defoliation reduced yields to a greater extent under high plant populations. The competition between plants restricted the ability of the plants to compensate for leaf area losses. Interestingly, the crop growth stage when defoliation losses occurred did not affect yields, e.g., defoliation at vining did not reduce yields more than during fruit enlargement. Thus, for growers trying to estimate impact of damage, butternut squash compensated for up to 50% loss of plant population or 33% loss of leaves through increases in individual plant productivity, particularly if damage occurred early in the season. Defoliation under high populations will reduce yields more than at lower populations.

Literature cited

AOAC International. 1995. Official methods of analysis of the AOAC International; Vitamins and other nutrients. AOAC Intl., Arlington, Va.

Brewer, M.J., R.N Story, and V.L. Wright. 1987. Development of summer squash seedlings damaged by striped and spotted cucumber beetles (Coleoptera: Chrysomelidae). J. Econ. Entomol. 80(5):1004–1009.

Manseka, V.D. 1997. Weight loss and other physiological aspects of butternut squash: Effects of prestorage and storage conditions. PhD diss. abstr. 97-16146. Cornell Univ., Ithaca, N.Y.

NeSmith, D.S. 1993. Plant spacing influences watermelon yield and yield components. HortScience 28(9):885–887.

Pedigo, L.P., S.H. Hutchins, and L.G. Higley. 1986. Economic injury levels in theory and practice. Annu. Rev. Entomol. 31:341–368.

Pharr, D.M., S.C. Huber, and H.N Sox. 1985. Leaf carbohydrate status and enzymes of translocate synthesis in fruiting and vegetative plants of *Cucumis sativus* L. Plant Physiol. 77:104–108.

Reiners, S. and D.I.M. Riggs. 1997. Plant spacing and variety affect pumpkin yield and fruit size, but supplemental nitrogen does not. HortScience 32(6): 1037–1039.

Robinson, R.W. and D.S. Decker-Walters. 1997. Cucurbits, p. 6–19. In: J. Atherton and A. Rees (eds.). Crop production science in horticulture series. CAB Intl., New York.

Stacey, D.L. 1983. The effect of artificial defoliation on the yield of tomato plants and its relevance to pest damage. J. Hort. Sci. 58(1):117–120.

Wareing, P.F., M.M. Khalifa, and K.J. Treharne. 1968. Rate-limiting processes in photosynthesis at saturating light intensities. Nature 220:453–457

Watson, D.J. 1937. The estimation of leaf area in field crops. J. Agr. Sci. 27:474–483.

Welles, G.W.H and K. Buitelaar. 1988. Factors affecting soluble solids content of muskmelon (*Cucumis melo* L.). Neth. J. Agric. Sci. 36:239–246.

Widders, I.E. and H.C. Price. 1989. Effects of plant density on growth and biomass partitioning in pickling cucumbers. J. Amer. Soc. Hort. Sci. 48:417–422.

Wien, H.C. 1997. The cucurbits: Cucumber, melon, squash and pumpkin, p. 345–386. In: H.C. Wien (ed.). The physiology of vegetable crops. CAB Intl., New York.

Economic Evaluation of Mechanized Pruning of Coffee in Hawaii

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ADDITIONAL INDEX WORDS. *Coffea arabica*, 'Mokka', 'Red Catuai', 'Yellow Catuai', hedging, stumping, partial budget

