing (Figure 1). The 250-ppm concentration followed with a rate of 81%, indicating that it still supports good growth potential. In contrast, the 750-ppm treatment resulted in a lower sprouting rate of 79%, suggesting that high gibberellic acid levels may inhibit growth. The treatment with gibberellic acid at 100 ppm resulted in the lowest sprouting performance at 71.5%. There was no significant difference in sprouting percentages among various gibberellic acid concentrations and media, with sprouting beginning 14 days post-sowing. River sand facilitated higher sprouting rates than sawdust, although both showed low performance at 100 ppm gibberellic acid.

Table 1 Effects of GA_3 treatment and sprouting on sprout count of rhizome nodal cuttings

GA_3 (ppm)	**Sprouting medium**	**Time (Days)**				
		14	28	42	56	70
100	River sand	11.00 ± 1.00^{e}	54.00 ± 1.73^{d}	63.00 ± 1.53^{c}	67.00 ± 0.58^{b}	73.00 ± 1.00^{a}
	Sawdust	40.00 ± 1.53^{c}	59.00 ± 0.58^{b}	56.00 ± 2.31^{b}	68.00 ± 1.15^{a}	70.00 ± 2.08^{a}
250	River sand	75.00 ± 1.73^{b}	75.00 ± 1.15^{b}	77.00 ± 1.15^{b}	79.33 ± 1.20^{ab}	81.00 ± 1.15^{a}
	Sawdust	60.00 ± 1.15^{c}	66.67 ± 1.20^{b}	75.00 ± 1.73^{a}	78.00 ± 1.53^{a}	79.00 ± 0.58^{a}
500	River sand	78.00 ± 1.15^{d}	78.00 ± 1.73^{d}	85.00 ± 1.53^{c}	94.00 ± 0.58^{b}	96.00 ± 0.58^{a}
	Sawdust	42.00 ± 0.58^{e}	50.00 ± 1.53^{d}	80.00 ± 1.53^{c}	87.00 ± 0.58^{b}	96.00 ± 1.15^{a}
750	River sand	64.00 ± 1.15^{c}	65.00 ± 2.31^{c}	72.00 ± 0.58^{b}	77.00 ± 1.00^{a}	79.00 ± 1.00^{a}
	Sawdust	31.00 ± 1.15^{e}	60.00 ± 1.73^{d}	69.00 ± 0.58^{c}	74.00 ± 0.58^{b}	77.00 ± 0.58^{a}

Means followed by the same letter along the column are not significantly different at a $p \leq 0.05$ probability level.

In contrast, 500 ppm gibberellic acid effectively stimulated both upward and horizontal growth, resulting in longer petioles and wider stems compared to lower GA_3 doses of 10 ppm and 250 ppm. Studies suggest that gibberellic acid, when combined with other plant growth regulators (PGRs), enhances critical physiological processes, such as cell elongation and division, which are key to successful sprouting and plant development.

This research reinforces the importance of optimizing gibberellic acid levels for maximum sprouting efficiency in arrowroot propagation. The results indicate that gibberellic acid affects sprouting in rhizome nodal cuttings, aligning with previous research on cellular processes crucial for growth activation in dormant vegetative organs. However, a foliar application above 500 ppm on the mother plant may hinder growth.

Overall, this study highlights the effective use of gibberellic acid for enhancing arrowroot propagation from nodal cuttings with two axillary buds, a method that has not been previously detailed for arrowroot. This unique characteristic of terminal bud dominance in arrowroot allows for more effective plantlet generation during division. At least one axillary bud and the multiplier effect on the rhizome would be enormous.

