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Seaweed-Based Dripping Stimulates Root Growth of Dragon Fruit (*Hylocereus undatus* [Haw.] Britton & Rose) Stem Cuttings

(Titisan Berasaskan Rumpai Laut Merangsang Pertumbuhan Akar Keratan Batang Buah Naga (*Hylocereus undatus* [Haw.] Britton & Rose))

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ABSTRACT

Developing a solid root system is essential in dragon fruit propagation not only for securing the succulent stem but also for facilitating the absorption of water and essential minerals from the soil. However, dragon fruit stem cuttings normally develop good root system for about 4-6 months after planting. There are commercially available growth hormones which hasten rooting, but these are relatively expensive. Hence, alternative hormones from natural materials that possess the ability to stimulate rooting are extensively explored. The efficacy of seaweed-based drippings (SD) as potential rooting bio-stimulant for dragon fruit cuttings were evaluated under nursery condition. Branch cuttings (30 cm long) were soaked at 6, 12 and 18 h at the rate of 50 mL, 100 mL and 150 mL SD per liter of water (H_2O), with H_2O, and ANAA (5 mL/L of H_2O) served as positive and negative control treatments, respectively. There were 18 cuttings in each experimental units, replicated thrice and arranged in a 3 × 5 Completely Randomized Design (CRD). Results showed that 12 h soaking initiated more and longer roots and shoots. In addition, it appeared that the application of a solution containing SD at 100 mL/L of H_20 resulted in the development of numerous and longer roots and shoots, a larger number of lateral roots, and a greater root-shoot ratio than other treatments. Furthermore, application of SD at 100 mL/L of H_20 through dipping for 12 h developed more lateral roots compared to other treatment combinations. In conclusion, it can be inferred that the presence of phytohormones, such as auxins, in seaweed concentrates has the potential to effectively stimulate root formation in pitaya.

Keywords: Asexual propagation; branch cuttings; pitaya; rooting hormone; seaweed drippings

ABSTRAK

Mewujudkan sistem akar yang kukuh adalah penting dalam pembiakan buah naga bukan sahaja untuk menjamin batang sukulen tetapi juga untuk memudahkan penyerapan air dan mineral penting daripada tanah. Walau bagaimanapun, keratan batang buah naga biasanya membentuk sistem akar yang baik selama 4-6 bulan selepas ditanam. Terdapat hormon pertumbuhan yang boleh didapati secara komersial yang mempercepatkan pengakaran, tetapi ini agak mahal. Oleh itu, hormon alternatif daripada bahan semula jadi yang mempunyai keupayaan untuk merangsang perakaran diterokai secara meluas. Keberkesanan titisan berasaskan rumpai laut (SD) sebagai bio-stimulan pengakaran yang berpotensi untuk keratan buah naga dinilai di peringkat nurseri. Keratan batang (30 cm panjang) direndam selama 6, 12 dan 18 jam pada kadar SD 50 mL, 100 mL dan 150 mL bagi setiap liter air (H_2O) dengan H_2O dan ANAA (5 mL/L H_2O) masing-masing berfungsi sebagai rawatan kawalan positif dan negatif. Terdapat 18 keratan dalam setiap unit uji kaji, diulang tiga kali dan disusun dalam Reka Bentuk Rawak Penuh (CRD) 3 × 5. Keputusan menunjukkan bahawa 12 jam perendaman mengeluarkan akar dan pucuk yang lebih banyak dan panjang. Selain itu, penggunaan larutan yang mengandungi SD pada 100 mL/L H_20 menghasilkan akar dan pucuk yang banyak dan lebih panjang, bilangan akar lateral yang lebih banyak dan nisbah pucuk-akar yang lebih tinggi daripada rawatan lain. Tambahan pula, penggunaan SD pada 100 mL/L H_20 melalui pencelupan selama 12 jam menghasilkan lebih banyak akar lateral berbanding gabungan rawatan lain. Sebagai kesimpulan, boleh disimpulkan bahawa kehadiran fitohormon, seperti auksin dalam pati rumpui laut mempunyai potensi berkesan untuk merangsang pembentukan akar dalam pitaya.

Kata kunci: Hormon pengakaran; keratan batang; pembiakan aseks; pitaya; titisan rumpai laut

Introduction

Dragon fruit or pitaya (*Hylocereus* spp.) is among the most attractive exotic fruits in the world (Mori et al. 2023). In the Philippines, dragon fruit production is considered a profitable enterprise and a promising means of raising the income of farmers. The country entered the export market when more than 600 kg fruits from one of farm in the province of Ilocos Norte was shipped to British Columbia in Canada for the first time in August 2016 through fruit importer Pahoa Produce (Eusebio & Alaban 2018). Since then, the production areas of the country have increased significantly due to the uprising popularity of this interesting and colorful fruit for the last six years. In fact, as of 2017, the country's total area planted to dragon fruit is 450 ha from 182 ha in 2012 (PSA 2018). However, the supply of dragon fruit in the market still comes short as compared to the increasing demand, although remarkable feat was experienced (Nguyen et al. 2019).

Dragon fruit plants are a fast-growing, terrestrial, epiphytic cactus with succulent stems that can grow up to 20 feet in height. The fruit is coated in green-tipped, bright pink to crimson overlapping scales, thus the name 'Dragon fruit'. It has a thin peel that protects a big mass of sweet-tasting white or crimson pulp with little black seeds inside (Ecosystems Research and Development Bureau 2013). In terms of production, plant propagation is one of the most important steps to support the availability of dragon fruit planting materials. Obtaining high quality, disease-free, true-to-type planting materials, and high survival rates in the field were just a few of the major problems in dragon fruit cultivation (Singh 2010; Vinodh & Sarmah 2023). Dragon fruit can be propagated either seeds or cuttings (Vinodh & Sarmah 2023). The seed propagation method is very simple, but seeds are not true-to-type due to cross-pollination and seeds can only be stored and maintained its viability for about 28 days (Andrade, Oliveira & Martins 2005). Hence, propagation through cutting is preferred as it enables the cuttings to be planted in a suitable potting media and containers for rooting, eventually develop a robust root system, and produce identical quality characteristics to parent material (Seran & Thiresh 2015). However, growth varies from the part of the branch, the cuttings are obtained due to availability of auxin. Cuttings obtained from young plants easily performs cell division which eventually form primordial roots than older plants due to reduced phenol content which functions as a cofactor (Sulichantini et al. 2014). Therefore, branch cuttings have been used and proven to produce homogenous growth in relatively large quantity (Hardjadinata 2010).