SUMMARY. **Marketable coffee (*Coffea arabica*) yield and cost of production under two systems of mechanized pruning—hedging and stumping—were investigated. Data were collected from 1997 to 2001—a single pruning cycle—on three cultivars on three farms on Kauai, Maui, and Molokai. Treatments were variations of hedging and stumping, including time of pruning, methods of re-growth control, and tree in-row spacing were applied to each coffee cultivar. Economic evaluation was based on a partial budget analysis of the actual costs per year of the different pruning systems used on each farm. Mechanical pruning costs per acre for best hedging and stumping treatments across cultivars were 90% and 83% less, respectively, than the current practice of manual pruning. Response to pruning system varied according to coffee cultivar, tree in-row spacing and farm location. The tall cultivar Mokka had higher yields when hedged at 5 ft (1.5 m) tall and 5 ft wide, and the semi-dwarf cultivar Yellow Catuai had higher yields when stumped at 2 ft (0.6 m) tall. Hedge pruning should be done early in the year, January to February, for the semi-dwarfs, 'Yellow Catuai' and 'Red Catuai', but can be delayed until May for 'Mokka'. Annual topping in the hedging systems should be done January to May for 'Yellow Catuai' but maybe delayed until May for 'Mokka' and 'Red Catuai' without yield loss. The economic evaluation revealed that the cost of stumping was higher than hedging. For 'Yellow Catuai' on Kauai the economic evaluation indicated that although the cost of stumping was higher, the accompanying higher yields resulted in a higher gross margin for this system. When stumping, vertical branches can be set with a contact herbicide spray to avoid higher hand pruning costs without lowering yields. Stumps should be narrowed after stumping if spaced, 2.5 ft (0.75 m) the current standard in-row spacing for mechanical harvesting. Wide in-row spacing (5 ft) should be considered by growers when planting or re-planting.**

Coffee has been grown in Hawaii for more than 150 years. The Kona district of Hawaii Island is renown for its Kona Coffee. However in the last decade the decreased profitability in the sugar cane production and its consequent decrease in acreage made available agricultural land suitable for coffee on other islands in the State of Hawaii (Cavaletto et al., 1992). The area of harvested coffee on the islands of Kauai, Maui, Molokai and Oahu has increased from 220 acres (89.0 ha) in 1990 to 4,100 (1,659 ha) in 2000 (Hawaii Agricultural Statistics Service, 2001).

In the Kona district of the island of Hawaii the acreage is scattered in small farms, with an average size of 5 acres (2.0 ha) (Hawaii Agricultural Statistics Service, 2001). On the other islands the acreage is represented primarily by a few large farms: Kauai Coffee on the island of Kauai, with 3,400 acres (1,376 ha), Kaanapali Estate Coffee on the island of Maui with 420 acres (170.0 ha), Coffee of Hawaii with 600 acres (242.8 ha) in the island of Molokai, and Waialua Coffee on the island of Oahu with 170 acres (68.8 ha) (Hawaii Coffee Association, 1998.).

These coffee farms having mechanized virtually all production practices including planting, irrigation, fertigation and harvesting represent a new era of coffee production in Hawaii

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(Bittenbender and Smith, 1999). This on-farm trial started in 1997 evaluated mechanized pruning technology based on earlier research (Bittenbender and Gautz, 1996).

Pruning is the last major labor activity to be mechanized for large-scale production (Bittenbender and Gautz, 1996). Pruning impacts production as coffee bears fruit on the previous year's lateral branch growth and a node will flower only once. Pruning is vital to stimulate the production of new wood. Secondly, it is important to keep the tree size manageable for harvest. An appropriate mechanized pruning system for coffee is likely to vary according to cultivar, location, age of trees, and type of farming system (Drinnan, 1995).

Fleming et al. (1998) estimated that the cost per year for hand pruning a typical farm in Kona, Hawaii is about $1,020/acre ($2,520/ha). Pruning is the second highest operating cost, accounting for 15% of the annual operating costs in Kona. On large newly mechanized coffee farms hand pruning is not economically feasible since the high labor demand per acre during pruning season (January to April) can not be met under Hawaii's current wage and housing situation.

With this context the experiment was developed with two objectives: 1) evaluate the yield potential and related production variables of different pruning strategies, and 2) determine the cost of these pruning strategies and their economic feasibility in different environments. This article reports on the latter. Our economic evaluation was based on a partial budget analysis. Partial budgets allow analysis of the cost difference of the treatments. All other costs incurred by the farm such as harvest and processing costs were not variables and did not affect the decision on which pruning strategy is most appropriate for each cultivar on each farm (Kay and Edwards, 1994).

