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Effect of Ratooning X17-2 x T5 Papaya Plants on Crop Yield and Survival

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Selected plants in a three-year-old 0.3-acre papaya ringspot virus resistant, transgenic X17-2 x T5 (Accession 2562) papaya planting were used to: a) compare the yield from single-stemmed and multiple-stemmed plants (Trial 1) and; b) to compare the yield of plants cut at different heights (Trial 2). The original planting sustained significant damage after a brief but intense tropical storm on 19 June 2014. Some plants lost their apex and most plants had small side-shoots left intact. On 2 February 2015 (Trial 1), 15 bisexual plants were cut to 120 cm above the soil line, removing the main trunk; the main trunks of 15 other bisexual plants were left intact. On 3 March 2015 (Trial 2), 16–32 randomly selected bisexual or female plants were left intact or cut to 30 cm, 60 cm, 90 cm, or 120 cm above the soil line. Fruit production was evaluated by counting the number of fruit per plant over seven harvests and five harvests in Trial 1 and 2, respectively. In Trial 1, there was no significant difference in mean number of fruit among plants with or without the main trunk left intact. Mean fruit per plant ranged 0.3–17 fruit per plant. In Trial 2, there was no significant difference in mean number of fruit per harvest among plants cut to 60 cm, 90 cm, and 120 cm; all plants cut to 30 cm died prior to the first harvest. Mean fruit per plant ranged 0.3–16 fruit per plant.

Papaya (*Carica papaya* L.) is large, primarily single-stemmed, potentially long-lived herbaceous tropical plant that produces a fruit column just below the apical leaves (Villegas, 1991). Papaya is grown commercially throughout the tropical and warm subtropical regions and its production, consumption and international trade are increasing (Evans et al., 2015). Areas in the United States with papaya production—in order of acreage and value—are the Hawaiian Islands (~2,025 acres), Puerto Rico (~700 acres), Florida (~300 acres), Texas (no data), and California (no data) (U.S. Census, 2017; FactFish, 2017).

A major production constraint is the aphid transmitted papaya ringspot virus (PRV), which is lethal to some papaya cultivars and/or debilitates others (Gonsalves, 1998). To overcome this constraint, genetically modified papaya (GM-papaya) cultivars resistant to PRV were developed in Hawaii and have been grown and marketed to Canada and the mainland United States for over 17 years and to Japan for six years (Evans and Ballen, 2013).

More recently, PRV resistant germplasm was developed in Florida and field-tested over the past 10 years (Davis and Ying, 2004; Davis et al., 2004), and deregulated in 2016 (J. Crane, personal communication). The potential annual economic benefit of growing GM-papaya in Florida has been estimated at $13 to $37 million (Li and Evans, 2015).

Besides PRV, two additional production constraints include the cost to harvest papaya plants as they increase in height and the > $4,800/acre initial cost of plant establishment (Evans et al., 2012). Harvest becomes more difficult and costs go up as the fruiting column of papaya plants continues to move upward. This, plus tree decline due to PRV, usually results in only a two- to three-year lifespan for commercial papaya plantings. To partially improve production efficiency and reduce replant costs, Elder et al. (2002) showed that cutting back (ratooning) plants to 75 cm over a three-and one-half-month period (i.e., not all plants were cut at once) allowed continued commercial production. Although there was a small yield reduction (~9%) over a 20-month period, there were still significant cost savings when compared to replanting the site anew. Jai et al., (2014) reported that plants cut to 60 cm height branched more, fruited earlier, and had the highest crop yield compared to plants cut at 15, 20, 45, 75, and 90 cm height. To reduce the harvest costs and the need to replant due to PRV, planting a PRV resistant GM-papaya selection and cutting excessively tall papaya plants to improve harvest efficiency is described.

Materials and Methods

Selected plants in a three-year-old, 0.3-acre, PRV-resistant, transgenic X17-2 x T5 (Accession 2562) papaya planting at the University of Florida Tropical Research and Education Center, Homestead were used to: a) compare the yield from single-stemmed and multiple-stemmed plants (Trial 1) and; b) to compare yield of plants cut at different heights, allowed to branch and fruit (Trail 2). The trees were established in 2012. They were spaced 7 ft in-row and 12 ft between rows and planted in plastic beds with two lines of drip-tape per bed (Menocal-Barerena, 2014). Plants were fertigated through the irrigation system with 4–0–8 (N–P–K) fertilizer and sprayed periodically with minor elements. Two-spotted mites (*Tetranchus urticae* Koch) were controlled with periodic releases of mite predators (Fasulo and

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Denmark, 2016) and/or applications of commercially available strains of *Beauvearia bassiana* (e.g., BotaniGard®). Papaya fruit flies (*Toxotrypana curvicauda* Gerstaecker) were controlled with Tanglefoot®-covered green Styrofoam balls placed just below the fruit column (Seleman et al., 2015).