In addition to obtaining plant material that retains its original characteristics, it is essential to have a solid root system. Low quality planting material such as cuttings with poor root system can reduce the amount of production and longer fruiting time (Dachlan et al. 2020). Generally, dragon fruit cuttings proliferate its roots and develop a good root system for about 4-6 months after planting (Crane & Balerdi 2004). Roots play a crucial role in the growth and development performance of the dragon fruit cuttings. It functions as anchorage of the succulent from the ground as it grows and absorbs water and dissolved minerals from the soil. The growth and development of the planting materials will be determined on how effective and established the root system (Fitter 2002; Srikanth et al. 2016). Root formation and establishment are very important before planting the cuttings in the field. Because it is responsible for the absorption and channelling soil nutrients for the plant growth and development (Srikanth et al. 2016).

Plant growth hormones such as Indole-3-acetic acid (IAA) and Indole-3-butyric acid (IBA) were proven effective in stimulating the rapid root development of plant cuttings. However, these phytohormones are becoming difficult and are relatively expensive (Shah et al. 2002). Hence, there is the need to propagate with alternative rooting hormones that support the rooting of cuttings (Rajan & Singh 2021). Alternative hormones are natural materials that possess the ability to stimulate the rooting of cuttings and are deemed suitable substitutes to synthetic hormones such as auxins, cytokinins, and gibberellins which are essential and popular rooting hormones (Shield 2012). Examples of alternative hormones used are honey, nut water, willow tea, aspirin, moringa extract, and saliva (Rajan & Singh 2021; Shield 2012).

Interestingly, organic inputs for agriculture use have enticed the agricultural sector and researchers due to its effect on the growth and yield performance of horticultural crops. Hence, various entities had worked on developing effective organic inputs such as bio-fertilizers from plant wastes or materials to address the need of the industry. Hence, a seaweed-based bio-fertilizer derived from the extracts or drippings of a species of red alga (*Kappaphycus alvarezii*) was developed. This has been demonstrated to have a positive impact on the growth and yield performance of several crops. Nitrogen, phosphorus, potassium, calcium, magnesium, copper, zinc, iron, and manganese are all found in the drippings of the *Kappaphycus* seaweed, which contribute to soil fertility (DOST-PCAARRD 2016). Furthermore, due to the presence of various plant growth-stimulating chemicals (Khan et al. 2009), such as auxin, cytokinin, and gibberellins, seaweed and seaweed-derived products have been widely used as amendments in agricultural production systems as cited by Shehata et al. (2011).

Furthermore, treatment of cuttings though soaking in a rooting solution influence adventitious rooting and shoot growth (Singh & Chauhan 2020). In Song et al.'s (2001) study, the most favorable rooting results were achieved by soaking the base of the cuttings in a solution containing 150 ppm of either IBA or NAA for a duration of 24 h. This was observed in four grape varieties resulting from crosses involving *Vitis amurensis*. Similarly, Patil et al. (2001) found that soaking the cuttings for a shorter duration, specifically 6 h, in solutions containing either IBA (100 ppm) or NAA (100 ppm) yielded the highest survival percentages, which were 86.33% and 76.00%, respectively. This outcome was observed in the grape cultivars 'Tas-A-Ganesh' and 'Kismish Chorny'. Furthermore, according to the findings of Garande et al. (2002), a more favorable sprouting percentage was reported when the cuttings were dipped in IBA at a concentration of 1500 ppm for a duration of 30 s. This was observed in the grape rootstocks 'Dogridge' and 'Salt Creek'.

Planting materials must be of good quality and vigorous to expand the dragon fruit production area and promote the use of organic inputs. Hence, this study hypothesized that seaweed-based drippings would influence the roots of dragon fruit, based on the effect of organic foliar fertilizer obtained from seaweed drippings on plants. This research was carried out to see if seaweed drippings may be used as a rooting bio-stimulant for dragon fruit and investigate if a seaweed dripping could improve the rooting efficiency of dragon fruit branch cuttings under nursery condition.

Materials and Methods

The study was conducted at the nursery area of Southern Philippines Agri-Business and Marine and Aquatic School of Technology (SPAMAST), Buhangin Campus, Buhangin, Malita, Davao Occidental from March to June 2020. An established nursery structure (60 ft. length/width × 30 ft. length/width) was built for artificial shading of dragon fruit cuttings. The roof was made of UV plastic film (100 µm thick) which filters direct heat of the sun and heavy rainfall. Sides were covered with black shade net mesh allowing the air to pass through and prevent stray animals from coming in. On the other hand, dragon fruit branch cuttings were raised in the nursery and were planted in polyethylene bags for evaluation on its rooting performance for 90 days after planting with 15 days interval.

Experimental Design and Treatments

This study was a two-factorial (3 × 5) experiment laid out in a Completely Randomized Design (CRD) with Factor A as soaking (S) time (S1=6 h, S2=12 h, and S3=18 h) and Factor B as levels (L) of SD (L1= H_2O ; L2= ANAA at 5 mL/L H_2O ; L3= 50 mL/ L H_2O; L4= 100 mL/L H_2O; and L5=150 mL/L H_2O). There were 15 treatment combinations and were replicated three times. There were 18 branch cuttings per replicate which accounted for a total of 810 branch cuttings used in this study.

