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Pineapple Field Establishment Using Slips

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Abstract. **Slips are side-shoots or fruit with large crowns that grow from buds on the pineapple (*Ananas comosus* L.) peduncle. The slips are widely used for pineapple vegetative propagation when crowns are left attached to the fruit that is marketed. There is a difference between the two most popular low-acid pineapple hybrids grown worldwide. The 'Pineapple Research Institute 73-50' (CO-2, MD-1) slips develop few roots when planted compared with 'Pineapple Research Institute 73-114' (MD2). The slow rooting of 73-50 leads to slow field establishment and can extend the crop cycle. Our objective was to determine the cause of this reduced rooting and evaluate treatments to increase the rooting rate. Rooting trials in moist, coarse vermiculite showed that larger slips and green slips with red hues also had a greater number of roots compared with smaller slips and green or yellow slips. Delaying harvesting of the slips after the fruit were harvested also resulted in a greater number of roots. Treatments including components frequently used for rooting cuttings did not significantly increase root numbers. An exception was a tendency for slips treated with potassium nitrate to have greater rooting during some tests. We present data that support the conclusion that the poor root development is associated with the mechanical impedance of the root from the tightly affixed basal leaf bracts. Removal of the lower ten bracts can lead to greater root numbers. When the slip with the bracts removed was tightly wrapped in plastic wrap and masking tape, rooting was reduced. The sizing and selection of slips that are green with a red hue and collected as late as possible after fruit harvest had the best rooting response.**

Pineapple is normally propagated using crowns, slips (Fig. 1A), or, less commonly, shoots borne at any position on the plant stem (suckers). When pineapples are grown for processing (e.g., canning, fresh cut), there are sufficient crowns available for replanting fields. However, when pineapples are sold as fresh fruit, the crown is left attached, depriving the grower of that source for replanting. Genetic variations in the numbers of slips produced per plant exist between clones and cultivars (Py et al., 1987; Sanford and Fo, 1960). Although slips do occur on basal fruitlets, the slips used as propagules originate on the peduncle itself. Types and sources of vegetative propagules (slips) are kept separate because the weight, nutritional history, and development environment are believed to affect the time to establishment and optimum plant size for fruiting. Therefore, these factors have the potential to introduce variability into the field (Hepton and Bartholomew, 2003). The time from planting to harvest is primarily dependent on the weight of the propagule.

A shortage of planting material can occur when fruit are sold fresh, because the fruit is usually marketed with the crown. Most commercial clones of 'Smooth Cayenne' produce only one to two suckers per plant, and seldom more than three slips. Several techniques are available to speed the propagule production; these are used for cultivar and clone development or to replace planting material sold with the fruit. Slips and suckers can be large, with the size mostly determined by the length of time on the plant. Sorting the planting material by size is crucial to obtain plants of uniform size at the time of floral forcing to assure uniform fruit development, size, and maturation (Py et al., 1987). The root number is correlated with the slip weight, but this correlation is lost when slips from different fields are combined (Sanford and Fo, 1960), suggesting a significant variation in the rooting ability of slips caused by the environment, including fertilization, time after fruit harvest, delay in planting, and location. The maximum number of roots occurs ≈3 to 5 weeks after planting, but roots continue to grow in length (Sanford and Fo, 1960).

The low-acid hybrid used in Hawaii, 'Pineapple Research Institute (PRI) 73-50' (CO-2, MD-1; D30; Hawaiian Gold), produces numerous slips on the fruit peduncle (Taniguchi et al., 2008). The slips of this cultivar are slow to root, and this delays crop growth compared with that of other low-acid hybrids (PRI 73-114; MD2) (Table 1). Growers of ornamental bromeliads have also reported difficulty rooting some species, such as the epiphytic *Guzmania* spp. (David Fell, 2015 March, personal communication).