Materials and methods

Separate randomized complete block design, on-farm experiments, on the three islands of Kauai, Maui and Molokai were conducted. Each experiment had three replications, the number of treatments varied from 10 to 14, according to the location and cultivar. The trees were 9-10 years old, planted as single trees in a hedge row spaced 2.5 × 12 ft (0.75 × 3.6 m) fertilized via drip irrigation, transplanted and harvested mechanically, farmer-managed and never pruned. On Kauai island the cultivar grown was 'Yellow Catuai', semi-dwarf, yellow fruited, drought resistant, a cross of 'Caturra' and 'Mundo Novo' (Medina-Filho et al., 1984). The cultivar was chosen by the grower for its high yield potential in Brazil. On Maui island the experiment was conducted at the same location with two cultivars, 'Red Catuai' and 'Mokka'. The former cultivar was related to 'Yellow Catuai' and produces red fruit (called cherry in the coffee trade). 'Mokka' was probably a Brazilian cross of *C. arabica* 'Tipica' and the landrace 'Mokka' originally from Yemen (Osgood, 1997). On Molokai island, the cultivar was 'Red Catuai'. The data from this site is only briefly mentioned in the results as damage to the irrigation system in the second year resulted in drought-induced dieback of the trees. The dieback drastically reduced production, and consequently the relevancy of the data. These three sites and cultivars except 'Yellow Catuai' were evaluated in a state-wide cultivar experiment by the authors in the late 1980s (Bittenbender et al., 1991), and selected by these farms to establish their orchards.

Pruning strategy. Two different mechanized pruning strategies, hedging plus annual topping and stumping, were evaluated (Table 1). Treatments were chosen based on 12 years of mechanized pruning experiments on 'Guatemala' a tall, land race of 'Tipica' grown in Kona for 100 years (Bittenbender and Gautz, 1996). Within each pruning system we asked questions such as effect of time of hedging, time of topping, and wider in-row spacing. Hedging refers to a one-time reduction of row height, with a horizontal cut, and width, with two vertical cuts, to 5 × 5 ft , at the beginning of the pruning cycle. The hedging treatments were performed either: early, 1 week after harvest (January), or late, 16 weeks after harvest (mid-April), to determine the importance of timing. The interval represented the likely period of the year when a farmer might prune.

Hedged trees were also topped every year (including year of hedging), at a variable date related to the anniversary of hedging. The annual topping reduced the tree height to the level of the highest fruit set for that season to avoid yield loss. The topping treatments used for hedging (Table 1) were early = 0 weeks after hedging anniversary; mid = 12 weeks after hedging anniversary; and late = 20 weeks after hedging anniversary. An additional hedging treatment had a wider in-row spacing, 5-ft instead of 2.5-ft spacing. This spacing was achieved by cutting every other tree at ground level. On Kauai there were two additional hedging treatments. In both the early and late hedging with early topping (in January and April) treatments an adjacent row was lightly tipped on both sides of the hedgerow removing a portion [4 to 6 inches (10.2 to 15.2 cm)] of the lateral branches at the same time as the annual topping.

The stumping strategy was based on the Beaumont-Fukunaga pruning method (Beaumont et al., 1956), developed in Hawaii; modified versions are used in Latin America today. The essence of this system is that all the vertical branches are the same age because all vertical branches are removed every 3 to 5 years. Regrowth is limited to three to six verticals on permanent short trunks to avoid a reduction of yield due to self-shading. Excess vertical branch regrowth is removed by hand (Beaumont et al., 1956; Bittenbender and Gautz, 1996). In the experiment, trees were cut at 2 ft, removing almost all vertical and most lateral branches.

