UVI Food and Agriculture

RESEARCH

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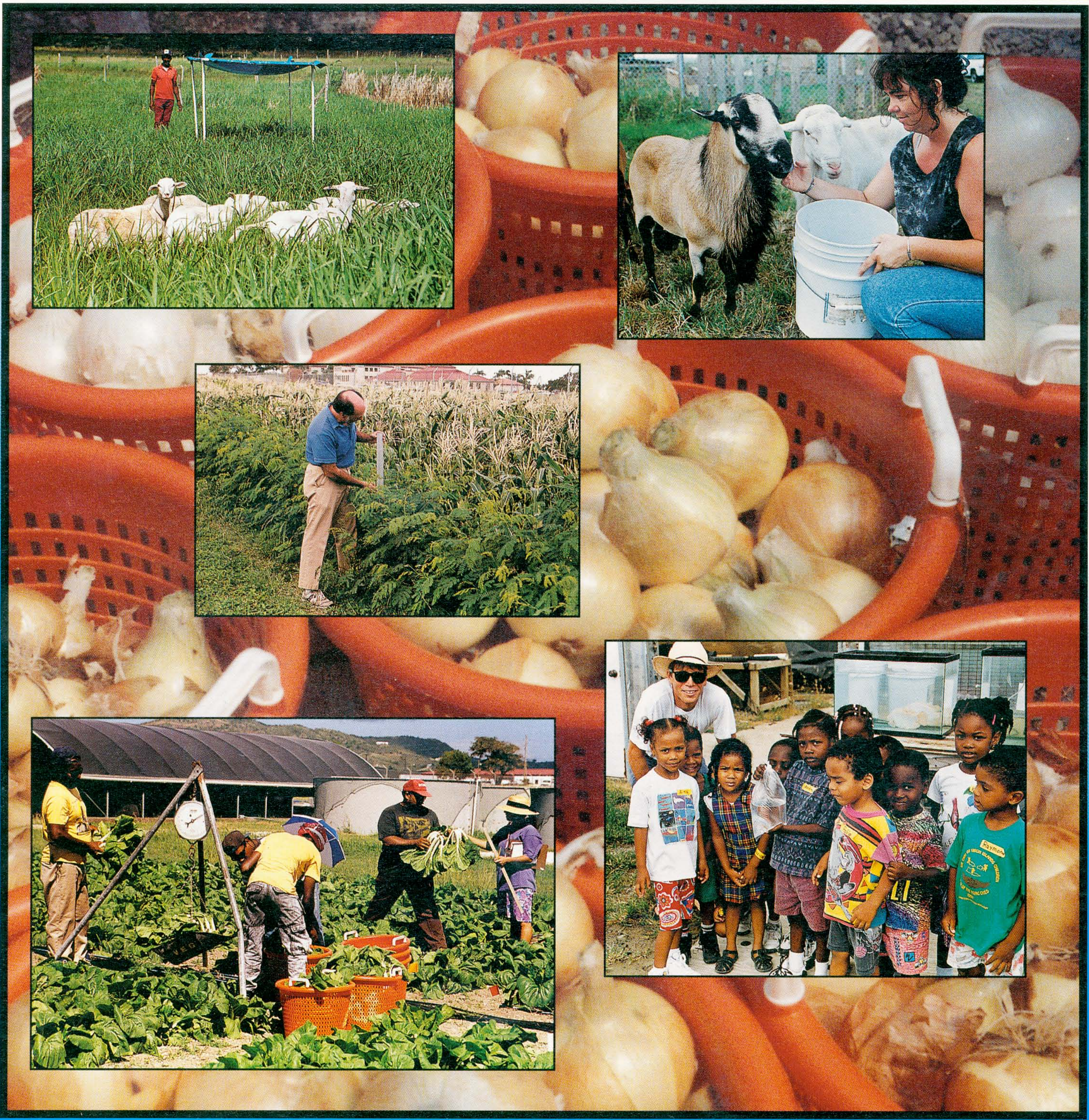
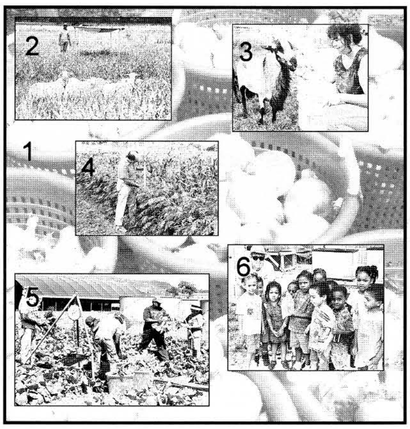


On our cover . . .