Sourcing and Selection of Dragon Fruit Cuttings

Branch cuttings of dragon fruit were used and obtained from a healthy mother plant collected early in the morning at Barbiera Farm, Hagonoy, Davao del Sur, Philippines. Each cuttings have similar sizes and measure 30 cm long in the middle portion of each branch. After selection of branch cuttings, a slanting cut was made at the branch base of the dragon fruit cuttings (Figure 1). Cuttings were wrapped with paper to keep the thorns from penetrating on the other cuttings during transport to the nursery.

Soil media used in potting was a combination of garden soil, carbonized rice hull and vermicast in a 1:1:1 ratio. Garden soil was soil sterilized for 4 h and cooled down before mixing to other soil media. The mixed soil was then transferred to a black polyethylene bag (5 inches length × 5 inches width × 8 inches height).

Soil Preparation and Potting

Preparation and Application of Treatments

KD Foliar fertilizer, a product registered by the Philippines' Fertilizers and Pesticides Authority (PPA) was used which was developed by the Southern Philippines Agri-Business and Marine and Aquatic School of Technology (SPAMAST). The product contains nitrogen (0.14%), phosphorous (1.14%), potassium (3.25%), calcium (0.018%), magnesium (0.041%), copper (112.50 ppm), zinc (50 ppm), and iron (50 ppm). Different levels of seaweed drippings were prepared on a container based on treatments identified in per liter of water.

FIGURE 1. Slanting cut at the branch base of the dragon fruit cuttings used in the study

After transporting from the farm to the experimental site, dragon fruit cuttings undergone curing process for 1 week (7 days) allowing the cut portion to heal. This process could also lead to dehydration of cuttings thus absorption of water fastened. After curing, prepared cuttings were soaked in the different treatments of seaweed drippings. Cuttings were soaked into the required concentrations per liter of water within 6, 12, and 18 h in a container. Each container contains 18 samples of dragon fruit cuttings and was kept in an ordinary room condition.

After soaking, cuttings were dipped in a fungicide solution within 2-3 s before planting. This will help to hinder fungal infection from penetrating wounded part. Treated cuttings were then planted in prepared planting medium with a depth of 2-3 inches (Figure 2). A foot-long bamboo stick was used as a support for the cuttings.

Planted cuttings on polyethylene bags were arranged randomly in the nursery area based on the treatments employed. These experimental samples were watered twice a week during hot dry condition. Common weeds on the nursery area were uprooted manually.

DATA GATHERED

Survival rate, number of roots, root length (cm), number of lateral roots, number of shoots, shoot length (cm) and root-shoot ratio were gathered appropriately with 15 days interval from the day of planting. Destructive sampling was used for parameters involving roots. The survival rate (%) was obtained by counting the number of cuttings survived at day 15 from planting up to day 90. This was calculated by using the formula: (number of plants survived/total number of test plants) × 100. For the number of roots per cutting, three sample plants per experimental unit were uprooted and the primary roots were counted during each period of observation and collection of data. The length of the primary roots of each sample was measured. This was measured from the tip of the root base to the tip of the longest root (cm). The number of lateral roots were determined by counting the lateral roots of three sample plants per experimental unit. On the other hand, the number of shoots proliferated from the dragon fruit cuttings of each treatment planted was counted. The length of longest shoot (cm) was gathered by measuring the longest shoot that grows from the mother plant for each treatment. For the root-shoot ratio, the sample plants were cut into two parts, the root, and the top. Afterwards, samples were placed inside the oven drier at 65 degrees centigrade. After drying, the dry matter of the root and top portions were weighed separately. The formula below was used to determine the root-shoot ratio:

$$\text{Root:Shoot} = \frac{\text{Dry weight for roots}}{\text{Dry weight for top of plant}}$$

STATISTICAL ANALYSIS

The data were analyzed using Analysis of Variance (ANOVA). The difference among the treatment means of significant results were compared using the Tukey's or Honest Significant Difference at 5% level of significance using Statistical Tool for Agricultural Research (STAR).

RESULTS AND DISCUSSION

SURVIVAL RATE (%)

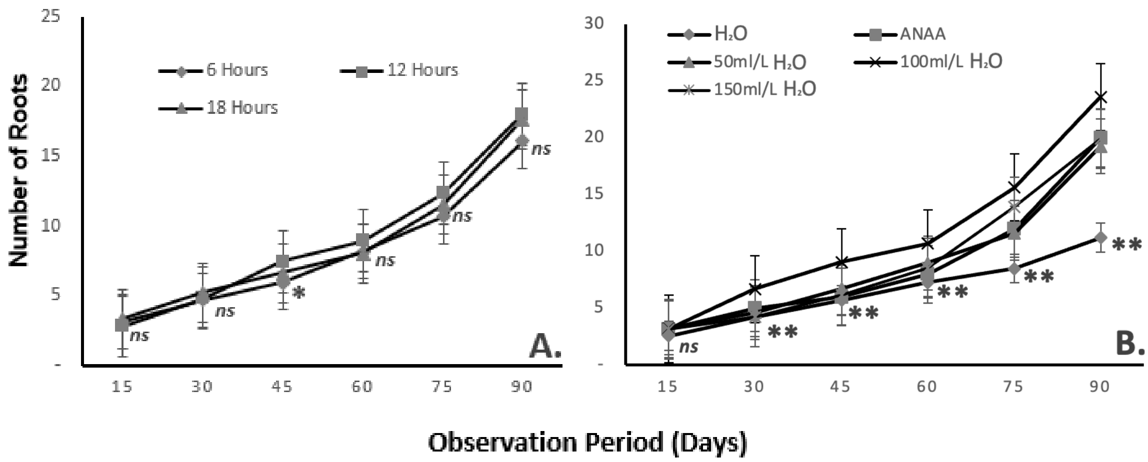
One of the indications of a successful stem cutting propagation is based on its capacity to survive. The results on the survival rate (expressed in percentage) of dragon fruit cuttings applied with different levels of seaweed-based dripping at various soaking time showed comparable results among treatments as well as on the interaction effects of the two factors being tested. It appeared that the treatments failed to show significant differences on the survivability of dragon fruit cuttings under nursery condition throughout its observation period. Results further indicate that dragon fruit stem