The original planting sustained significant damage after a brief but intense tropical storm on 19 June 2014. After the storm, most plants developed side-shoots. On 3 Feb. 2015 (Trial 1), 30 bisexual papaya plants, 15 with a main trunk (apex) intact with developing side shoots and 15 plants with a missing trunk apex and only side shoots were selected. On 3 Mar. 2015, the 15 plants with missing apex were cut back to 120 cm above the soil; three of their side-shoots were left intact (Fig. 1). On 9 Mar. 2015 (Trial 2), the main trunk of an additional 16 to 38 randomly selected bisexual or female plants with side shoots were cut to 30 cm, 60 cm, 90 cm or 120 cm above the soil surface. There were 16 to 38 plants per treatment. Fruit production was evaluated by counting the number of mature (33% or more color-break) fruit per plant over seven harvests and five harvests in Trials 1 and 2, respectively (Table 1). Mature fruit were removed after counting. Tree mortality by treatment was recorded in Trial 2. Fruit counts were taken periodically over 568-days and 385-days in Trial 1 and Trial 2, respectively. Both trials were disrupted by an Oriental fruit fly eradication program from 28 Sept. 2015 to 27 Nov. 2015 (~60 days), when all fruit were removed from all plants as a precaution against infestation.

Fig. 1. Transgenic X17-2 x T5 (Accession 2562) papaya plants after some plants were cut to about 120 cm above the soil surface and others were left with a dominant main trunk. Note the side branching.

Table 1. Dates of fruit count harvests of single-stemmed and branched plants (Trial 1) and plants cut at 60 cm, 90 cm, and 120 cm from the soil surface (Trial 2).

	Harvest no.	Date
Trial 1	1	17 June 2015
	2	5 Aug. 2015
	3	14 Sept. 2015
	4	28 Sept. 2015
	5	13 Jan. 2016
	6	14 Apr. 2016
	7	24 Aug. 2016
Trial 2	1	5 Aug. 2015
	2	14 Sept. 2015
	3	13 Jan. 2016
	4	14 Apr. 2016
	5	24 Aug. 2016

Data from both trials was analyzed by repeated measures analysis (SAS, GLIMMIX Procedure) and means separated by least measures analysis at the University of Florida, IFAS Statistical Consulting Unit.

Results and Discussion

Trial 1: Single-stemmed and multiple-stemmed plants. There was no significant treatment—harvest date interaction and no significant difference among treatments in the mean number of fruit per plant for any harvest (Fig. 2). This suggests other factors, such as environmental conditions, were more important in affecting fruit production than the applied treatment.

Trial 2: Effect of cutting height. Nearly all (94%) of plants cut to 30 cm died prior to the first harvest and were therefore excluded from the harvest analysis. By the last harvest 100%, 19%, 31%, and 34% of the 30 cm, 60 cm, 90 cm, and 120 cm plants, respectively, had died. There were no significant interactions among plant sex type (i.e., bisexual and female) and cut plant height (60 cm, 90 cm, and 120 cm), and/or harvest date. There was a significant difference in fruit numbers among harvest dates. However, there was no significant differences in mean number of fruit per plant among plants cut at 60 cm, 90 cm, and 120 cm

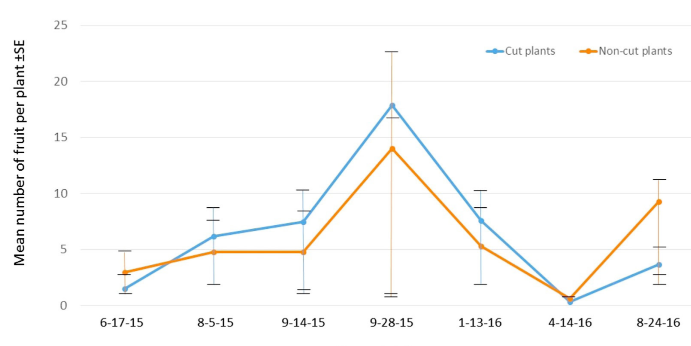

Fig. 2. Effect of cutting or not cutting X17-2 x T5 (Accession 2562) papaya plants at 120 cm on subsequent mean number of fruit produced per plant.

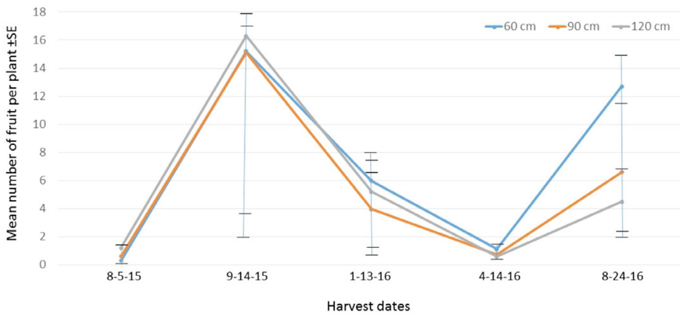

Fig. 3. Effect of cutting or not cutting X17-2 x T5 (Accession 2562) papaya plants at 60 cm, 90 cm, or 120 cm on subsequent mean number of fruit produced per plant.

height on any harvest date (Fig. 3). The number of fruit harvested per plant ranged from a 0.3–1.2 fruit per plant for harvest one to a maximum of 15.2–16.3 fruit per plant from the second harvest; number of fruit per plant were intermediate at other harvests. This suggests other factors besides plant height affected fruit production—such as soil and air temperatures and effective pollination.

Summary

The yield from single- and multi-stemmed papaya plants was comparable. Production from GM-papaya plants cut at 60–120 cm above the soil line was similar over a 586-day period. The combination of PRV-resistance and cutting plants to force ratoon cropping may enable continued plant growth and production despite the presence of PRV in the production area, prolong the period of efficient harvesting (i.e., harvesting from the ground), and potentially reduce the necessity of replanting papaya fields every 2–3 years.

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