1. A bountiful harvest of onions from a variety trial.
2. Antonio Rodriguez herds a flock of St. Croix White hair sheep in a rotational grazing study on native pastures.
3. Joni Rae Collins feeds Barbados Blackbelly and St. Croix White hair rams which are used in studies comparing these two breeds.
4. Jim O'Donnell measures the height of *Leucaena leucocephala*, a nitrogen-fixing shrub, as part of a study in which vegetables are cultivated in alleys between hedgerow species.
5. Reinardo Vasquez, Nelson Benitez, Roger Southwell, Paulino Perez and Jacqueline Kowalski (left to right) harvest a field of pak choi that were irrigated and fertilized in a study to compare aquaculture effluent with conventional methods.
6. Kurt Shultz demonstrates the joys of fish farming to a group of Head Start children.

UVI Food and Agriculture

RESEARCH

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Effluents From Intensive Tilapia Tank Culture as a Nutrient Source for Pak Choi Production

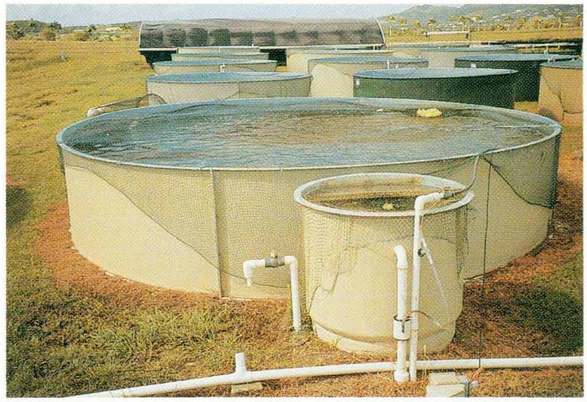
William M. Cole, Manuel C. Palada, Stafford M.A. Crossman, Kurt A. Shultz and Jacqueline A. Kowalski

Shortage of freshwater resources limits both fish and vegetable production in the Virgin Islands. Farmers rely on irrigation in dry periods to maintain steady production. Well water is the primary source of irrigation water, although rainwater catchment is also used. Tanks or plastic-lined ponds used for water storage may also be used to culture fish, thus using the water for two crops. High yields of fish per unit volume of water can be obtained with intensive fish culture in tanks, which reduces land and water requirements. An essential requirement of these systems is the concentration of solid wastes (sludge) by sedimentation or filtration before removal. Sludge, which has a high concentration of organic matter, nitrogen and phosphorus, is a good nutrient source for crop production. A study was conducted at the University of the Virgin Islands Agricultural Experiment Station to compare rearing tank water and sludge from tilapia culture with commercial fertilizer for the production of pak choi (*Brassica rapa* L. Chinenses). The study also compared tilapia production and water quality in outdoor tanks from which solids were removed (SR) to those with no solids removed (NSR).

All-male Florida red tilapia, originally derived from a cross between *Oreochromis urolepis hornorum* and *0. mossambicus,* (initial weight = 16.5 g) were stocked at a rate of 24 fish/m^3 in six 31.2 m^3 circular rearing tanks and fed a 32% protein feed for 168 days. The initial feeding

Table 1. Fish production parameters for all-male Florida red tilapia (initial weight = 16.5 g) cultured for 168 days in outdoor tanks with (SR) and without (NSR) solids removal. For each row, values followed by the same letter are not significantly different by t-test analysis, (P>0.05).

	SR	NSR
Final weight (g)	422.5a	363.8b
Growth rate (g/d)	2.4a	2.1b
Feed conversion ratio (FCR)	1.60a	1.61a
Survival (%)	88.3a	86.3a
Yield (g/m³/d)	51.2a	42.6b
Final biomass (kg/m³)	9.0a	7.6b



"Crop irrigation with nutrient-rich aquaculture effluents is an example of sound resource management through the reuse of water and the recycling of nutrients."

rate was 4% of biomass per day and was gradually reduced to 0.8 or 1.4% of biomass. All tanks were aerated with a 1/20-hp vertical lift pump. Each of three SR rearing tanks was equipped with a 1.4-m³ cylindro-conical, external clarifier (settling tank) to facilitate settling of solids. Water was drawn from the center drain in the rearing tank to the clarifier using an air-lift pump and then returned by gravity at a rate of approximately 22 L/min. Sludge from each SR system was drained from the clarifier twice daily, combined and stored in a 2-m³ tank. Samples of rearing tank water and sludge were analyzed at 14-day intervals for total ammonia-nitrogen (TAN), nitrite-nitrogen (NO_2-N), nitrate-nitrogen (NO_3-N), total phosphorus (TP), potassium (K), total suspended solids (TSS) and chlorophyll *a*. Dissolved oxygen (DO) in the rearing tanks was measured weekly.

At the end of the experiment, mean values for final weight, growth rate, feed conversion ratio (FCR, total feed administered : wet weight gain of fish biomass), survival, yield and final biomass were compared. Treatment means for fish production and water quality parameters were compared by t-test analysis and were considered significant at the 0.05 level of probability.