FIGURE 2. Planting of treated dragon fruit cuttings on polyethylene bags

cuttings can survive propagation under nursery condition with or without exogenous application of plant growth regulator. According to Le Bellec and Judith (2002), nearly 90% of dragon fruit cuttings are likely to survive and initiate root growth during propagation, provided that these cuttings are sourced from a healthy mother plant measuring at least 30-40 cm in length. They also underscored that a higher survival rate can be attained when the rooting medium is both sterile and well-drained, ensuring ample aeration, while also retaining sufficient moisture to avoid frequent watering. Moreover, the environmental conditions in the experimental area play a crucial role in promoting a higher survival rate for dragon fruit cuttings, as they enable the provision of adequate light-a key requirement for the plant's photosynthesis and food production process (Landi et al. 2020; Paradiso & Proietti 2022). Conversely, the cutting materials utilized in this study were sourced from the branches of young dragon fruit plants. Sulichantini et al. (2014) elucidated that cuttings obtained from young plants exhibit a greater propensity for cell division and the formation of primordial roots compared to cuttings obtained from older plants. This disparity is attributed to the lower phenol content in younger plants, which serves as a cofactor in the process. Consequently, dragon fruit cuttings in this study exhibited survival irrespective of the treatments administered.

NUMBER OF ROOTS

It is widely recognized that roots not only provide structural support for plants but also play a vital role in absorbing essential water and nutrients from the soil, which are crucial for the survival, growth, and development of plants. Figure 3 illustrates the number of roots of dragon fruit cuttings initiated under nursery condition as influenced by different soaking time and levels of seaweed-based dripping. Based on the statistical analysis, results showed that soaking time and levels of seaweed drippings showed significant result on the number of initiated roots. On soaking duration, data shows that dragon fruit cuttings soaked for 12 h had a greater number of roots initiated compared to cuttings soaked for 6 and 18 h as evident on day 45 of observation. On the other hand, the levels of seaweed drippings showed remarkable effect on the number of roots initiated per cutting. Utilization of seaweed-based drippings with concentration level of 100 mL per liter of water consistently produced more roots compared to other levels. This manifestation was observed from day 30 until day 90. However, on day 60, dragon fruit cuttings applied with 50 mL of seaweed drippings showed comparable result to 100 mL concentration. Similarly, 150 mL concentration also showed comparable result to 100 mL concentration as evident on day 75 of observation. In



ns= denotes not significant; *= denotes significant; ** = denotes highly significant

FIGURE 3. Number of roots of dragon fruit cuttings as influenced by soaking time (A) and levels of seaweed-based drippings (B)

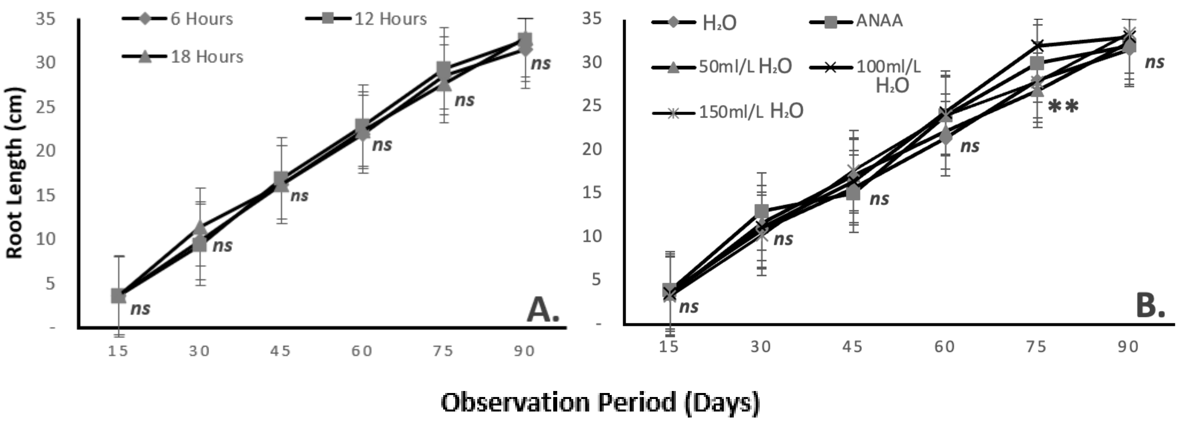
terms of the interaction effects of different soaking time and levels of seaweed-based drippings, results failed to show any significant difference on the number of roots initiated from day 15 until day 90 of observation.

These results manifest that the efficacy of seaweed extracts in stimulating plant growth, aligning with their classification as biofertilizers (Zodape 2001). It is worth noting that biofertilizers are considered a subset of bio-stimulants (Du Jardin 2015). Seaweed extracts have been a subject of experimentation to investigate their bio-stimulant effects in both plant science and agriculture (Panda et al. 2012; Spann & Little 2011). Seaweed extracts containing auxins, such as seaweed drippings, significantly contribute to enhancing photosynthetic activity and the production of photo assimilates. Consequently, the increased sugar levels observed during rooting are associated with reduced leaf senescence, higher survival rates, enhanced root development, and improved nutrient uptake in cuttings (Krajnc, Turinel & Ivancic 2013). Additionally, As the concentration of auxins rose, there was a consistent increase in the percentage of rooting, the quantity of primary roots, the total length of primary roots, and the length of the longest primary root (Dessalegn & Reddy 2003). The application of seaweed extracts to maize roots exhibited a stimulating impact on root growth in several tests, with a response comparable to that of auxin, an important hormone known for promoting root growth (Jeannin, Lescure & Morot-Gaudry 1991).