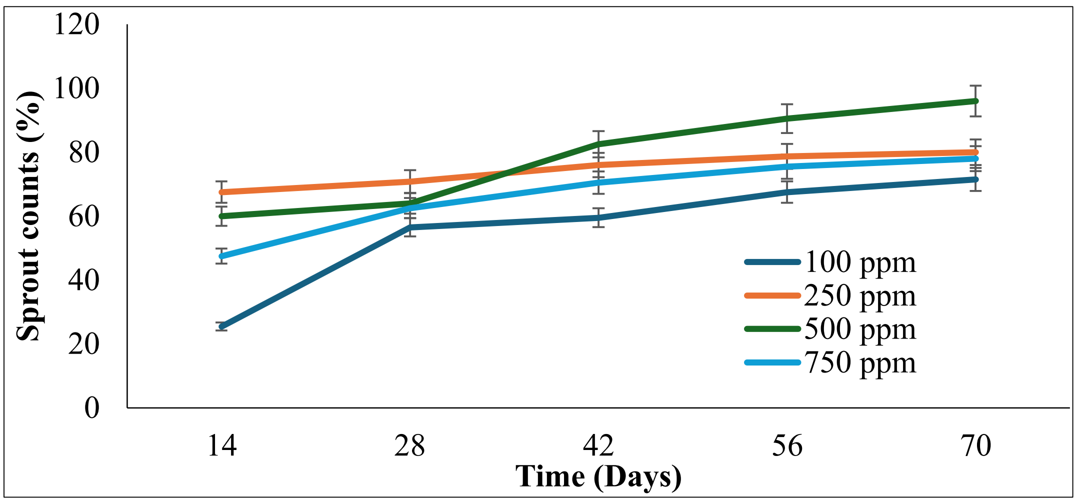

Figure 1 Effect of GA_3 on sprout count of rhizome nodal cuttings.

3.2 Effects of sprouting media on sprout count of rhizome nodal cuttings

The experiment evaluated the effectiveness of two types of sprouting media, river sand and sawdust, for cultivating rhizome nodal cuttings, as illustrated in Figure 2 and summarized in Table 2. The results show that during the initial stages of the experiment, river sand exhibited superior performance compared to sawdust, as evidenced by significantly higher sprouting rates, quicker emergence of plantlets, and increased vigour in the developing plants. This advantage can largely be attributed to the unique properties of river sand, which promote optimal airflow and drainage. Such characteristics are crucial for fostering robust root development, as they help prevent waterlogging and ensure roots have adequate access to oxygen.

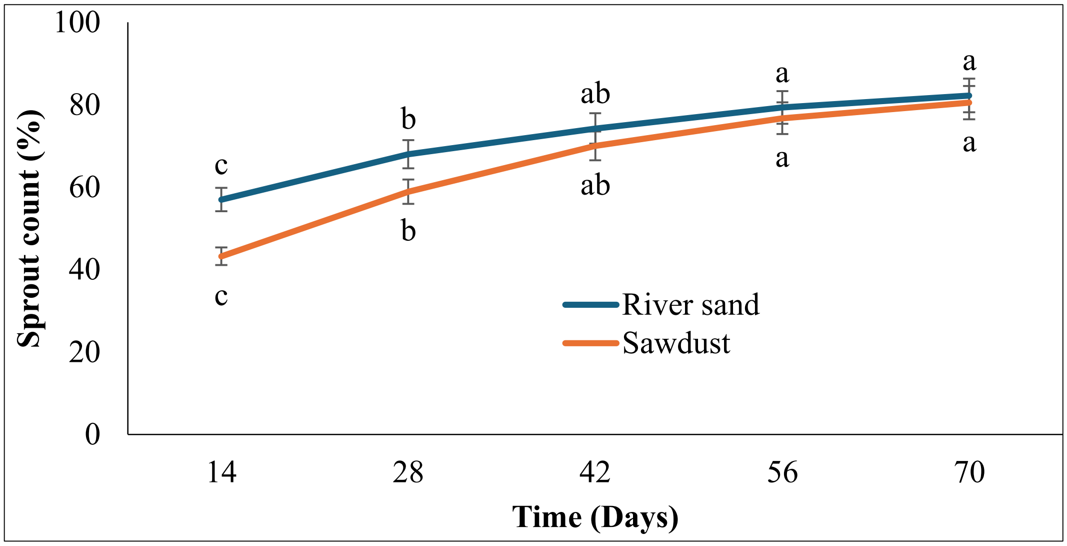

Figure 2 Effect of sprouting media on the sprout count of rhizome nodal cuttings.