Slips are produced from buds in the axils of the floral bracts on the peduncle (Sanford and Fo, 1960) (Fig. 1A). The comma-shape slip contrasts with the straight stem of suckers and crowns. If slips are allowed to remain on the plant for a few months after fruit harvest, then they can grow to 250 to 450 g (Fig. 1B) and produce more numerous visible roots (Sanford and Fo, 1960). The club-shape stem that also occurs in slips has short internodes, with an axillary bud at each node (Krauss, 1949a, 1949b). Adventitious roots grow through the stem epidermis and vary in length from a few millimeters near the top of the slip to several centimeters at its base. Adventitious roots are produced from preformed root primordia in the stem (Fig. 1C). Krauss (1948) separated the roots into "soil" roots that develop at the base of the stem and form the underground root system and "axillary" roots, which form above the soil surface in the leaf axils. The axillary roots absorb both water and nutrients, facilitating the utilization of foliar-applied nutrients (Krauss, 1948). The main absorptive area of the root is in the unlignified white tissue of the root tip. Roots without white tissues at the root tips are not actively growing and are inefficient at absorbing water; the root tips may have been lost because of root rotting pathogens and nematode feeding.

Fruit yield is reduced because unquantified variations (size, physiological characteristics, and morphological characteristics) in planting material result in relatively large numbers of small plants that produce fruit of insufficient size to be of commercial value, both in the plant crop and the ratoon. Slips can be sorted based on volume (screw sorters) or density (air sorters). Neither of these methods accounts for the fact that slips of the same mass or volume can have greatly differing amounts of leaf area, possibly differing amounts of storage reserves, and certainly different stem diameters, resulting in greater or lesser numbers of root initials. There is no clear information about how these characteristics influence the rate of slip development or whether they have any effect on the yielding potential of the plant produced. The pineapple cultivar PRI 73-50 can produce 12 or more slips per plant, but it does not readily produce new roots when planted in the field. In comparison, the sibling of 'PRI 73-50', 'PRI 73-114' (Taniguchi et al., 2008), rarely produces more than three slips and readily produce new roots when planted. 'PRI 73-50' is regarded as being more suited for the cooler tropics and provide higher yield under these conditions (Taniguchi et al., 2008). However, its poor rooting leads to a delay in establishment, and excessive slip dehydration and transplanting "shock" delay establishment by 2 to 4 weeks. This limited rooting can lead to problems for the ratoon crop with an inadequate root system (Gowing and Klemmer, 1961). Our objectives were

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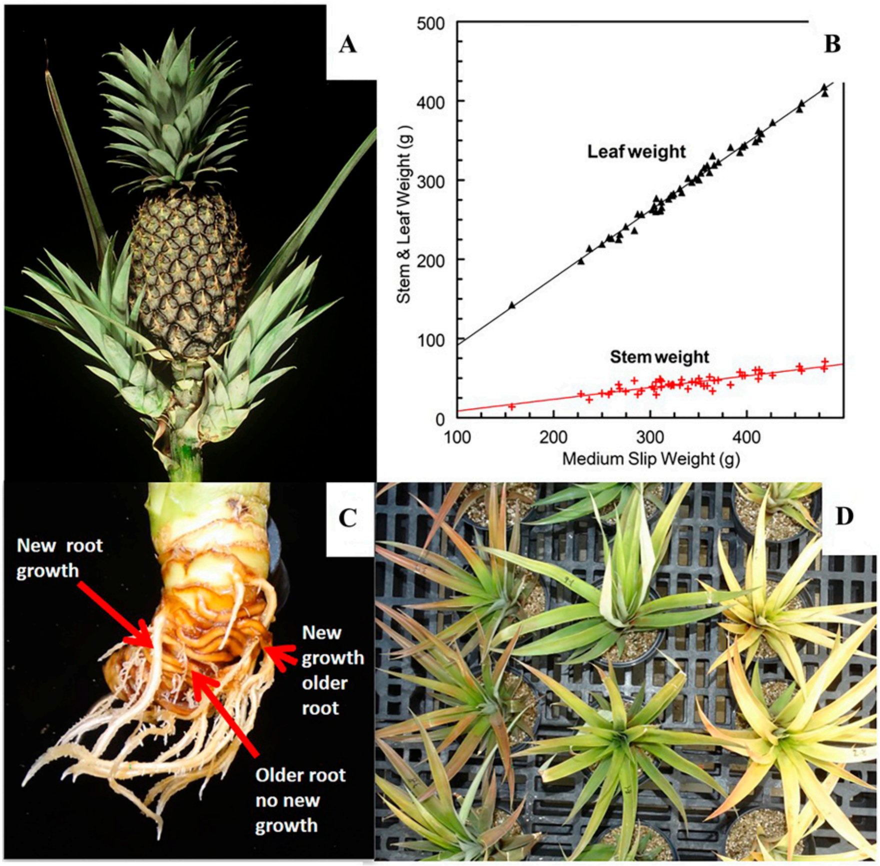