Seaweed extracts encompass a diverse blend of polysaccharides, organic acids, vitamins, plant hormones, and mineral elements, among various other chemical constituents (La Torre et al. 2016). They serve as a rich source of multiple nutrients that can enhance a plant's well-being by promoting various facets of growth and development. This research aligns with the findings of other studies conducted by different researchers (Le Bellec & Judith 2002; Pramanick et al. 2016). This phenomenon can be attributed to the presence of bioactive compounds, as well as micro- and macronutrients, within seaweed extracts. These components have the potential to expedite plant growth and, consequently, stimulate the initiation of root development (Madende & Hayes 2020). Several marine algae varieties, whether occurring naturally or under commercial cultivation, are believed to harbor chemical compounds that exhibit similar activity to cytokinins, auxins, and gibberellins (Crouch & van Staden 1993). These compounds have demonstrated the capability to enhance root growth by stimulating protein synthesis, fostering cell division, and facilitating the mobilization of essential nutrients crucial for growth (Patier et al. 1993).

ROOT LENGTH

Having a deep root system is an advantage in growth and development of cuttings. Aside from creating a stable ground for development of the plant, roots can obtain available soil nutrients and water on the deep soil growing plant. Figures 4 and 5 demonstrate the data on



ns= denotes not significant; **= denotes highly significant

FIGURE 4. Root length of dragon fruit cuttings as influenced by soaking time (A) and levels of seaweed-based drippings (B)

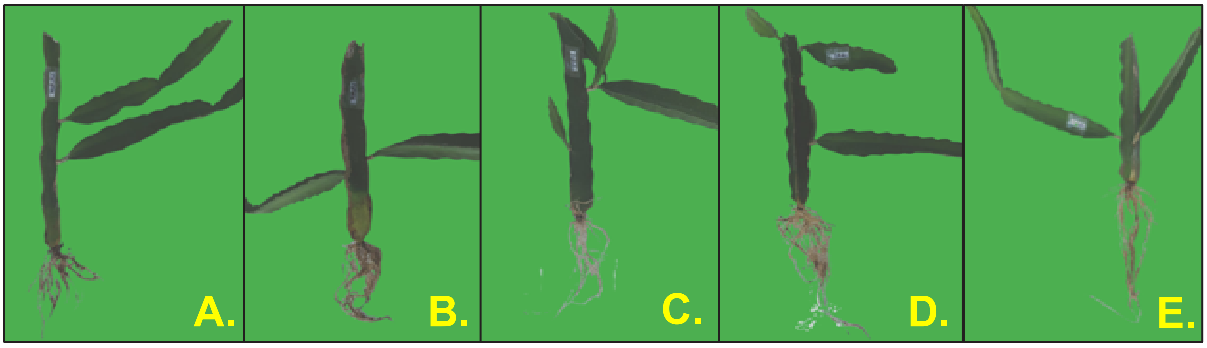


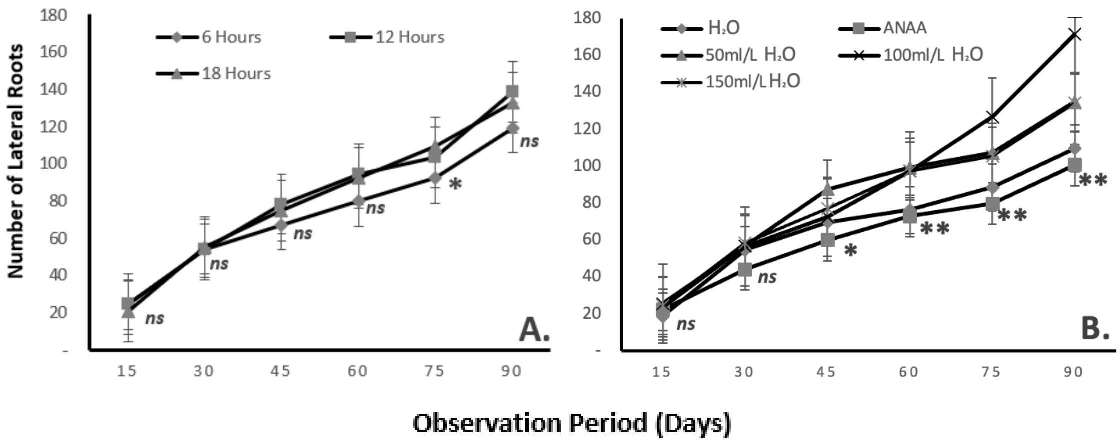
FIGURE 5. Roots of dragon fruit cuttings developed in response to levels of seaweed-based drippings or SD (A–H_2O, B–ANAA at 5 mL/L H_2O, C–50 mL SD, D–100 mL SD, E–150 mL SD) at 75 days after planting

the length of longest roots of dragon fruit cuttings as influenced by soaking time and different levels of seaweed drippings under nursery condition. Statistical analysis of these data shows that different levels of seaweed drippings significantly affect the length of roots while the other factors are insignificant. Subjecting the dragon fruit cuttings to seaweed drippings showed comparable results among different soaking durations (6, 12 and 18 h). However, on the levels of seaweed drippings, it appeared that cuttings dipped at 100 mL of seaweed drippings obtained the longest length of root as compared to dragon fruit cuttings treated with 50 mL and 150 mL, as well as on ANAA and water at day 75 of observation. Furthermore, the interaction effects of these two factors showed no significant differences throughout the whole observation period.