However, as the experiment progressed into the second week, the differences in growth performance between the two media began to diminish considerably. By this stage, both river sand and sawdust had proven effective as substrates for supporting the sprouting of arrowroot nodal cuttings. This outcome suggests that while river sand may initially provide benefits, sawdust can also effectively sustain plant growth, potentially during later stages of development.

These findings underscore the adaptability of arrowroot to various growing conditions. It emphasizes the importance of selecting media that is tailored to the specific needs of plants at different growth phases. Although both river sand and sawdust can be successfully used for sprouting arrowroot, river sand may be the preferred option during the critical periods of nodal cutting and early sprouting due to its advantages in promoting initial growth. These insights can help growers make informed decisions about their choice of medium, based on specific growth objectives and desired timelines for plant development.

The results indicate a significant variation in sprout development among the various media used. Similarly, Muktar *et al*. (2023) reported sawdust promotes the rooting of cassava cuttings. From the findings, we can infer that certain media types provide a more favorable environment for sprouting, probably due to nutrient availability, moisture retention, and aeration (Pugalendhi & Velmurugan, 2020). Higher sprout counts in specific medium suggest that these conditions may enhance the growth potential of rhizome nodal cuttings. In this study, river sand and sawdust supported high percentages of sprouts. Equally, sprouting media that results in lower sprout counts may pose challenges, for instance, sawdust, which can be due to a lack of essential nutrients, poor drainage, or insufficient oxygen, leading to the death of nodal cuttings (Bhende & Kurien, 2015).

The data obtained in the study underscores the importance of selecting appropriate media to optimize rhizome sprouting and overall growth, Sagoe *et al*. (2018) conducted research to examine the effect of growth media for vegetative propagules and seed, observed that the media influenced the rooting of stem cutting, further stated that river sand supported earlier. Higher germination, therefore confirming the results reported by Ahmed *et al*. (2022), was also observed in the present experiment. Therefore, the findings emphasize the significant role that sprouting media play in nurturing rhizome nodal cuttings. The information will guide future cultural practices in propagation techniques (Norman *et al.*, 2022).

3.3 Effects of GA_3 and sprouting media on growth parameters

Figure 2 shows the results of sprouting of nodal cuttings grown in the two media under test; During the initial stages of the experiment, river sand exhibited superior performance compared to sawdust, as evidenced by significantly higher sprouting rates, quicker emergence of plantlets, and increased vigour in the developing plants. This advantage can largely be attributed to the unique properties of river sand, which promote optimal airflow and drainage. Such characteristics are crucial for fostering robust root development, as they help prevent waterlogging and ensure roots have adequate access to oxygen.

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This finding underscores the adaptability of arrowroot to various growing conditions. It emphasizes the importance of selecting media that is tailored to the specific needs of plants at different growth phases. Although both river sand and sawdust can be successfully used for sprouting arrowroot, river sand may be the preferred option during the critical periods of nodal cutting and early sprouting due to its advantages in promoting initial growth. These insights can help growers make informed decisions about their choice of medium, based on specific growth objectives and desired timelines for plant development.

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The data obtained in the study underscore the importance of selecting appropriate growing media to optimize the sprouting and overall health of rhizome plants. Sagoe *et al*. (2018) examined the effect of growth media on vegetative propagules and seeds, observing that the media influenced the rooting of stem cuttings. They further stated that river sand supported earlier and higher rooting, as well as higher germination, thereby confirming the results reported by Ahmed *et al*. (2022), which were also observed in the present experiment. Therefore, the findings emphasize the significant role that sprouting media play in nurturing rhizome nodal cuttings. The information will guide future cultural practices in propagation techniques (Norman *et al.*, 2022).