Fig. 1. Nature of slips used for pineapple propagation. (**A**) Slips are fruit-like crowns on the fruit peduncle. (**B**) The relationship found between the medium slip weight and leaf and stem weights. (**C**) Classification of types of roots on the slip base (Krauss, 1948), Type I are older suberized roots that did not grow when placed in damp vermiculite for 3 weeks. Type II are brown roots that grew from the end. Type III are new roots that arose from the slip stem. (**D**) Slip coloration from left to right: green with red hue and green and yellow slips.

to assess the rooting characteristics of 'PRI 73-50' slips, evaluate factors influencing root development, and identify treatments to enhance the root number and root growth after field planting.

Materials and Methods

The fruit peduncle-derived slips of 'PRI 73-50' and 'PRI 73-114' were harvested year-round from the fields of Dole Foods Inc. in Oahu, Hawaii. During the cultivar comparison tests, slips from both varieties were harvested on the same day. Unless otherwise indicated, all other tests were performed with 'PRI 73-50'. Harvest occurred unless otherwise indicated at a similar time as when commercial slips were harvested for new field plantings. Slips were harvested at intervals up to 10 weeks after fruit harvest from the ratoon that was not fertilized and had received adequate rainfall for growth. Slips were harvested with different sizes and leaf colors as required for individual experiments. After harvest, the slips were taken to the laboratory, allowed to dry for ≈4 d, and then sorted according to size and color. Commercially, slips are graded visually into three sizes: small, medium, and large. Only medium and large slips are used in field planting. Medium slips from the subjective grading for size weighed between 200 and 450 g; when separated into leaves plus bracts and stem, they showed greater increases in leaf and bract weights than in stem weights (Fig. 1B). Large slips generally weighed more than 450 g. The rooted slips of each treatment (same size and color) were evaluated each month to determine the seasonal differences in rooting ability.

Slips were placed in water in 250-mL jars during the earlier tests or coarse vermiculite in pots. Slips in water were maintained at 22 °C, with 12 h of dark and 12 h of fluorescent light (15 $\mu mol \cdot m^{-2} \cdot s^{-1}$). The slips held in water or treatment solutions to induce rooting during earlier tests were replenished as needed. Slips planted in coarse vermiculite (4–8 mm) in 5-inch pots after treatment were maintained in a glasshouse on campus using a completely randomized design. Treatments included chemical treatment comprising mainly inorganic salts or fertilizers, plant growth regulators, and physical treatments such bracts removal and trimming slip leaves, different irrigation frequencies, and growing media. The vermiculite was watered on Mondays, Wednesdays, and Fridays, unless otherwise indicated.

At 3 weeks after the experiment initiation, the slips were evaluated to assess the number of new roots and root lengths of all roots using a ruler. Slip stems and leaves were analyzed to evaluate the mineral element content by inductively coupled plasma mass spectrometry by the Agricultural Diagnostic Service Center on campus. Bract removal force was measured with a mechanical force gauge (LKG-14; Ametek Hunter Spring, Hatfield, PA) with a claw attachment that slid under the bract.

Each treatment generally had three replications of four or five slips each, and all experiments were duplicated with the same treatment of other experiments or repeated at least once. For the duplication, the results were not pooled. The root number and length were log-transformed before the analysis using the SAS GLM procedure; mean separation was performed using the Waller–Duncan test (SAS Institute Inc., Cary, NC).

Table 1. Variations in the number and average length of new roots of the two most common low-acid pineapple hybrids. Crowns and slips were maintained in water for 3 weeks; then, the root number and root length were evaluated.