Based on the results of the experiment, it was apparent that cuttings soaked in seaweed drippings at 100 mL/L water significantly contributed not only on the number of roots initiated but on the root length as well. This is most likely because the seaweed extract contains micronutrients, auxins, cytokinins, and other growth-promoting chemicals (Spinelli et al. 2009). Numerous studies have underscored the pivotal role of these phytohormones in augmenting cell size and division, and their synergistic action when used in conjunction. Auxins, for instance, play a significant role in fostering root development in plants. Additionally, seaweed extract contains carbohydrates, predominantly oligosaccharides, which can potentially impact plant growth by modulating gene expression and influencing nitrogen absorption and basic metabolism (Abd El-Mohdy 2017). Recent research findings also indicate that seaweed treatment leads to an increase in root length. This effect can be ascribed to the induction of auxin-related genes by alginate oligosaccharides, resulting in elevated auxin concentrations, which, in turn, facilitate root development and elongation (Zhang et al. 2014). Moreover, the application of cuttings triggers the rapid hydrolysis of polysaccharides within the cuttings, converting them into physiologically active sugars. These sugars provide energy through respiratory processes and contribute to the swift elongation of meristematic tissues, ultimately leading to the initiation of longer roots (Siddiqua et al. 2018).

NUMBER OF LATERAL ROOTS

Lateral roots help to secure the plant in the soil, increase water uptake, and make the extraction of nutrients necessary for the plant's growth and development easier (Santos Teixeira & Ten Tusscher 2019). It also expands a plant's root system's surface area. Figure 6 shows the data trend on the number of lateral roots of dragon fruit cuttings as influenced by soaking time and different levels of seaweed drippings under nursery condition. Based on the analysis of variance, results showed that the soaking time and levels of seaweed drippings as well as the interaction effects of these two factors showed significant differences. Soaking of dragon fruit cuttings for 18 h have greater number of lateral roots initiated as evident on day 75 of observation. On the other hand, it was evident that 50 mL/L water of seaweed drippings show highest number of lateral roots initiated on day 45 onwards.



ns= denotes not significant; *= denotes significant; **= denotes highly significant

FIGURE 6. Number of lateral roots of dragon fruit cuttings as influenced by soaking time (A) and levels of seaweed-based drippings (B)

TABLE 1. Interaction effects on the number of lateral roots and number of shoots of dragon fruit cuttings as influenced by soaking time and levels of seaweed-based drippings

Treatments	No. of Lateral Roots @75 Days of observation *	Number of Shoots @90 Days of observation *
6 h + H_2O Alone	74.97c	3.33b
6 h + ANAA	84.92bc	3.67b
6 h + SD 50 mL/L H_2O	95.17abc	3.33b
6 h + SD 100 mL/L H_2O	108.17abc	3.58b
6 h + SD 150 mL/L H_2O	97.50ab	3.58b
12 h + H_2O Alone	99.58bc	3.17bc
12 h + ANAA	75.67c	3.33b
12 h + SD 50 mL/L H_2O	93.17bc	3.00bc
12 h + SD 100 mL/L H_2O	140.33a	5.23a
12 h + SD 150 mL/L H_2O	109.25b	2.67c
18 h + H_2O Alone	91.33bc	2.83c
18 h + ANAA	78.92c	2.50c
18 h + SD 50 mL/L H_2O	133.33a	2.92c
18 h + SD 100 mL/L H_2O	131.75a	5.67a
18 h + SD 150 mL/L H_2O	109.25b	3.50b
CV (%)	12.95	14.44

Means having common letter superscripts are not significantly different at 5% level by HSD test; *- denotes significant

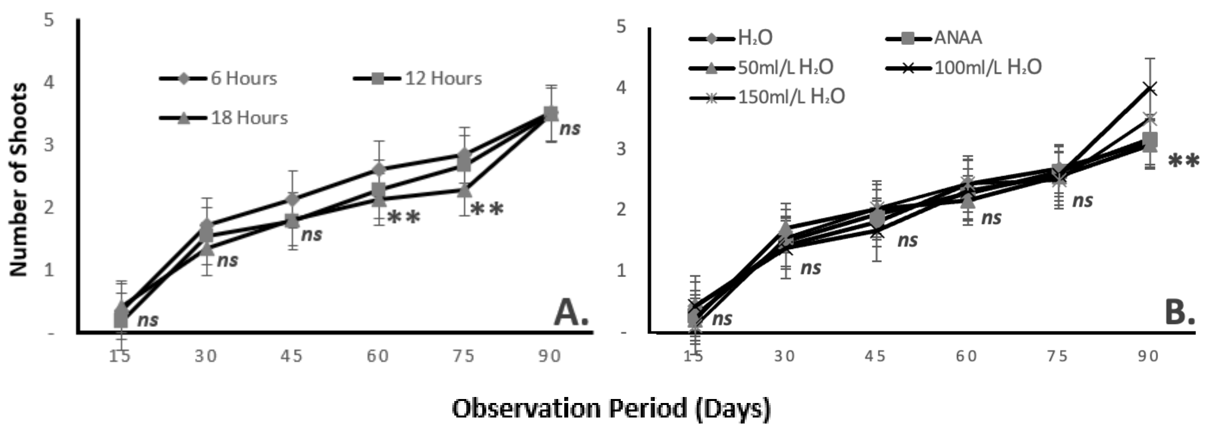
However, on the succeeding observation period (day 60 and day 75), 50 mL levels showed comparable results to 100 mL and 150 mL level. Ultimately, on day 75 and day 90, dragon fruit cuttings applied with 100 mL level of SD emerged with the highest number of lateral roots compared with other treatments. On the aspect of interaction effects, it appears that dragon fruit cuttings dipped with 6, 12 and 18 h combined with 50, 100 and 150 mL of SD per liter of water manifested comparable results as to the number of lateral roots as evident on day 75 of observation (Table 1). Although numerically, it can be noticed that cuttings soaked to SD at 100 mL/L water for 12 h has the highest number of lateral roots at 140.33 cm compared to other treatment combinations.