The stumping treatments evaluated three factors: across row width of the multi-stem trunks, method of removing excess regrowth, and in-row spacing. Trunks were narrowed to 10 inches (25.4 cm) across the row using a chain saw or left uncut, more than 10 inches wide. Excess vertical branch regrowth was removed by hand 3 and 5 months after stumping, leaving three new vertical branches or by spraying with 1% a.i. paraquat herbicide. The herbicide was applied when vertical branches were 12 to 18 inches (30.4 to 45.7 cm) in length and basal bark was still green. Paraquat did not harm the trunk as its bark had lignified. Using a tractor-mounted shielded sprayer with flat fan herbicide nozzles the spray was directed to cover the trunk, up to 20 inches (50.8 cm) on one side and up to 24 inches (61.0 cm) on the other side. Vertical branches from the unsprayed zone and escapes were sufficient to renew production. As in the hedged treatments there was one treatment with wide in-row spacing (5 ft).

Treatments were initially imposed using hand-held power equipment —hedgers, chainsaws, and pneumatic loppers, but subsequent topping was with tractor-mounted equipment. To-

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Table 1. Description of mechanized pruning treatments used on coffee farms on Kauai, Maui, and Molokai, Hawaii.

Code	Treatment and description
1	Early hedge 1 week after harvest, mid annual topping 12 weeks after hedge anniversary, regular in-row spacing.
2	Early hedge 1 week after harvest, late annual topping 20 weeks after harvest, regular in-row spacing.
3	Early hedge 1 week after harvest, early annual topping on hedge anniversary, regular in-row spacing.
3.5	Early hedge 1 week after harvest, early annual topping and tipping on hedge anniversary, regular in-row spacing. ('Yellow Catuai' only)
4	Late hedge 16 weeks after harvest, mid annual topping 12 weeks after hedge anniversary, regular in-row spacing.
5	Late hedge 16 weeks after harvest, late annual topping 20 weeks after hedge anniversary, regular in-row spacing.
6	Late hedge 16 weeks after harvest, early annual topping on hedge anniversary, regular in-row spacing.
6.5	Late hedge 16 weeks after harvest, early annual topping and tipping on hedge anniversary, regular in-row spacing. ('Yellow Catuai' only)
7	Early hedge 1 week after harvest, mid annual topping 20 weeks after hedge anniversary, wide in-row spacing
8	Stump at 19.7 inches (50 cm) high, leave trunk width unchanged, remove excess vertical stems with paraquat, regular in-row spacing.
9	Stump at 19.7 inches high, leave trunk width unchanged, remove excess vertical stems by hand, regular in-row spacing.
10	Stump at 19.7 inches high, leave trunk width unchanged, remove excess vertical stems by hand leave six verticals, wide in-row spacing.
11	Stump at 19.7 inches high, narrow trunk width to 9.8 inches (25 cm), remove excess vertical stems with paraquat, regular in-row spacing.
12	Stump at 19.7 inches high, narrow trunk width to 9.8 inches, remove excess vertical stems by hand, regular in-row spacing.

day, these farms use tractor-mounted articulated three-armed saws and sickle bars or self-propelled fixed plane saws to perform all pruning tasks. Our economic analysis is based on equipment actually used by farms at the conclusion of the experiment, tractor-mounted or self-propelled.

The pruning cycle started in January1997. The early hedging and stumping treatments were started approx 1 week after the final harvest of the season. On Kauai the pruning cycle was concluded in January 2000. Only 2 years of harvest were done, as in 1997, the year of pruning, the crop from hedged trees was considered too small to harvest by the farmer. This farm did not to continue the experiment after the 1999 harvest because it had adopted the stump pruning strategy. On Maui the pruning cycle ended for the two cultivars in January 2001. At this site the farmer determined there was sufficient crop on the hedged treatments in 1997 to harvest. No stump pruning treatments were harvested in 1997, which is normal for this severe method of pruning.

