Krome Memorial Section

Proc. Fla. State Hort. Soc. 129:22–24. 2016.

Propagation of Papaya (*Carica papaya* L.) with Large-sized Cuttings

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Additional index words. Agri-mycin®, IBA®, Abound®, clonal

Papaya plants are typically propagated by seed; however, clonal propagation may be needed to maintain or increase individual selections with particularly desirable characteristics. Previously published methods for rooting small papaya shoots utilized rooting hormone in combination with exposure to bottom heat and mist. After one to two months, shoots developed sufficient roots for transplanting in the field, followed by an additional two to five months to flower and set fruit. In the present study, a method using larger cuttings was developed that avoided the need for bottom heat and reduced the period from transplanting to flowering to one or two months. This was achieved using side shoots 2–3 feet in length and having a 1 1/2- to 3-inch basal diameter. The lamina of all mature leaves were removed, leaving the petioles, plus any immature leaves. The base of each shoot was dipped into a rooting mixture containing hydroxyethyl cellulose, streptomycin sulfate, indole butyric acid, riboflavin, azoxystrobin, and Hoagland's solution and then inserted into well-drained media. Shoots were well rooted within three to five weeks and subsequently planted in the field. Flowering was observed one to two months later.

Commercially grown papaya plants are usually propagated from seed; however, in Israel and South Africa some commercial plantings use tissue cultured plants or cuttings (Allan, 1990; Allan and Carlson, 2013; Reuveni and Shlesinger, 1990; Traub and Marshall, 1937). Such clonal propagation has several advantages: 1) it eliminates the need to cull unwanted (male and female flowering) plants; 2) it reduces the time to harvest, since plants from cuttings bloom and set fruit earlier and at a lower height than seedlings; 3) it allows the continuation or increase of plants exhibiting superior horticultural traits; and 4) allows for genetically uniform plantings (Fitch et al., 2005a and b).

Papaya plants typically have one main stem; however, mature plants (usually >1-year-old) exposed to environmental conditions that cause growth cessation e.g., cool temperatures and/or drought may form one or more lateral shoots (branches) when favorable growing conditions return. As these branches mature, the proximal end swells and forms a corky phellem containing undifferentiated cells capable of forming roots or shoots (Reuveni and Shlesinger, 1990). Previous investigators have developed methods for using this tissue to generate multiple shoots that are then treated with plant growth regulators, placed into artificial media over bottom heat and then typically exposed to intermittent mist (Allan, 1990; Allan and Carlson, 2013; Reuveni and Shlesinger, 1990; Fitch et al., 2005a). Taub and Marshal (1937) obtained rooting of 2–3 ft long papaya shoots after treatment of the base with indole-3-acetic acid and placement over bottom heat in 90% shade. A method to root large cuttings without the need for bottom heat and exposure to intermittent mist would simplify propagation of superior hybrids from a breeding program with a potential to flower and fruit soon after planting.

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Materials and Methods

Several preliminary investigations determined that: 1) removal of all but a portion of the petiole of the oldest leaves prevented rotting of the cutting (see Allan, 1990 and Allan, 1995); 2) intermittent misting of large shoots (1–3 ft long) cut above the proximal swollen base usually caused rotting prior to root formation; and 3) rooting of large shoots was unsuccessful without treatments to prevent microbial growth and in the absence of a plant growth regulator to stimulate root formation. A gel formulation was developed to prophylactically treat stem rot and to induce prolific root formation (Pamela Moon, unpublished data). This gel consisted of hydroxyethyl cellulose, streptomycin sulfate, indole butyric acid (IBA), riboflavin (Drew et al., 1993), azoxystrobin and Hoagland's solution (Drew and Miller, 1989) (Table 1). From this, a protocol was developed that is nearly 100% successful for rooting large papaya cuttings in a greenhouse with 30% shade cover.