In general, bio-stimulants can exert an influence on root development by encouraging the production of lateral roots and augmenting the overall volume of the root system (Mancuso et al. 2006; Vernieri et al. 2005). The presence of endogenous auxins and other compounds within these extracts may contribute to the promotion of a more robust root system (Crouch et al. 1992). Lateral roots emerge as a result of cell proliferation in the pericycle, the layer of cells encircling the central vascular cylinder.

This proliferation leads to the formation of additional cell layers that penetrate the outer cell layers of the primary root, ultimately giving rise to a secondary root meristem (Hobbie 2003). Multiple lines of evidence suggest that the transfer of auxin plays a pivotal role in stimulating the growth of lateral roots. Elevated auxin levels in the roots lead to an increase in lateral root development. Techniques such as mutations, transgenic expression, and the external application of auxin to the entire root or the severed root's stump have all been employed to elevate auxin levels. Conversely, reduced auxin levels or reduced responsiveness to auxin in the primary root result in fewer lateral roots. Techniques like inhibiting polar auxin transport at the root–shoot junction or inducing mutations to decrease auxin responsiveness have been utilized to achieve this effect. It appears that auxin stimulates pericycle cells at the outset of lateral root formation and may also play a role later in the outgrowth process (Hobbie 2003). Seaweed products, such as seaweed drippings, possess growth-promoting properties. Plant hormones that facilitate plant growth and development, including cytokinins, auxins, and compounds related to abscisic acid (ABA), induce alterations in cellular metabolism within treated plants, resulting in increased growth and crop yield (Ordög et al. 2004). Furthermore, when maize was treated with seaweed extract during the early stages of growth, a robust stimulation of root growth was observed, with a response comparable to that of auxin (Jeannin, Lescure & Morot-Gaudry 1991). When using a commercial seaweed extract like Kelpak, a 2% increase in root weight was noted compared to the control group.

NUMBER OF SHOOTS

Shoots are important in dragon fruit and other succulents since this organ is the site of photosynthetic activities of the plants. Illustrated in Figure 7 are the number of shoots proliferated from dragon fruit cuttings as influenced by



ns= denotes not significant; *= denotes highly significant

FIGURE 7. Number of shoots of dragon fruit cuttings as influenced by soaking time (A) and levels of seaweed-based drippings (B)

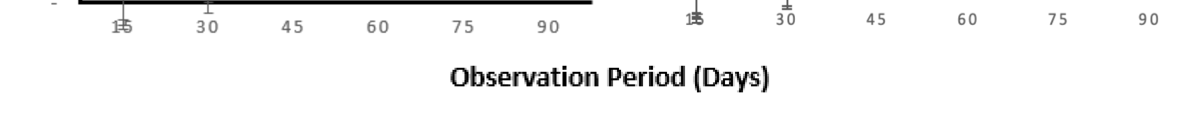
soaking time and different levels of seaweed drippings under nursery condition. Based on the analysis of variance, it showed that factor A (soaking time) and factor B (levels of seaweed-based dripping) as well as its interaction effects has significantly influenced the number of shoots.

Dragon fruit cuttings soaked for about 6 h showed the highest number of shoots proliferated on day 60 and day 75 of observation. However, this treatment was comparable with 12 h soaking on day 75. On the other hand, it was evident that dragon fruit cuttings treated with 100 mL of seaweed drippings developed more shoots significantly as compared to other levels on day 90 of observation. In terms of the interaction effects of the two factors, it appears that dragon fruit cuttings soaked at 12 and 18 h combined with 100 mL concentration of seaweed drippings developed more shoots compared to other treatment combinations. This manifestation was observed on day 90 of observation (Table 1).

The results apparently showed that the treatments imposed influenced the initiation of shoots of dragon fruit cuttings. This holds significant importance because the initiation of shoots serves as an indicator that an ample quantity of available nutrients has been absorbed and effectively utilized by the plants. This phenomenon could be attributed to the presence of seaweed extracts rich in auxins, which are recognized for their capacity to stimulate root regeneration. They achieve this by promoting processes such as hydrolysis, mobilization, and the utilization of nutritional reserves in the areas where root and shoot formation occur (Chen et al. 2021). The application of seaweed during the early stages led to a substantial increase in the plant's chlorophyll content (Mukherjee & Patel 2020). The rise in chlorophyll content can be attributed to a decrease in chlorophyll breakdown, which may be partly due to the presence of betaines found in the seaweed extract (Whapham et al. 1993). Glycine betaine, for instance, has been observed to postpone the loss of photosynthetic activity by inhibiting chlorophyll degradation under storage conditions in isolated chloroplasts (Genard 1991). Previous studies have consistently shown the growth-enhancing effects of seaweed extract, particularly extracts derived from *A. nodosum*, on plants compared to control groups. Plants treated with seaweed extract exhibited a more advanced developmental stage when compared to untreated plants, despite potential variations in mineral content. It is important to note that while bio-stimulants like seaweed extract may contain varying mineral levels, they do not supply all the necessary nutrients to plants in the required quantities (Schmidt, Ervin & Zhang 2003). Nevertheless, their primary benefit lies in their ability to enhance the uptake of minerals by plant roots (Vernieri et al. 2005) and leaves (Mancuso et al. 2006).

LENGTH OF LONGEST SHOOT

While the shoot is unquestionably significant, the length of the shoot also holds significance. Longer shoots could develop more photosynthetic activity which



ns= denotes not significant; *= denotes significant; **= denotes highly significant

FIGURE 8. Shoot length of dragon fruit cuttings as influenced by soaking time (A) and levels of seaweed-based drippings (B)

means more food reserves for the whole plant during its growth, maintenance, reproduction, and other processes requiring carbon resources (Skillman et al. 2011). Presented on Figure 8 is the length of shoots of dragon fruit cuttings as influenced by soaking time (Factor A) and levels of seaweed-based drippings (Factor B) under nursery condition. Results showed that both factors were statistically significant in influencing the length of the longest shoots of dragon fruit cutting while the interaction effect was insignificant.

