summer, then ceases flowering and bears no fruit in midsummer, and subsequently yields a light crop in autumn. A lengthened fruiting season is essential to build an economically healthy passion fruit industry in Florida and similar subtropical areas. Yellow passion fruit vines as a rule crop well through summer and into the autumn here, but their fruit is not preferred for the fresh market in North America and Europe. One objective of our current breeding effort of crossing inbred yellow and purple-fruited lines is to obtain F-1 plants that ripen fruit of good quality over a longer season than that currently filled by 'Possum Purple'.

Discussion and Conclusion

In summary, it is easy to state what is needed in lines or cultivars of passion fruit for commercial production: enhanced resistance to fungal disease in all parts of the plant, including the growing and mature fruit, plus dependable, heavy production of fruit of high market acceptability. Preference to date has been for maroon or dark red-colored fruit, but yellow fruit is also marketed to some extent. Fruit of good quality needs to be available throughout the season, from first ripening in spring until the last harvest in late autumn. Less obviously necessary, but of interest for their potential effects in lowering production costs and the rate of fruit spoilage between time of picking and marketing, are characters for dwarfness and for retention of ripe fruit on the vine. The tendency to have one or more extra locules in the fruit also may prove valuable if it assures well-filled fruit, eliminating the threat of "light", partially-filled fruit.

From the information presented here it is evident that the *Passiflora* germplasm assembled to date offers breeders a number of presently unexploited opportunities that can help alleviate the numerous problems that confront passion fruit production at the present time. Furthermore, the number of useful characters found already as a result of relatively limited plant exploration suggests the desirability of a well-coordinated effort to find new sources of disease resistance and enhanced environmental adaptation for this crop among wild populations that grow within the natural area of distribution of the species.

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REJUVENATION OF A MATURE, NON-PRODUCTIVE 'LULA' AND 'BOOTH 8' AVOCADO GROVE BY TOPPING AND TREE REMOVAL

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Abstract. **The effect of topping height and tree removal on yield of over-crowded, non-productive, 34-year-old 'Lula' and 'Booth 8' avocados (*Persea americana* Miller) was studied. Trees were periodically topped at 9 (subsequently 12), 16, or 22 ft with or without eventual removal of every other tree on a diagonal within the grove. 'Lula' produced no fruit during the first three seasons after topping. During the fourth season, 'Lula' topped at 16 and 22 ft with trees removed had more fruit per tree (1.6 and 2.2 bu/tree, respectively) than other topping treatments. 'Lula' trees topped to 22 ft with and without trees removed produced more fruit per acre (119 and 108 bu, respectively) than trees topped at 9 ft (43 bu/acre) and 16 ft with trees removed (86 bu/acre). 'Booth 8' topped at 22 ft with no trees removed and 16 and 22 ft with trees removed produced fruit during the second season after topping. More fruit was produced in 'Booth 8' plots topped to 16 and 22 ft with trees removed (469 and 464 bu/acre, respectively for two years combined) than those topped to 9 ft with trees removed and 22 ft with no trees removed (130 and 249 bu/acre, respectively for two years combined). Topping at 16 and 22 ft with tree removal increased the percentage of fruit in the lower third of 'Lula' and 'Booth 8' canopies, whereas more fruit was produced in the middle of the canopy for trees topped at 22 ft without tree removal. Profitability estimates suggest that topping 'Booth 8' at 16 and 22 ft with tree removal and topping 'Lula' at 22 ft without tree removal were the most cost effective treatments to date.**

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Avocado ranks as the major tropical fruit crop in South Florida in terms of acreage despite a decrease from a high of 12,872 acres in 1983 to about 9,078 acres in 1990 (Anonymous, 1990). Production was estimated to be worth about $18 million dollars (gross) during the 1988-89 season (Mosely, 1990). Remaining viable acreage after Hurricane Andrew is estimated to be 6,000 acres. Before the hurricane, about 94% of the groves were 10 or more years old.

Traditional plant spacings recommended for avocado production in Florida range from 25 to 35 feet in-rows and 25 to 40 feet between-rows (Ruehle, 1963). These spacings preclude crowding of adjacent mature trees and the loss of productive canopy. Due to economic considerations during the 1960s and 1970s, however, many groves were planted at in-row spacings of 15 to 20 ft and between-row spacings of 20 to 25 ft which resulted in increased yields and returns while the trees were young. In addition, many plantings were established with the intent that a regular topping and tree removal program would be initiated as trees matured, in order to prevent crowding and the loss of bearing volume in the lower one-third of the canopy.

Topping and tree removal programs in many closely planted groves were not accomplished, however, resulting in loss of all or most of the bearing canopy in the lower one to two-thirds of the tree. Crowded trees taller than 22 ft generally decline in production from two to four bushels per tree per year to one bushel or fewer. Thus many overcrowded groves produce little saleable fruit.