Table 2 Effect of sprouting media and GA_3 on growth parameters of plantlets

GA_3 (ppm)	Spouting medium	Plant height (cm)	Stem diameter (mm)	Root length (cm)	Leaf area (cm^2)
100	River sand	12.27 ± 2.11^{b}	3.27 ± 0.39^{a}	18.14 ± 2.96^{a}	23.52 ± 6.80^{b}
	Sawdust	14.78 ± 2.40^{a}	4.21 ± 0.44^{a}	36.37 ± 7.05^{a}	34.22 ± 8.62^{a}
250	River sand	14.99 ± 2.44^{b}	3.89 ± 0.41^{a}	24.18 ± 3.77^{a}	37.31 ± 10.11^{a}
	Sawdust	13.84 ± 2.33^{a}	3.68 ± 0.33^{ab}	34.97 ± 7.08^{a}	22.92 ± 5.96^{b}
500	River sand	14.26 ± 2.60^{b}	3.56 ± 0.44^{a}	22.88 ± 2.59^{a}	39.73 ± 10.23^{a}
	Sawdust	12.98 ± 2.06^{a}	3.09 ± 0.25^{b}	28.88 ± 4.16^{a}	23.35 ± 6.56^{b}
750	River sand	17.16 ± 2.88^{a}	3.44 ± 0.39^{a}	24.58 ± 3.84^{a}	34.42 ± 8.85^{ab}
	Sawdust	15.73 ± 2.80^{a}	3.13 ± 0.36^{b}	31.05 ± 5.95^{a}	27.28 ± 7.09^{ab}

Means with the same letter along the column within each rooting media are not significantly different at $p \leq 0.05$

Table 2 presents growth outcomes for plantlets from nodal cuttings of arrowroot rhizomes. Plant height increased in both river sand and sawdust with GA_3 treatments, peaking at 70 days after sowing. Heights ranged from 12.27 cm (100 ppm) to 24.32 cm (750 ppm) in river sand, and 14.78 cm to 15.73 cm in sawdust, with no significant difference between media. Mean leaf area showed a similar pattern, peaking at 100 days. Stem diameter varied with lower GA_3 concentrations, favouring growth, with diameters of 3.27 mm (100 ppm) to 3.44 mm (750 ppm) in river sand, while sawdust showed a decrease from 4.31 mm to 3.13 mm.

Root length measurements indicated maximum elongation at 500 ppm, with the longest roots recorded at 36.37 cm in sawdust at 100 ppm, compared to 18.14 cm in river sand. Increased GA_3 concentrations negatively impacted root length in sawdust, suggesting phytotoxic effects at higher doses. Higher GA_3 concentrations (500 and 750 ppm) resulted in larger leaf sizes, enhancing photosynthetic efficiency. The 500-ppm treatment group also exhibited the highest survival rate, supporting robust plantlet health.

These findings highlight the significant influence of growing media on stem diameter and root length, with specific media promoting structural development and nutrient uptake (Eed *et al*., 2015; Rahman *et al*., 2018). Selecting suitable media is crucial for optimizing growth, as it can impact nutrient content, moisture retention, and pH levels, ultimately aiding in the propagation of plantlets from rhizome nodal cuttings.

Caliskan *et al*. (2021) suggest that the root length response may be influenced by GA_3 treatment. Variations in plantlet growth can be attributed to the effects of the rooting medium and GA_3 on the mother plant, consistent with findings by Masuda *et* *al*. (2012). Optimizing sprouting media in conjunction with GA_3 enhances the growth of nodal cuttings (Ahmed *et al.*, 2022). Identifying trends in the presented data can help determine the most effective media and treatment strategies for plantlet growth.