Typically coffee trees in Hawaii have three or more hand harvests per season. Some mechanically harvested farms prefer a one-pass harvest regardless of the seasonal spread of ripening; others use a multi-pass strategy. Only single harvests were used in these experiments, therefore total harvested yields and revenues reported in this data might have been higher.

The weight of cherry collected by an over-the-row mechanical coffee harvester (Korvan 9200; Korvan Industries, Inc., Lynden, Wash.) was recorded by plot. Samples were taken at random intervals on the harvester and sorted into immature, ripe, and overripe categories. For each category, the total weight and the weight of 100 cherries were recorded. Maturity composition, percentage of immature, ripe, and overripe cherry was calculated for the harvested yield per plot.

The recovery by weight of green beans (seeds) was determined from the samples of 100 ripe cherry. These were forced air oven dried at 131.0 °F (55 °C) for 24 h then hulled, winnowed, and the weight of the green beans obtained adjusted to 12% moisture content. Green bean recovery from immature cherry was taken from growers' reports as 10% of fresh immature cherry weight. Yield was calculated as the recovery of green bean from the total harvest partitioned according to the sample maturity composition.

Price and yield data from each farm was collected to determine the gross revenues from the sales of green beans, from immature, ripe and raisin (over ripe and dried on the tree fruits that can not be pulped) cherries. Treatments were compared on an economic basis using a partial budget of the mechanized pruning costs and the gross revenues. Other production costs were assumed to be constant, a whole farm budget was therefore not necessary.

The costs reported are the actual costs, incurred for the pruning process at the conclusion of the experiment when mechanical pruning was done on a commercial scale. In the case of Kauai both mechanical hedge and stump pruning were adopted as standard practice during the course of the project. On Maui only hedging was performed commercially, therefore Kauai stumping costs were used to predict those on Maui. Costs for hedge pruning varied for the two farms because of different pruning equipment and wage rates. Difference in the pruning equipment determined hours needed to prune a given area, maintenance and spare parts costs.

The total cost of stumping and hedging means total cost per pruning cycle. The indicated cycles were different for the two locations. In general the length of the pruning cycle was related to the size of the trees. The harvester passes over the trees, therefore the tree size should not greatly exceed the opening of the harvester for optimal harvest. Usually the pruning cycle was considered to be 3 to 5 years, varying also between hedging and stumping, the latter was longer due to the severity of pruning.

Green bean prices differed between farms, cultivars, and green bean quality. On Maui the beans were separated into two categories based upon source: beans from immature and from ripe and overripe cherries. The sale prices used were \$0.50/lb (\$1.10/kg) for green beans from immature cherries for both cultivars, \$3.75/lb (\$8.25/kg) for green beans from ripe and raisin cherries for 'Mokka', and \$3.45/lb (\$7.60/kg) for 'Red Catuai'. On Kauai the number of categories was greater, based upon separation methods of green bean in the mill. For comparison the categories were grouped into two classes: beans from immature cherries and from ripe and raisin cherries using an average of the sale prices of the Kauai categories falling into those two classes. Sale price for 'Yellow Catuai' green beans from immature cherries was \$1.00/lb (\$2.20/kg) and from ripe and raisin cherries was \$3.00/lb (\$6.60/kg). Selling prices used were averages of the prices in the years between 1997 and 2001.

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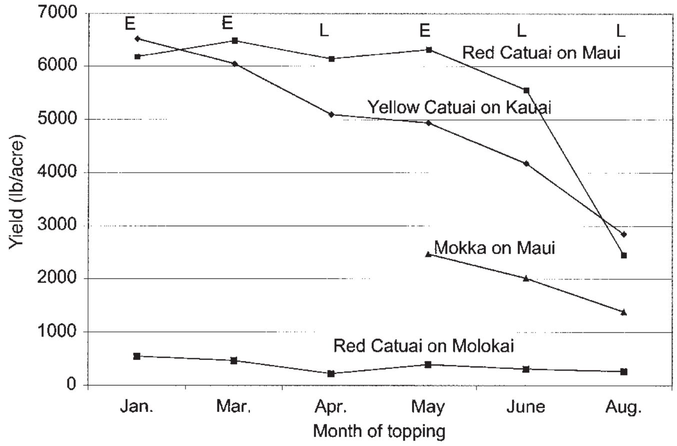