Controlling the size of avocado trees and thinning are recommended practices in California (Platt, 1975; Platt, 1976), Israel, Australia, and South Africa, and topping has been recommended for Florida avocado groves for many years (Newman, 1971; Ruehle, 1963). Control of tree size is beneficial because competition for light among adjacent trees is decreased; the lower bearing canopy is retained; harvesting is easier, more efficient and safer; pest control practices are more effective; equipment movement is facilitated; and the grove is less susceptible to wind damage.

The purpose of this study was to investigate the effect of topping height and periodic tree removal on yields of mature, non-productive avocado groves in South Florida.

Materials and Methods

Solid blocks of mature (34-year-old), 'Lula' and 'Booth 8' avocado trees located in a commercial grove in Homestead, Florida were used for this study. 'Lula' trees have an upright growth habit and tend to lose their lower canopy quickly when overcrowded, whereas 'Booth 8' trees have a more spreading growth habit and maintain some lower canopy even when crowded. Neither the 'Lula' or 'Booth 8' trees had been pruned for many years. As a result, 'Lula' trees were between 40 to 60 ft tall and 'Booth 8' trees 25 to 35 ft tall prior to initiation of the study. Both cultivars had lost the lower one- to two-thirds of their bearing canopy and produced little (<1 bu/tree) marketable fruit.

One 2.9 acre block of 'Lula' and one 2.9 acre block of 'Booth 8' were used in the trial. Tree rows were oriented in an east-west direction with 20 ft × 20 ft spacing, resulting in 108 trees per acre. Treatments consisted of regular topping and periodic removal of every other tree on a diagonal within the grove beginning in 1988 for the 'Lula' grove and in 1989 for the 'Booth 8' grove (Table 1).

Table 1. Topping and tree removal sequence for mature, non-productive 'Lula' and 'Booth 8' groves.

Cultivar	Treatment	Year	Treatment sequence
Lula	1	1988	topped at 9 ft in March
		1989	topped at 12 ft in February
		1990	topped at 14 ft in November
		1991	no treatment applied
	2	1988	topped at 11 ft in March
		1989	topped at 16 ft in February
		1990	topped at 16 ft in November and every other tree removed on the diagonal in December
		1991	no treatment applied
	3	1988	topped at 22 ft in March
		1989	topped at 22 ft in February and every other tree removed on the diagonal in May
		1990	topped at 22 ft in November
		1991	no treatment applied
	4	1988	topped at 22 ft in March
		1989	topped at 22 ft in February
		1990	topped at 22 ft in November
		1991	no treatment applied
Booth 8	1	1989	topped at 9 ft in February
		1990	topped at 12 ft in November
		1991	topped at 12 ft in November and every other tree removed on the diagonal in December
	2	1989	topped at 16 ft in February and every other tree removed on the diagonal in May
		1990	topped at 16 ft in November
		1991	topped at 16 ft in November
	3	1989	topped at 22 ft in February and every other tree removed on the diagonal in May
		1990	topped at 22 ft in November
		1991	topped at 22 ft in November
	4	1989	topped at 22 ft in February
		1990	topped at 22 ft in November
		1991	topped at 22 ft in November

Topping was done mechanically and tree removal was done by cutting trees with chain saws at the soil line. Each treatment was applied to four adjacent rows with 14 to 32 trees per row. Two outside rows were periodically topped to 8 ft and served as buffer rows. Prunings of wood >3 inches in diameter were stacked between trees within the row, whereas wood <3 inches in diameter were placed in row middles and shredded. Trees were whitewashed immediately after topping to prevent sunburning of the trunk and main scaffold limbs. Due to the nature of the treatments and the necessity that treatments be applied on a relatively large scale, treatment blocks were not replicated.

Fruit production data were estimated visually on 12 Sept. 1991 for 'Lula' treatments, and 14 Aug. 1990 and 12 Sept. 1991 for 'Booth 8' treatments. Actual crop yield data collected during the 1991-92 season corresponded very closely to visual estimates, therefore, only visual estimates are reported. Crop yields are reported as the mean of 4 rows (14 to 32 trees per row). Location of the fruit was estimated visually and is reported as a percentage of the total crop in the lower, middle, and upper third of the tree canopy. Cost estimates for each treatment were based on

actual machine and labor costs incurred for the project for each treatment on a per acre basis.