Cultivar PRI	Treatment	Root number per slip	Root length (cm)
Test 1			
73-50	Crown (225 g)	0.8 b[i]	11.9 b
73-114	Crown (200 g)	37.8 a	57.1 a
Test 2			
73-50	Small slips (90 g)	2.1 b	9.2 b
73-50	Large slips (170 g)	8.5 ab	21.1 b
73-114	Small slips (75 g)	13.3 a	36.3 a
73-114	Large slips (150 g)	13.5 a	43.6 a
Prob > F	Cultivar	0.0002	<0.0001
	Size	0.0999	0.0074
	Cultivar × size	0.1176	0.5018

[i] Mean separation by the Duncan-Waller multiple range test. n = 12. $P < 0.05$.

Results

Types of slip root development. Three types of roots were recognized on the slips after allowing rooting to occur for 3 weeks. Type I were brown (suberized) roots under the lower bracts of the slip and wrapped around the stem (Fig. 1C). These roots were present at slip harvest and did not grow when placed in a moist environment. Type II were lighter brown at harvest and were also wrapped around the lower stem under the bracts. When placed in a moist environment, new root growth occurred at the tip of these type II roots, producing a white root with root hairs and some branching. Type III were new white roots that developed from the stem; they were the most numerous and longest when evaluated.

Varietal rooting differences. 'PRI 73-50' and 'PRI 73-114' showed marked differences in new root development and new root growth. 'PRI 73-114' crowns and slips produced more and longer roots within 3 weeks compared to 'PRI 73-50' (Table 1). Larger slips (150–170 g) from both varieties also produced more and longer roots than small slips (75–90 g). There was a significant cultivar effect for both root number and root length, and there was a significant effect of size on root length, with no significant cultivar × slip size interaction.

Effect of slip weight on rooting. No correlation existed between the slip weight and number of type 1 suberized roots (Fig. 1), although a relationship did exist between slip weight and the length of the new type III roots (type III root length = 41.42 + 0.0556 slip weight; $r^2 = 0.061$; $P = 0.0111$; n = 12). The number of type I roots was negatively related to the number of new type III roots (type III root number = 10.18 – 0.365 number old type I roots; $r^2 = 0.0718$; $P = 0.0145$; n = 12), but it was not related to the type III root length. Similarly, the number of type I roots was correlated to the number of type II roots (type I root number = 1.529 + 0.559 type II root number; $r^2 = 0.424$; $P < 0.0001$; n = 12).

The number of new roots increased with the increasing slip weight (Table 2). Medium (≈165 g) to large (≈270 g) slips produced longer roots than small (≈100 g) slips.

Seasonal effect on slip rooting. Slips of similar size that were harvested at different times of the year and evaluated in coarse vermiculite showed variations in the number and length of roots (Fig. 2). A greater number of roots emerged in slips harvested during the warm season (May through mid-October) than during the cool season (November to April).

Time after fruit harvest when slips were harvested. Delaying slip harvest up to 10 weeks after fruit harvest increased both the new root number and root length (Table 3). The largest increase in slip root length occurred 3 to 6 weeks after fruit harvest, and the largest increase in root number continued up to 10 weeks.

Slip color at harvest. During all three experiments, green slips with red coloration consistently had a greater number of developed roots that were longer (Table 4) than those of the slips that were either green or yellow (Fig. 1D). Sometimes, the green and yellow slips did not consistently root.

We found no broad pattern relating the mineral composition of these slips with different leaf or stem colorations (Table 5). However, slips that were green with a red tinge had lower nitrogen levels in both the leaves and stem, with the stem also having lower phosphorus and iron levels. Additionally, the slips with yellow leaves had higher levels of most mineral elements, including nitrogen, in both the leaves and stem.

Table 2. Effect of the pineapple slip weight (PRI 73-50) on the number and average length of new roots when slips were maintained for 3 weeks in coarse vermiculite in the glasshouse and watered three times per week.

Slip wt (g)	Root number per slip	Root length (cm)
Small (average, 98 g)	4.0 b[i]	22.4 b
Medium (average, 165 g)	5.9 ab	39.1 a
Large (average, 273 g)	10.6 ab	43.9 a

[i] Mean separation by the Duncan-Waller multiple range test. n = 12. $P < 0.05$.