Fig. 1. Green bean yields of mechanized hedging treatments for pruning cycle by date of topping, (E and L indicate if topping were done on early or late hedged treatments) on Kauai, Maui and Molokai for 'Mokka', 'Red Catuai', and 'Yellow Catuai' (1 lb/acre = 1.12 kg·ha^{-1}).

Results and discussion

Green bean yield based upon collected cherry varied according to the pruning treatments, cultivars and locations. Among the hedging treatments, early hedging had higher yields than late hedging. In all locations hedging treatment 5, late hedging late topping, had the lowest yields due to insufficient time after annual topping in September for maturation of new vegetative growth to flower the following spring. Because of this, treatment 5 was dropped from the last year (2000-01) data collection in Maui for 'Red Catuai' at the farm's request. Yields of 'Red Catuai' on Molokai were low because of impact of water-stress from irrigation failure, although still following the trend of all other cultivars. (Fig 1.)

On Maui, 'Mokka' responded poorly to stumping (Table 2). Green bean yields for the hedge treatments averaged 1,060 lb/acre (1,160 kg·ha^{-1}) larger over the pruning cycle than with stumping because stumped trees did not produce as many lateral branches. Treatment 2, early hedging late topping (May), provided the highest yield for this cultivar, followed by treatment 7, early hedging mid topping (March) and wide in-row spacing, and treatment 1, early hedging mid topping (March). All early hedging treatments yielded better than late hedging ones.

Both 'Red Catuai' and 'Yellow Catuai' responded positively to stumping. Highest yields for 'Red Catuai' were: early hedge mid topping (March); narrow stump, paraquat-set-verticals; narrow stump, hand-set-verticals; and wide stump, hand-set-verticals with wide in-row spacing. For this cultivar narrow stump, standard in-row spacing performed better then wide stump in terms of yield production, with a difference of as much as 1,500 lb/acre (1,650 kg·ha^{-1}).

'Yellow Catuai' had the highest yields. The highest yielding treatment was wide stump, hand-set-verticals with wide in-row spacing followed by the narrow stump, hand-set-verticals; early hedge, early topping (January); early hedge, early topping and tipping; and early hedge, mid topping (March) with wide in-row spacing.

On Kauai, the costs for the 3 years pruning cycle for hedging treatments were: regular hedging plus annual topping in subsequent years, $246/acre ($607/ha) (treatments 1 through 6); hedging and topping with an additional annual tipping $292/acre ($721/ha) (treatments 3.5 and 6.5); and regular hedging but with a wide in-row spacing $198/acre ($488/ha) (treatment 7). Stumping costs were higher: stumping and paraquat setting of vertical branches $460/acre ($1,136/ha) (treatment 8) vs. hand setting of vertical branches $1,367/acre ($3,377/ha) (treatment 9); stumping and narrowing the stump and paraquat setting of vertical branches $530/acre ($1,309/ha) (treatment 11) vs. hand setting of vertical branches $1,437/acre ($3,550/ha) (treatment 12) and finally stumping and hand setting vertical branches with a 50% reduction of trees due to wide in-row spacing: $835/acre ($2,063/ha) (treatment 10).

Hedging cost for a 4 year cycle for the Maui farm was $476/acre ($1175/ha). Hedging cost for the wider in-row spacing treatment 7 was $334/acre ($824/ha). Since the Maui farm had not adopted stumping on a commer-

Table 2. Comparison of highest yielding mechanical hedging and stumping pruning strategies recommended for mechanized coffee production for various cultivars, locations, showing annual mean production, pruning costs and gross margins based on partial budget analysis of pruning and related costs.