Table 2 and Figure 3 show how different media influence the leaf area of nodal cuttings. Variations in rooting media affect plantlet growth, impacting leaf area as reported by Guo et al. (2020). Certain media promote better leaf expansion due to enhanced nutrient availability and moisture retention (Sagoe *et al*., 2018). For instance, a medium rich in organic matter can lead to larger leaves compared to inert substrates (Norman *et al*., 2022). The findings suggest that selecting the appropriate media is crucial for maximizing leaf area and ensuring the healthy growth of plantlets (Muktar *et al*., 2023).

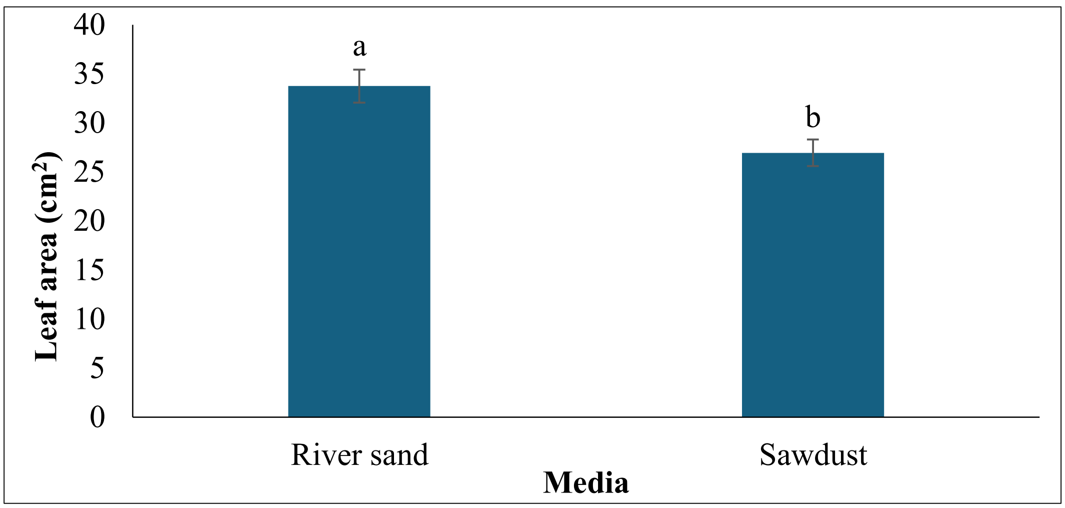

Figure 3 Effect of sprouting medium on the leaf area of nodal cutting plantlets.

Table 3 Effects of GA_3 treatment and sprouting media on the growth parameters of nodal cuttings plantlets