Mechanical cutting of slips and rooting. Type I and II roots were found under the tightly appressed basal bracts wrapped around the stem. To evaluate whether the bracts impede root emergence, we cut the end of the slip and made cuts lengthwise to the end of the slip curve. Neither of these treatments had any impact on root number or length (Table 6). Similarly, it was found that removing half of the top of the leaves from large slips had no effect on the root number or root length (data not reported).

Lower slip leaf bracts removed and rooting. Stripping the lower ten bracts from slips increased the number of new roots and their root length (Table 7). Stripping the bracts and then wrapping the stripped end with stretch wrap and masking tape reduced both the root number and length below those of the nonstripped control. Wrapping slips when the bracts were not removed had no effect on new root number, although wrapping did reduce the new root length ≈10% compared with the unwrapped control. The second bract from the bottom required 10.79 ± 0.33 N and the fourth bract from the bottom required 19.61 ± 4.71 N for detachment from the stem.

Chemical treatments and slip rooting. Numerous treatments that included plant growth regulators, sugars, mineral nutrients, and other stimulants and nutrients were evaluated. These tests were performed over 6 years; no treatment provided a consistent increase in the root number or length. Several treatments, such as naphthalene acetic acid and other

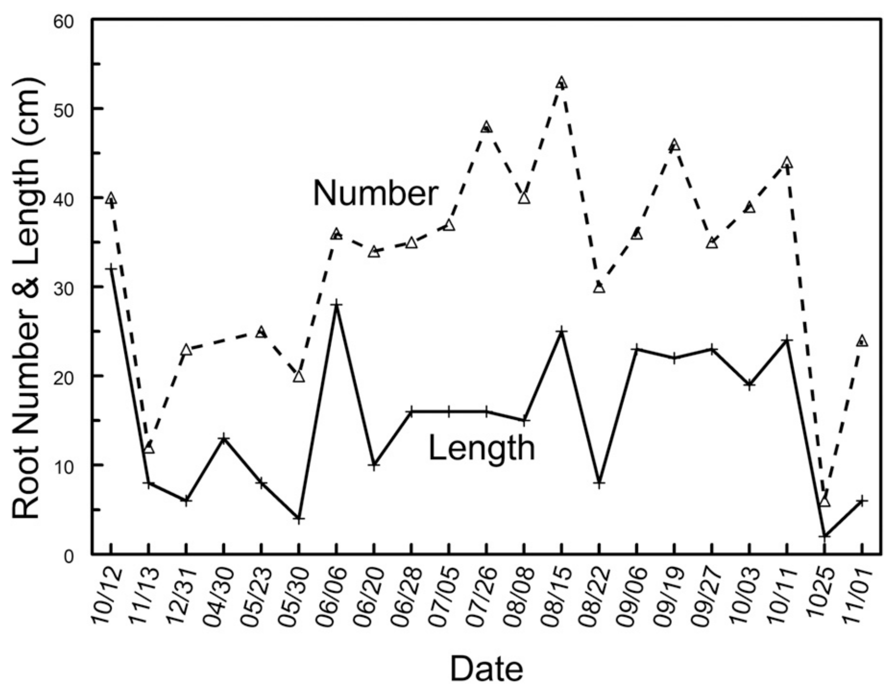

Fig. 2. Number and average length of new roots from pineapple slips harvested from different fields throughout the year. Slips were maintained for 3 weeks in coarse vermiculite in the glasshouse and watered three times per week.

Table 3. Effects of time after pineapple fruit (PRI 73-50) harvest when slips were collected from that field on root number per slip and average length of new roots when allowed to root for 3 weeks in water.

Slip harvest, weeks after fruit harvest	Root number per slip	Root length (cm)
1	9.2 c[i]	20.8 c
3	22.3 b	46.3 ab
6	24.8 b	30.0 bc
10	37.0 a	38.9 ab

[i] Mean separation by the Duncan-Waller multiple range test. n = 12. $P < 0.05$.

Table 4. Effect of pineapple slip color at harvest on the number and average length of new roots when slips were maintained for 3 weeks in coarse vermiculite in the glasshouse and watered three times per week.