Cultivar and location[x]	Treatment (code)[w]	Annual green bean yield[z] (lb/acre)	Annual gross revenue ($/acre)	Annual pruning cost ($/acre)	Annual gross margin[y] ($/acre)
Mokka, Maui	Hedge (2)	616[v]	2,200[u]	119	2,090
	Stump (8)	423	1,550	115	1,430
Red Catuai, Maui	Hedge (1)	1,620	5,370	119	5,250
	Stump (11)	1,610	5,350	132	5,220
Yellow Catuai, Kauai	Hedge (3)	2,170	5,590	82	5,510
	Hedge (7)	2,110	5,710	66	5,640
	Stump (10)	2,400	6,730	278	6,450
Guatemalan[t], Kona	Kona style	883	4,970	1,020	3,950

[z]Green beans for Kauai and Maui are from immature and ripe and overripe cherries, sale prices vary. For Kona due to selective hand picking green beans are only from ripe cherries, one sale price.
[y]Gross margin = revenues from green bean sales minus pruning costs.
[x]Pruning cycle length: Maui = 4 years, Kauai = 3 years, and Kona = 1 year.
[w]Treatment with the highest green bean yield and gross margin among hedging and stumping.
[v]1 lb/acre = 1.12 kg·ha^{-1}.
[u]$1/acre = $2.47/ha.
[t]Kona production and revenue data from Hawaii Agricultural Statistics Service (1999); Kona pruning costs from Fleming et al. (1998).

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cial scale stumping costs for Maui were Kauai costs. Pruning costs were the same for both cultivars on Maui.

Costs for stumping ranged from two to six times higher than hedging. The stumping system used on Kauai required more passes through the field for pruning and mulching and damaged the irrigation system more than hedging. Nevertheless the gross margin (total revenues minus pruning costs) was higher for stumped trees due to the higher yield recovered. For 'Yellow Catuai' the very high yields of treatments 10 and 12, although both stumped with hand setting treatments, with the third and the highest pruning cycle costs respectively, resulted in higher gross margins. For 'Mokka' the difference in yield between hedged and stumped treatments was so great that distribution of treatment means of both yields and gross margin were the same.

Another outcome revealed by the gross margin analysis was a deficit in the first year of pruning when stumped because there was no yield. Yield response to hedging in the first year varies by tree age, cultivar and degree of pruning severity; 'Red Catuai' on Maui yielded enough in the year of pruning that returns from every hedging treatment paid for the pruning costs. The gross margin reported that first harvest were in the range of $822 to $2,313/acre ($1,979 to $5,586 /ha) according to the yields of different treatments. The yields for the other hedging treatments were not determined because the growers considered them too low to harvest. These costs must be carried to the following crop harvest, resulting in a larger deficit for stumping which had higher costs the first year.

Conclusions

Mechanical pruning is feasible and cost effective. Mechanical hedge pruning costs were 90% less than manual pruning. The costs of stumping were generally greater than hedging and more concentrated in the year of pruning. Using more robust forestry pruning equipment for small size tree harvesting would probably increase the initial capital costs but decrease the total number of passes through the orchard needed to complete stumping, and thus decrease the hours of labor. Vertical stems can be set with herbicide at lower costs than manual setting with no significant impact on yield.

If hedging were chosen, then hedging and annual topping should be performed early in the year, soon after harvest and topped on the hedging anniversary (Fig. 1). The suggested timing for topping 'Red Catuai' on Maui was January to May. Optimum timing for annual topping of 'Yellow Catuai' on Kauai was January to February. The combination of late hedging (end of March to beginning of April) and late topping (August - September) had negative impact on the production due to a poor tree performance for all cultivars and locations.