Results

Crop yields. No crop was produced in any of the 'Lula' treatments during the 1988-89, 1989-90 and 1990-91 seasons. This was due to the vigorous regrowth in all treatments after topping and possible cold damage after the Dec. 1989 freeze. Fruit production resumed for the 1991-92 season with the trees topped to 22 ft with tree removal (Treatment 3) producing 2.2 bu/tree compared to 1.6, 0.4, and 1.0 bu/tree for trees originally topped at 16 ft with tree removal (Treatment 2), and 9 ft and 22 ft without tree removal (Treatments 1 and 4), respectively (Table 2). Trees topped at 22 ft with tree removal (54 trees/acre) produced slightly more fruit per acre (119 bu) than 108 tree/acre for trees topped to 22 ft without tree removal.

In contrast to 'Lula' trees, 'Booth 8' trees topped to 16 and 22 ft with tree removal (Treatments 2 and 3, respectively) and 22 ft without tree removal (Treatment 4) produced a crop within 18 months after their initial treatment in 1989 (Table 2). During the 1990-91 crop season, trees topped to 16 and 22 ft with tree removal produced a mean of 3.3 and 2.6 bu/tree, respectively. Trees topped initially to 9 ft without tree removal produced no crop while trees topped to 22 ft without tree removal produced a mean of 1.1 bu/tree.

During the 1991-92 crop season, trees topped to 16 and 22 ft with tree removal produced the greatest yields (6.1 and 5.3 bu/tree, respectively). Trees topped to 22 ft without tree removal produced slightly more per tree than during the 1990-91 season. Trees originally topped to 9 ft without tree removal produced a crop (1.2 bu/tree) for the first time.

On a per acre basis, both the 16- and 22-ft treatments with tree removal (54 tree/acre) produced more fruit than the 9- and 22-ft treatments without tree removal during the 1990-91 and 1991-92 crop seasons. This was due to the vigorous vegetative response of 'Booth 8' trees initially topped to 9 ft and the continued shading and lack of productive canopy of trees topped to 22 ft without tree removal.

Canopy location of the crop. Topping treatments had a pronounced effect on fruit location in the canopy (Table 3). 'Lula' trees topped to 9 ft without tree removal had about the same percentage of fruit in the middle (49%) and lower (51%) tree canopy and no fruit in the upper canopy. In contrast, trees topped to 16 and 22 ft with tree removal and 22 ft without tree removal had 66% to 85% of their fruit in the middle third of their canopy, 10% to 33% in the lower canopy, and 1% to 5% in the upper canopy.

Table 2. Seasonal per tree and per acre yields of 'Lula' and 'Booth' trees topped with or without tree removal.[z]

Cultivar	Treatment	Mean Yield/tree/season (bu)[y] 1990-91	Mean Yield/tree/season (bu)[y] 1991-92	Yield/acre/season (bu)[y] 1990-91	Yield/acre/season (bu)[y] 1991-92
Lula	1	0	0.4	0	43
	2	0	1.6	0	86
	3	0	2.2	0	119
	4	0	1.0	0	108
Booth	1	0	1.2	0	130
	2	2.6	6.1	140	329
	3	3.3	5.3	178	286
	4	1.1	1.2	119	130

[z]Treatments 1 and 4 had 108 trees per acre, treatments 2 and 3 had 54 trees per acre after tree removal.
[y]One bu is equal to 55 lbs.

Table 3. Seasonal estimated canopy location of 'Lula' and 'Booth 8' fruit after topping and/or tree removal.

Cultivar	Treatment[z]	Canopy location	Percent of total crop 1990-91	Percent of total crop 1991-92
Lula	1	lower third	—	51
		middle third	—	49
		upper third	—	0
	2	lower third	—	33
		middle third	—	66
		upper third	—	1
	3	lower third	—	28
		middle third	—	68
		upper third	—	4
	4	lower third	—	10
		middle third	—	85
		upper third	—	5
Booth 8	1	lower third	—	63
		middle third	—	37
		upper third	—	0
	2	lower third	58	49
		middle third	42	51
		upper third	0	0
	3	lower third	30	34
		middle third	70	60
		upper third	0	6
	4	lower third	33	15
		middle third	67	83
		upper third	0	2

[z]See text for description of treatments.

During the 1990-91 and 1991-92 seasons, the trend in canopy location of fruit production of 'Booth 8' trees topped to 22 ft with or without tree removal was similar to the 'Lula' treatments. In contrast, 'Booth 8' trees topped to 16 ft with tree removal produced more fruit in the lower tree canopy (58%) compared to the middle (42%) or upper (0%) canopy during the 1990-91 season and nearly equal percentages of fruit in the lower (49%) and middle (51%) canopies during the 1991-92 season. Trees topped to 9 ft with tree removal produced most of their fruit in the lower third of the canopy.

Estimated costs and returns. Initial topping costs were between $112 and $225 per acre depending upon the size of the wood removed (Table 4). The cost of tree removal was about $700 per acre and included stumping and stacking of pruned wood in the tree rows.