GA_3 (ppm)	**Time (Days)**	**Plantlet height (cm)**		**Stem diameter (mm)**		**Root length (cm)**		**Leaf area (cm^2)**	
		River sand	Sawdust	River sand	Sawdust	River sand	Sawdust	River sand	Sawdust
100 ppm	55	4.43 ± 0.52^{b}	5.03 ± 0.34^{d}	1.24 ± 0.07^{c}	2.33 ± 0.27^{c}	7.17 ± 0.92^{d}	8.17 ± 2.05^{c}	2.69 ± 0.32^{d}	3.25 ± 0.51^{d}
	70	6.77 ± 0.60^{b}	9.43 ± 1.28^{c}	4.35 ± 0.26^{a}	3.55 ± 0.08^{b}	10.00 ± 0.00^{c}	18.67 ± 0.88^{b}	4.28 ± 0.84^{c}	12.49 ± 3.78^{c}
	85	20.13 ± 2.14^{a}	19.97 ± 0.59^{b}	3.45 ± 0.38^{b}	5.51 ± 0.70^{a}	26.00 ± 0.95^{b}	58.83 ± 0.62^{a}	32.94 ± 4.13^{b}	47.74 ± 3.82^{b}
	100	17.73 ± 1.21^{a}	24.70 ± 0.71^{a}	4.03 ± 0.35^{a}	5.47 ± 0.06^{a}	29.40 ± 1.92^{a}	59.80 ± 2.63^{a}	54.19 ± 9.09^{a}	73.39 ± 5.48^{a}
250 ppm	55	5.03 ± 0.23^{d}	4.80 ± 0.70^{d}	1.70 ± 0.11^{c}	2.27 ± 0.06^{d}	8.83 ± 1.48^{d}	10.00 ± 0.58^{c}	3.10 ± 1.28^{c}	2.44 ± 0.07^{c}
	70	9.13 ± 0.41^{c}	7.87 ± 0.30^{c}	4.13 ± 0.39^{b}	3.12 ± 0.09^{c}	16.67 ± 2.33^{c}	13.33 ± 1.20^{b}	13.70 ± 1.72^{b}	7.02 ± 2.33^{b}
	85	22.70 ± 0.86^{a}	19.97 ± 0.69^{b}	5.09 ± 0.11^{a}	4.95 ± 0.19^{a}	33.00 ± 3.25^{b}	59.87 ± 1.88^{a}	64.36 ± 22.24^{a}	35.35 ± 4.53^{a}
	100	23.10 ± 0.75^{b}	22.73 ± 0.95^{a}	4.63 ± 0.20^{ab}	4.36 ± 0.30^{b}	38.20 ± 3.47^{a}	56.67 ± 2.40^{a}	68.06 ± 6.88^{a}	46.86 ± 7.40^{a}
500 ppm	55	4.40 ± 0.35^{c}	5.20 ± 0.15^{d}	1.56 ± 0.21^{c}	1.78 ± 0.07^{b}	12.67 ± 1.45^{d}	12.00 ± 0.00^{d}	4.60 ± 1.20^{d}	4.29 ± 0.19^{d}
	70	7.20 ± 0.62^{b}	8.10 ± 0.15^{c}	2.89 ± 0.07^{b}	3.56 ± 0.13^{a}	17.00 ± 1.53^{c}	21.17 ± 2.20^{c}	12.27 ± 1.87^{c}	8.16 ± 1.04^{c}
	85	22.67 ± 1.19^{a}	16.20 ± 1.01^{b}	4.88 ± 0.20^{a}	3.37 ± 0.29^{a}	33.43 ± 1.44^{a}	35.27 ± 2.92^{b}	82.99 ± 10.67^{a}	27.75 ± 6.24^{b}
	100	22.77 ± 1.30^{a}	22.43 ± 0.45^{a}	4.90 ± 0.48^{a}	3.66 ± 0.28^{a}	28.40 ± 0.81^{b}	47.07 ± 3.01^{a}	59.05 ± 8.30^{b}	53.19 ± 12.47^{a}
750 ppm	55	6.27 ± 0.13^{b}	4.23 ± 0.27^{d}	1.41 ± 0.06^{c}	1.40 ± 0.11^{c}	10.00 ± 1.15^{d}	10.03 ± 1.30^{d}	4.93 ± 1.20^{c}	2.49 ± 0.51^{d}
	70	9.47 ± 0.52^{b}	10.04 ± 0.15^{c}	3.36 ± 0.17^{b}	2.79 ± 0.32^{b}	14.33 ± 1.20^{c}	16.83 ± 0.60^{c}	12.61 ± 5.67^{b}	6.29 ± 0.47^{c}
	85	27.40 ± 2.58^{a}	21.23 ± 0.52^{b}	4.71 ± 0.15^{a}	4.32 ± 0.15^{a}	39.10 ± 1.87^{a}	59.53 ± 3.99^{a}	64.12 ± 17.19^{a}	44.91 ± 3.12^{b}
	100	25.50 ± 0.10^{a}	27.40 ± 2.53^{a}	4.27 ± 0.31^{a}	4.01 ± 0.26^{a}	34.87 ± 1.20^{b}	37.80 ± 3.16^{b}	56.00 ± 6.95^{a}	55.45 ± 3.94^{a}

Means with the same letter along the column within each GA_3 treatment level are not significantly different at a $p \leq 0.05$ probability levels.