Treatment	Root number per slip	Root length (cm)
Green	17.2 b[i]	47.9 b
Green with red	29.5 a	59.9 a
Yellow	19.9 b	47.4 b

[i] Mean separation by the Duncan-Waller multiple range test. n = 12. $P < 0.05$.

compounds used for rooting cuttings, inhibited the root number and/or root length (Supplemental Table S1). Some nutrient treatments, such as those with nitrate, stimulated the root number and growth; however, this increase in the root number was not always duplicated. However, the application of 1% weight/volume potassium nitrate consistently provided longer root growth.

Discussion

Pineapple is normally propagated using crowns, slips, or, less commonly, suckers. Marketing fresh fruit with the crown attached can lead to a shortage of planting material. However, slips are used, and some varieties only produce a few slips per plant and may not meet the replant needs. Forcing pineapple plants to flower with a chemical such as Ethephon and then treating the plants with chlorflurenol (Maintain® CF 125), which is a plant growth regulator of the morphactin group, within 1 week of forcing can result in the development of multiple propagules (Glennie, 1981; Py et al., 1987; Reinhardt et al., 2018). Stem sectioning, gouging, and chemical treatment are also used to stimulate propagule development, but these methods are not as widely practiced. These practices are used to increase the planted area and develop new cultivars (Reinhardt et al., 2018).

The use of larger slips (larger weights) increased the number of new roots (Table 2). However, very large slips present handling problems and are not generally used. Medium slips, when sorted, are in the range of 200 to 400 g, although the leaf weight fraction increases faster than the stem weight fraction as the slip weight increases (Fig. 1B). Stem weight probably has a greater impact on the stem apex size; therefore, increasing the slip weight to 400 to 600 g results in greater leaf mass with only a marginal increase in stem weight. Bigger slips had more and longer roots than small slips (Table 3). Additionally, the number and length of new roots on slips varied with harvest time, with both the number and length being greater for slips harvested during the warm season.

Slips harvested from the same field at various intervals after fruit harvest showed that slips left on the peduncle for longer periods after fruit harvest had a greater root number and root length (Table 3). However, delaying the slip harvest for 10 weeks may have an adverse effect on new sucker development of the parent plant (Py et al., 1987) that will bear the ratoon crop. Curiously, slips that were green with red edges and tips consistently had greater number and longer new roots than slips that were either green or yellow (Table 4). A mineral analysis of the stem and leaves on the slips of different color did not show any consistent differences in mineral composition (Table 5). Slips that were yellow tended to have higher nitrogen levels than those that were green or green with a red hue. Yellow slips did have higher magnesium and manganese levels in the slip leaves and higher manganese levels in the stem, suggesting a form of manganese toxicity. High manganese level-induced iron deficiency is not uncommon in some Hawaiian oxisol soils (Hue et al., 2001).

Table 5. Mineral composition of the leaves and stem from slips harvested with different slip leaf colors.

	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	B
Stem	%	%	%	%	%	%	ug/g	ug/g	ug/g	ug/g	ug/g
Green	1.47 a	0.36 a	2.64 b	0.27 a	0.34 a	0.01 a	27.0 ab	543 b	34 ab	8.0 b	12 b
Green with red	1.29 a	0.30 b	2.10 b	0.19 a	0.29 a	0.01 a	18.7 b	540 b	25 b	8.0 b	9 b
Yellow	1.56 a	0.36 a	3.62 a	0.37 a	0.44 a	0.02 a	29.7 a	1032 a	47 a	9.3 a	11 ab
Leaves											
Green	1.10 a	0.18 b	2.61 b	0.09 b	0.15 b	0.01 a	67.7 a	471 b	11 a	4.7 b	17 b
Green with red	0.94 b	0.19 ab	2.74 b	0.08 b	0.14 b	0.01 a	82.0 a	535 b	11 a	5.0 ab	19 ab
Yellow	1.21 a	0.21 a	3.82 a	0.16 a	0.21 a	0.02 a	95.0 a	1012 a	237 a	5.7 a	22 a

[i] Mean separation by the Duncan-Waller multiple range test. n = 4. $P < 0.05$.