Semi-dwarf cultivars ('Red Catuai' and 'Yellow Catuai') responded well to stumping; the stumped treatments with standard in-row spacing and narrowed stumps had higher yields than not narrowed stump treatments. However due to the outstanding performance of both hedge (7) and stump with wide in-row spacing (10) treatments it is strongly recommended to consider wider in-row spacing when planting or replanting an orchard. This would reduce establishment, as well as some costs related to annual cultural practices, like pruning.

Some cultivars like 'Mokka' respond negatively to stumping, therefore pruning needs to be evaluated with respect to a cultivar's response to stumping.

At the Kauai and Maui farms growth data (Gautz et al., 2002) indicated that the length of pruning cycle was different for the two locations. This was due to cultivar, location, climate and horticultural practices of the two farms. The data suggested that the pruning cycle on Kauai should be 4 years not 3 as in the experiment. Maui should be 5 years not 4 as in the experiment. Once created, partial budgets can be used as an interactive tool to adjust for variations of costs or equipment by inserting new data. This process allowed each farm to customize the spreadsheet analysis using its own data.

Literature cited

Beaumont, J.H., A.H. Lange, and E.T. Fukunaga. 1956. Initial growth and yield response of coffee trees to a new system of pruning. J. Amer. Soc. Hort. Sci. 67: 270–278.

Bittenbender, H.C., and L.D. Gautz. 1996. Mechanized pruning. Proc. Hawaii Coffee Assn. 1:29–34.

Bittenbender, H.C., G. Upreti, N. Y. Nagai, and C.G. Cavaletto. 1991. Evaluating performance of coffee cultivars in Hawaii using stability analysis. Proc. Association Scientifique Internationale du Café. 14: 677–673.

Bittenbender, H.C., and V.E. Smith. 1999. Growing coffee in Hawaii. College Trop. Agr. Human Resour., Univ. Hawaii Manoa, Honolulu.

Cavaletto, C.G., N.Y. Nagai, and H.C. Bittenbender. 1992. Yield, size and cup quality of coffee grown in the Hawaii State coffee trial. Proc. Assn. Scientifique Intl. du Café. 14:674–678.

Drinnan, J. 1995. Managing bearing trees, p. 61–78. In: R. Lines-Kelly (ed.). Coffee growing in Australia—A machine-harvesting perspective. Rural Ind. Res. Dev. Corp., Kingston, Austral. Capitol Territory.

Fleming, K.D., H.C. Bittenbender, and V. Easton Smith. 1998. The economics of producing coffee in Kona. College Trop. Agr. Human Resour., Univ. Hawaii Manoa, Honolulu, AgriBusiness (July) AB-11.

Gautz, L.D., H.C. Bittenbender, and S. Mauri. 2002. Effect of mechanized pruning on coffee regrowth and fruit maturity timing. 2002 Annu. Mtg. Amer. Soc. Agr. Eng., Chicago, 28–31 July. Paper 021110.

Hawaii Agricultural Statistics Service. 1994. Statistics of Hawaii agriculture. Hawaii Agr. Stat. Serv. USDA, Honolulu.

Hawaii Agricultural Statistics Service. 1999. Statistics of Hawaii agriculture. Hawaii Agr. Stat. Serv. USDA, Honolulu.

Hawaii Agricultural Statistics Service. 2001. Hawaii coffee. 24 Dec. 2002. <http: //www.nass.usda.gov/hi/speccrop/ coffee.htm>

Hawaii Coffee Association 1998. Growers panel. Proc. Hawaii Coffee Assn. 3:21–24

Kay, R.D. and W.M. Edwards. 1994. Farm management. 3rd ed. McGraw-Hill, New York.

Medina-Filho, H.P., A. Carvalho, M.R. Sondahl, L.C. Fazuoli, and W.M. Costa. 1984. Coffee breeding and related evolutionary aspects. Plant Breed. Rev. 2:101–150.

Osgood R.V. 1997. Importance of a breeding program for coffee. Does Hawaii need a coffee breeding and selection program? Proc. Hawaii Coffee Assn. 2:36–40.

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