All 'Lula' treatments responded to topping by vigorous vegetative growth for the first three years of the trial (1988-1991), and no treatments posted a net gain in revenue (Table 4). During the 1991-92 season all treatments produced a crop; however, the estimated revenue generated did not cover the cost of Treatments 1 and 2. Topping trees to 22 ft without tree removal (Treatment 4) was the most economical treatment after 4 years. Topping to 22 ft with tree removal (Treatment 3) was the next best treatment. Initially, topping to 9 (Treatment 1) and 11 ft

Table 4. Estimated costs and returns for 'Lula' trees topped with or without tree removal.[z]

Treatment[x]	Year	Treatment cost/acre ($)	Yield/acre (bu)[w]	Revenue[y] Gross ($)	Revenue[y] Net ($)
1	1988	225	0	0	–225
	1989	112	0	0	–112
	1990	112	0	0	–112
	1991	0	43	430	430
	1992	820	—	—	–820
	Sum	1,269	43	430	–839
2	1988	225	0	0	–225
	1989	112	0	0	–112
	1990	760	0	0	–760
	1991	0	86	860	860
	1992	112	—	—	–1,209
	Sum	1,209	86	860	–349
3	1988	112	0	0	–112
	1989	814	0	0	–814
	1990	112	0	0	–112
	1991	0	119	1,190	1,190
	1992	112	—	—	–112
	Sum	1,150	119	1,190	40
4	1988	112	0	0	–112
	1989	112	0	0	–112
	1990	112	0	0	–112
	1991	0	108	1,080	1,080
	1992	112	—	—	–112
	Sum	448	108	1,080	632

[z]Cost estimates do not include production costs (e.g., fertilizing, picking, hauling, pesticides, etc.).
[y]Revenue based on a $10.00 price per bushel.
[x]See text for description of treatments.
[w]One bu equals 55 lbs; no crop harvested in 1992.

(Treatment 2) with tree removal resulted in a net loss of income over the four year period of the trial.

In contrast, all 'Booth 8' treatments resulted in a net gain in revenue after three years of the trial (Table 5). The best to worst treatments for generating a positive net income were topping trees to 16 ft and 22 ft with tree removal (Treatments 2 and 3, respectively), topping to 22 ft without tree removal (Treatment 4) and topping to 9 ft with tree removal (Treatment 1).

Discussion

Severe topping to 9 ft resulted in a loss of two years of fruit production in 'Booth 8' trees topped to 9 ft and three years of production in all 'Lula' treatments (Table 2 and 3). In contrast, topping at 16 and 22 ft with tree removal and 22 ft without tree removal substantially increased fruit yields of 'Booth 8' trees during the 1990-91 and 1991-92 seasons.

Topping and removing trees increased the amount of fruit produced in the middle and lower thirds of the tree canopies. This indicates that as the middle and lower third of the trees refoliated, fruit production resumed in those areas. Fruit produced in the lower and middle canopy areas is easier to care for and pick.

Table 5. Estimated costs and returns for 'Booth 8' trees topped with or without tree removal.[z]

Treatment[x]	Year	Treatment cost/acre[w] ($)	Yield/acre (bu)[v]	Revenue[y] Gross ($)	Revenue[y] Net ($)
1	1989	225	0	0	–225
	1990	112	0	0	–112
	1991	814	130	1,300	486
	Sum	1,151	130	1,300	149
2	1989	814	0	0	–814
	1990	112	140	1,400	1,288
	1991	112	329	3,290	3,170
	Sum	1,038	469	4,690	3,644
3	1989	814	0	0	–814
	1990	112	178	1,780	1,668
	1991	112	286	2,860	2,748
	Sum	1,038	464	4,640	3,602
4	1989	112	0	0	–112
	1990	112	119	1,190	1,078
	1991	112	130	1,300	1,188
	Sum	336	249	2,490	2,266

[z]Cost estimates do not include production costs (e.g., fertilizing, picking, hauling, pesticides, etc.).
[y]Revenue based on a $10.00 price per bushel.
[x]See text for description of treatments.
[w]No treatments were applied in 1992; no harvest in 1992.
[v]One bu equals 55 lbs.

Rejuvenating mature, non-productive avocado groves is an expensive process. However, topping trees to 16 or 22 ft with tree removal resulted in the greatest yield increases for both 'Lula' and 'Booth 8' cultivars. Based on costs and returns, the delay in fruit production for 'Lula' treatments may not economically justify a rejuvenation program as attempted here. In contrast, tree removal along with topping may be economically justified in 'Booth 8' groves.

Those avocado cultivars with an upright, vigorous growth habit (e.g., 'Taylor', 'Brookslate', 'Reed', and 'Tonnage'), may not produce fruit for several years after topping. We suggest that non-productive groves be rejuvenated in small blocks over 2 to 5 years in order to distribute the initial costs over several years.

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