The basal leaf bracts of slips are tightly appressed to the stem, and consideration was given to the possibility that they were mechanically impeding new root development and growth. Making cuts along the slip base to the stem or cutting the curved portion of the slip did not have a significant effect on the root number or length (Table 6). However, when the basal ten bracts were stripped from the slip stem, the number of roots almost doubled and root length increased by 50% (Table 7). Removing the bracts required 10 to 20 N of force. After removing the basal ten bracts, the basal section of the stem was wrapped in stretched polyethylene film; this masking drastically reduced both the root number and length, supporting the conclusion that the lower bract mechanics impede new root development and growth. This finding is similar to the behavior observed in a commercial nursery growing the ornamental species *Ananas lucidus*, which rooted better when the lower bracts were stripped (D. Fell, personal communications, 2021). The mechanical impediment to root growth has been a focus of much research (Atwell, 1993; Lynch, 1995), especially with container-grown plants (Bourgault et al., 2013; Passioura, 2006; Potocka and Szymanowska-Pulka, 2018). Pineapple planting densities range from 50,000 to 70,000 plants per hectare; hence, some type of machine would be necessary to strip the lower bracts.

In an attempt to increase the rooting rate and root growth as an alternative to basal bract removal, numerous chemical treatments and potting media were evaluated (Supplemental Table S1). Compounds typically used to initiate root growth in plant cuttings often had a negative effect on the root number and length. During some tests, fertilizer and, specifically, potassium nitrate would stimulate greater root growth, but not more roots. Different potting media led to an increase in the root number and length; however, the cause is unknown.

Conclusions

The data support the conclusion that new root growth from 'PRI 73-50' slips was limited by mechanical impedance to growth. Removal of the lower slip leaf bracts can lead to greater root number under standard conditions in the glasshouse. Removing slips from the peduncle at a later interval after harvest resulted in greater rooting. Larger slips, and especially those that were green with a red

Table 6. Effect of cutting the lower part of the slip (PRI 73-50) on the number and average length of new roots when slips were maintained for 3 weeks in coarse vermiculite in the glasshouse and watered three times per week.

Treatment	Root number per slip	Root length (cm)
Control	6 a[i]	12.5 a
Cut end of the slip to the outer curve of slip	4.5 a	12.9 a
Five cuts lengthwise along the end of the slip to the outer curve	5.3 a	10.8 a

[i] Mean separation by the Duncan-Waller multiple range test. n = 12. $P < 0.05$.

Table 7. Effect of removing lower bracts from the base of pineapple slips on the number and average length of new roots when slips were maintained for 3 weeks in coarse vermiculite in the glasshouse and watered three times per week.

Treatment	Root number per slip	Root length (cm)
Control	6.5 b[i]	29.2 a
Stripped 10 bottom bracts	11.7 a	44.2 a
Stripped 10 bottom bracts, base wrapped with stretch polyethylene and masking tape	3.2 c	13.5 b

[i] Mean separation by Duncan-Waller Multiple Range test. n = 12, $P < 0.05$.

hue, also had more and longer developed roots. Chemical treatments including compounds frequently used for rooting cuttings had no effect. However, there was a tendency for slips treated with potassium nitrate to have greater rooting.

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Supplemental Table S1. Summary of results of the number and length of new roots treated during 51 physical, chemical, biochemical, and growth medium tests performed from 2014 to 2021. Slips were maintained for 3 weeks in coarse vermiculite, unless otherwise indicated, in the glasshouse and watered three times per week. Treatments were based on the literature that indicated the potential effects on the rooting rate and growth. The evaluated treatments showed no significant difference (NSD) or inhibited root number or root growth.