In soaking time, dragon fruit cuttings soaked for 18 h shows the highest length of shoots from day 30 until day 45 of observation. However, on the succeeding days of observation (days 60, 75 and 90), dragon fruit cuttings soaked for 12 h obtained the highest length of shoot. On day 90, 12 h showed comparable result to 6 h soaking.

On the other hand, dragon fruit cuttings applied with 100 mL seaweed dripping concentration consistently showed the highest shoot length recorded for the longest shoot throughout the observation period. In terms of interaction effects of these two factors, no significant relationship was observed among the shoot length of dragon fruit cuttings. The length of shoots as showed on Figure 8 denotes that it could be influenced by seaweed drippings. This is probably because seaweeds are an important source of plant growth regulators, together with organic osmolytes, amino acids, mineral nutrients, vitamins, and vitamin precursors. Seaweed extracts have been noted to have beneficial effects on many crops. It was studied that a high cytokinin activity in a commercial seaweed extract, which was responsible for many of its effects (Anderson 2023). Seaweed extracts containing cytokinins play a regulatory role in various plant functions, which encompass cell division, protein and CO_2 metabolism, as well as the aging and senescence of leaves (Syõno & Torrey 1976). The utilization of seaweed extracts has demonstrated the capacity to improve plant growth and crop yield, promote root development, delay the aging process, and enhance resistance to environmental stresses like drought, salinity, and temperature fluctuations (Nabati, Schmidt & Parrish 1991). In a study by Atzmon and van Staden (1994), seedlings of *Pinus pinea* L. cultivated in plastic containers were treated with concentrated seaweed extract derived from *Ecklonia maxima.* Application to the shoots primarily contributed to an increase in overall plant weight, primarily due to enhanced shoot growth. This was evidenced by greater shoot length and weight, along with a reduction in the root-to-shoot ratio.

ROOT-SHOOT RATIO

Roots, stems, and leaves are functionally interconnected, and these three systems work together to uphold a constantly changing equilibrium in biomass. This equilibrium mirrors the proportional availability of above-ground resources (such as light and CO_2) in comparison to below-ground resources (including water and nutrients) (Poorter et al. 2012). The data presented in Table 2 shows the root:shoot ratio of dragon fruit cuttings as influenced by soaking time and levels of seaweed-based drippings under nursery condition. Statistical analysis of these data showed that the levels of seaweed-based drippings are significantly different among treatment while the differences on soaking time and interaction effects are insignificant. It was observed that dragon fruit cuttings treated with 100 mL seaweed-based drippings incur the highest root:shoot ratio among all the levels of seaweed drippings imposed.

As stated in the aforementioned discussions, seaweed extracts contain different nutrients and plant growth hormones like auxins that promote and enhance plant root growth and development. Roots allow a plant to absorb water and nutrients from the surrounding soil, and a healthy root system is key to a healthy plant. The root/shoot ratio is one measure to help you assess the overall health of your plants. The results showed that 100 mL/L water application of seaweed-based drippings on dragon fruit cuttings enhanced the root/shoot ratio (Table 2) compared to other levels of seaweed drippings. This pertains that, seaweed-based drippings enhanced root:shoot ratios and biomass accumulation of dragon fruit cuttings by stimulating root growth. In a similar study, wheat plants treated with a seaweed-based product known as Kelpak displayed an increase in the ratio of root mass to shoot mass. This observation suggests that the components present in the seaweed had a significant impact on the development of the root system (Nelson & van Staden 1986). The enhancement of the root system could be attributed to the presence of endogenous auxins and other compounds within the extracts. Additionally, research has shown that seaweed extracts can enhance the uptake of nutrients by plant roots (Crouch, Beckett & van Staden 1990). For instance, a study on soybeans reported a notable 15% increase in the uptake of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K) (Rathore et al. 2009). This improvement in nutrient absorption contributes to more efficient water and nutrient utilization by the root system, ultimately leading to enhanced overall plant growth and vigor.

TABLE 2. Root-shoot ration of dragon fruit cuttings as influenced by soaking time and levels of seaweed-based drippings

Treatments	Root dry weight (g/plant)	Shoot dry weight (g/plant)	Root-shoot ratio
Soaking time			ns
6 h	0.64	71.59	0.0108
12 h	1.15	102.52	0.0107
18 h	1.49	115.13	0.0111
Levels of seaweed-based drippings			**
H_2O	1.02	91.84	0.0084 [d]
ANAA	1.19	95.66	0.0094 [cd]
50 mL/L H_2O	0.93	89.70	0.0103 [cd]
100 mL/L H_2O	1.00	94.71	0.0146 [a]
150 mL/L H_2O	1.33	110.16	0.0116 [b]
CV (%)			11.06

Means having common letter superscripts are not significantly different at 5% level by HSD test; ns = denotes not significant; * = denotes significant; ** = denotes highly significant

CONCLUSIONS

The study's results underscore the efficacy of seaweed-based dripping in enhancing plant growth and development. Specifically, for dragon fruit, this approach shows potential as a rooting bio-stimulant. Regarding the soaking time, immersing dragon fruit cuttings in seaweed-based drippings for 12 h demonstrated better rooting performance. Additionally, the optimal level of seaweed-based dripping for enhanced rooting in dragon fruit stem cuttings was found to be 100 mL. Notably, the synergy between soaking time and seaweed dripping levels highlighted that a 12-h soak in 100 mL seaweed-based drippings fosters robust root and shoot growth. Given these compelling findings, it is recommended that to enhance rooting performance, enhance plant vigor, bolster resistance to environmental stresses, and expedite the propagation of dragon fruit stem cuttings, a 12-h soak in 100 mL/L seaweed-based drippings should be employed. Furthermore, extending the study to encompass the fruiting stage within a field environment is also advised for a comprehensive understanding of the effects of seaweed-based drippings.

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