The results in Table 3 demonstrate the interaction between GA_3 concentrations and different sprouting media for rhizome nodal cuttings. Plantlet height significantly increased with higher GA_3 concentrations, especially at 750 ppm in river sand. In contrast, lower concentrations, such as 100 ppm, resulted in significantly shorter plants, aligning with the findings of Talwana *et al*. (2010). For stem diameter, 100 ppm GA_3 in sawdust achieved the best results, possibly due to a combination of GA_3, cultivar, and environment (Caliskan *et al*., 2021). Higher GA_3 levels had less pronounced effects on stem diameter, particularly in river sand (Rahman *et al*., 2018).

Root length was optimal at 100 ppm in sawdust, with higher concentrations showing reduced growth. The analysis of leaf area indicated that moderate GA_3 levels (100 and 250 ppm) in both media were more effective for early growth than higher concentrations, a finding similar to that of Aljaser and Anderson (2021). The study also revealed significant differences in sprouting efficiency between river sand and sawdust, with river sand initially promoting better sprouting due to its drainage and aeration properties.

This change suggests that while river sand may promote quicker sprouting and initial growth, sawdust offers long-term benefits due to its ability to retain moisture, which supports consistent seedling growth (Sagoe *et al*., 2018). The differences in sprouting efficiency underscore the importance of understanding the properties of various growth media, particularly their moisture retention and air circulation (Pugalendhi & Velmurugan, 2020). These factors affect root and shoot development, influencing plant health and viability (Caliskan *et al*., 2021). Growers should tailor their choice of growth medium to their plants' specific needs and growth cycles, thereby maximizing both immediate and long-term benefits (Ubalua *et al*., 2016).

Gibberellic acid (GA_3) has become popular in agriculture for enhancing both food crops (Chindi & Tsegaw, 2021; Rahman *et al*., 2018) and ornamental plants (Eed *et al*., 2015). Research indicates that GA_3 enhances yield and can expedite the propagation process, facilitating the production of uniform planting material (Manju *et al*., 2017). This is especially beneficial for arrowroot, where traditional methods often require substantial amounts of planting materials that can be difficult for small-scale farmers to source (Aljaser & Anderson, 2021). Using GA_3 for propagation from corm-rhizomes offers a cost-effective alternative (Tumuhimbise *et al*., 2015), which helps meet the growing demand.

This method also increases arrowroot production rates, as seen in studies on plant growth regulators in *Capsicum annuum* L. (Ahmed *et al*., 2023). By addressing the challenge of planting material scarcity (Saini *et al*., 2021), this approach could enhance accessibility and affordability for both subsistence and commercial farmers. Finding sufficient healthy planting materials is a key production challenge, and the multiplication protocol developed in this study has significant commercial potential if scaled up.

4. Conclusion

This research suggests that nodal cuttings from arrowroot rhizomes treated with gibberellic acid (GA_3) can successfully sprout, presenting a promising alternative to traditional planting materials. Among various sprouting mediums, river sand emerged as the most effective due to its superior drainage and aeration properties. A concentration of 500 ppm GA_3 was found to significantly enhance sprouting percentages, underscoring its importance in promoting vegetative growth. Additionally, high-temperature and high-humidity environments in sprouting chambers were beneficial for initial growth. Arrowroot growers should incorporate gibberellic acid at a concentration of 500 ppm to improve rhizome development and sprouting success, while also favoring river sand over sawdust as the preferred sprouting medium. Future research should investigate the potential of utilizing single-node cuttings to enhance multiplication rates and decrease input costs. Farmers are encouraged to assess the scalability of these methods in various field conditions to optimize yield and adaptability before commercial implementation. If these practices are validated, they could significantly enhance productivity and profitability in arrowroot farming.

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Conflict of Interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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