The protocol for large cuttings includes the following steps (Fig. 1):

1. Prepare 1 gallon pots with a 2:1:1 of perlite, Promix® and coconut coir mix, respectively; moisten soil media to run-off.
2. Remove side shoots (1–3 ft long, 1 to 3-inch diameter) from the parent plant about halfway between the top and base of the proximal swollen base (phellem tissue) (Fig. 2).
3. Remove the leaf lamina of all mature leaves but retain the petioles (Fig. 3).
4. Dip the base of the shoot into the gel for 3–5 min. (Fig. 4).
5. Set the cuttings into media-filled pot and stake if needed (Fig. 5).
6. Care of the cuttings includes:
   a. Manual watering of the potting media every other day to the point of run-off.
   b. Fresh application of 15 mL of gel to the base of the cuttings by pouring the mixture around the base of the

Table 1. Anti-microbial and plant growth regulator gel formulation for rooting large papaya plant shoots without exposure to bottom heat and mist.

Chemical name	Brand name	Concentration
Hydroxyethyl cellulose	Sigma-Aldrich, St. Louis, MO	12 g/L
Streptomycin sulfate	Agrimycin®17, Nufarm Americas Inc., Burr Ridge, IL	200 mL/L
Indole butyric acid	Phytotechnology Laboratories, Shawnee Mission, KS	5 mg/L
Riboflavin	Sigma-Aldrich, St. Louis, MO	4 mg/L
Azoxystrobin	Abound® Flowable, Syngenta Crop Protection, LLC, Greensboro, NC	500 μL/L
Hoagland's solution	See Hoagland and Arnon, 1950	0.5 x strength

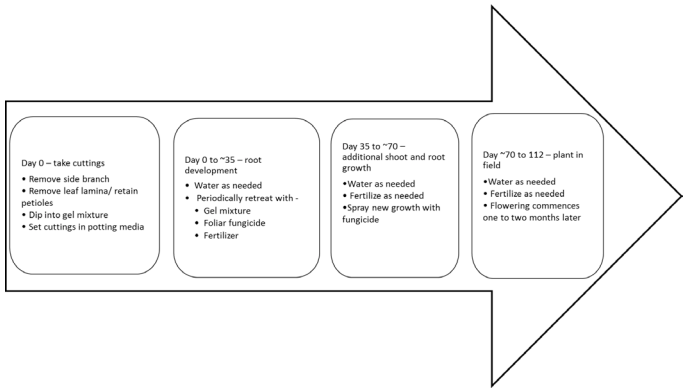

Fig. 1. General protocol and timeline for production of large papaya cuttings

Fig. 2. Papaya side shoot showing swollen base and area to cut (arrow).

Fig. 3. Intact petioles after removal of leaf lamina. These petioles will eventually drop.

stem every other day (week 1), every two days (week 2), every third day (week 3), and once in week four (Fig. 6).

c. Spray the apex of the cutting and all new leaves with fungicide-nutrient solution two to three times a week or apply liquid fertilizer to soil.

At the end of 4–5 weeks, the cuttings will have rooted and should be fertilized weekly thereafter until planting (Fig. 7). An additional four to five weeks is required until plants are ready to be planted in the field. During this period, they should

Fig. 4. Dipping the proximal end of the shoot into the gel mixture for 3–5 min.

Fig. 5. Large cutting planted into media filled container.

Fig. 6. Application of gel mixture to the base of the cutting.

Fig. 7. Root system after two months (potting media removed).

be exposed to natural sunlight conditions for about 10 d. The plants may begin to bloom approximately 4–6 weeks later, weather permitting (Fig. 1 and Fig. 8).

Conclusions

Our results substantiate the utility of rooting large papaya shoots. Other authors found that exposure to bottom heat and misting were required for successful results in addition to using IBA (Allan, 1990; Reuveni and Sclesinger, 1990; Traub and Marshall, 1937). However, the protocol we have developed requires neither bottom heat nor mist and can be used under relatively high light conditions. The technique described in this study provides a relatively quick method for clonally propagating unique and desirable papaya plants that have the potential to flower in 84–112 d after taking the cutting. This is 7–20 weeks sooner than reported for other methods of propagation by cuttings (Allan, 1990; Allan 1995; Fitch et al., 2005a and b).

Fig. 8. Planted cutting in the field three months after propagation. Close-up shows flower buds.

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