Treatment	Application	Root number	Root growth
Chemical treatments			
Potassium chloride	(2% weight/volume) Preharvest, pretreatment, and sprays	NSD	NSD
Calcium chloride	(2%, weight/volume) Preharvest, pretreatment, and sprays	NSD	NSD
Miracle Grow (Scotts Miracle-Gro Co., Marysville, OH)	5 g/L in solution	NSD	Longer
KNO_3	1% (weight/volume) foliar for 3 d	NSD	Longer
KNO_3	2% (weight/volume) with or without Terra-Sorb (Lebanon Seaboard Corp., Lebanon, PA) dip for 3 h	NSD	NSD
KNO_3	2% (weight/volume) with WetCit (ORO AGRI, Inc., Fresno, CA), dip for 3 h	NSD	Longer
Ca_2NO_3	2% (weight/volume) Foliar 4 d	NSD	NSD
Sucrose	5% (weight/volume) Dip 48 h	NSD	NSD
Fe chelate	6% (weight/volume) Sesquestrene-330 (Becker Underwood Inc., Ames, IA) 24 h, soaked, with or without foliar applied	NSD	NSD
Potassium phosphate dibasic	25 mM, Dip 48 h	NSD	NSD
Potassium phosphate dibasic	2.5 mM, Dip 48 h	NSD	NSD
Boric acid	0.1 mM, Dip 4 h	NSD	NSD
Zinc sulphate	2g/l (weight/volume) Dip 4 h	NSD	NSD
Zinc sulphate	2g/l + NAA 1 mg/L (weight/volume) Dip 4 h	NSD	NSD
Plant growth regulators			
NAA	1 ppm Dip 20 min	NSD	NSD
NAA 10 ppm	10 ppm Dip 20 min	NSD	NSD
NAA 100 ppm	100 ppm Dip 20 min	NSD	NSD
NAA 200 ppm	200 ppm Dip 20 min	Fewer	Shorter
NAA 400 ppm	400 ppm Dip 20 min	Fewer	Shorter
Thidiazuron	5 μM, Dip 3 h with Wetcit	Fewer	NSD
IBA	40 mg/L (weight/volume) Drip 3 h with Wetcit	NSD	Shorter
Methyl jasmonate	1% (weight/volume) Spray	Fewer	Shorter
GA_3	200 ppm Dip 3 h	NSD	NSD
DipNGrow (Dip'N Grow Inc., Clackamas, OR)	1% IBA, 0.5% NAA, 1:10 dilution, 3 h Dip	NSD	NSD
Ethephon	100 ppm, Dip 3 h	NSD	NSD
"Take Root" (Garden Safe Brand, St. Louis, MO)	0.1% IBA dip, Cut/noncut slip end	NSD	NSD
Fluridone	100 nM, Dip 20 min	NSD	NSD
Fluridone	500 nM, Dip 20 min	NSD	NSD
ABA	200 uM, Dip 24 h	NSD	NSD
Wright's Liquid Smoke (B&G Foods Inc., Parsippany, NJ)	1:100, Dip 6 h	NSD	NSD
Auxano Kelp extract (Ulexandes - USA, LLC., Camano Island, WA)	10 uM Dip, plant	NSD	NSD
Auxano Foliar Kelp extract	10 uM Dip, sit 2 d, plant	NSD	NSD
Auxano Foliar Kelp extract	10 uM Dip 5 h, sit 2 d, plant	NSD	NSD
Melatonin	500 uM, Dip 3 h	NSD	NSD
Morin hydrate	1 μM, 48 h	NSD	NSD
Naringenin	1 μM, 48 h	NSD	Longer
		Greater	NSD
		NSD	Shorter
		NSD	NSD
Naringenin	1 μM, with Wetcit, 48 h dip	NSD	NSD
Naringenin	1 μM, 4 h	NSD	NSD
Naringenin	1 μM with Wetcit, 4 h	NSD	NSD
Naringenin	100 μM, 4 h	NSD	NSD
HB 101 (Flora USA, Inc., Beaverton, OR)	1 drop/L, 6 h	NSD	NSD
Brassinolide	0.1 ppm, 2 h	NSD	NSD
Brassinolide	0.2 ppm, 2 h	NSD	NSD
Vermi compost tea	Foliar	NSD	NSD
Physical treatments			
Watered from above MWF		NSD	NSD
Watered from below MWF		NSD	NSD
Water MWF		NSD	NSD
Watered Monday only		NSD	NSD
Growing media			
ProMix Ultimate (Premier Tech Ltd., Quakertown, PA)		Greater	Longer
Sterilized ProMix Ultimate		Greater	Longer
Black Gold Peat Moss Plus (Sun Gro Horticulture, Inc., Agawam, MA)		NSD	NSD
Black Gold Seedling Mix		NSD	NSD
Vermiculite	+1 tablespoon Terrasorb per pot	NSD	NSD

M = Monday; W = Wednesday; F = Friday.