Two sequential trials (experimental period = 42 and 37 days) were conducted to evaluate the effect of rearing tank water and sludge from the tilapia tanks on the yield of field-grown pak choi. Twenty-day-old seedlings were transplanted into 6.0 x 1.8 m plots. Each plot contained four rows spaced 45 cm apart. Beginning two weeks after transplanting, the plants were drip irrigated or fertilized with the following treatments:

1) Rearing tank water from which sludge was removed (SR) and applied using Hardie E-2 drip emitters.

2) Rearing tank water from which no sludge removed (NSR) applied using Hardie E-2 emitters.

3) Sludge applied via drip irrigation using a 15-mm poly-ethylene (PE) hose with 0.5 cm emitters spaced every 30 cm and applied once per week.

4) Sludge application similar to treatment 3, but applied 2-3 times per week.

5) Sludge applied once per week via drip irrigation using 15-mm PE hose with microtubing emitters spaced at 30 cm.

6) Liquid nitrogen fertilizer (fertigation) applied through drip irrigation using Hardie E-2 emitters. The fertilizer was injected at a total rate of 100 kg N/ha divided into eight equal weekly applications. Granular P and K were applied (50kg 1ha each) to plots one week after transplanting.

7) Granular fertilizer applied 10 cm

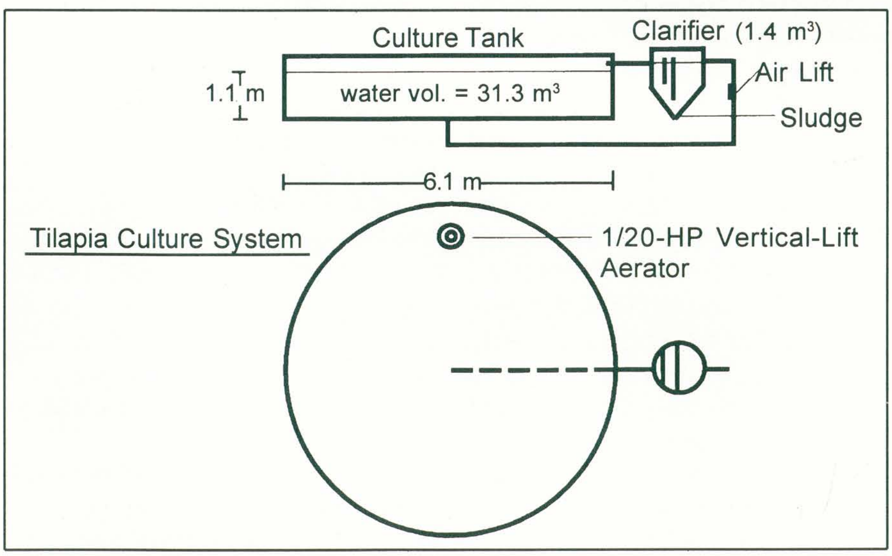


Table 2. Mean concentrations of water quality parameters analyzed at 14-day intervals over 168 days in which Florida red tilapia were cultured in outdoor tanks with (SR) and without (NSR) solids removal. Within SR and NSR rows, values followed by the same letter are not significantly different by t-test analysis, ($P>0.05$).

	SR	NSR	Sludge
Dissolved oxygen (mg/L)	6.9a	6.5a	--
Total ammonia-nitrogen (mg/L)	0.32a	0.33a	0.78
Nitrite-nitrogen (mg/L)	1.96a	2.17a	4.70
Nitrate-nitrogen (mg/L)	71.1a	46.4b	40.2
Total phosphorus (mg/L)	7.21b	15.24a	107.08
Potassium (mg/L)	52.3a	52.8a	52.8
Total suspended solids (mg/L)	227b	682a	11071
Chlorophyll *a* (μ/L)	655b	1029a	22197

from the base of the plants at a rate of 100N-50P-50K kg/ha. The N was equally applied in three splits at one, three and five weeks after transplanting. Plots were drip irrigated using Hardie E-2 emitters.

To maintain similar levels of P and K, all plots were fertilized with 50 kg P and 50 kg K per ha as basal application. Tensiometers were installed at a 15 cm depth in representative plots to monitor soil moisture tension which was maintained at 20 kPa. All treatments were replicated four times in a randomized complete block design. At the end of each trial, treatment means for plant size and total yield were compared and separated for significant differences using Duncan's Multiple Range Test.

Tilapia cultured in SR tanks had a significantly higher final weight and growth rate than fish cultured in the NSR tanks (Table 1). Feed conversion ratios and survival did not significantly differ between the SR and NSR treatments. Mean concentrations of TAN, NO_2-N and DO were not significantly different between the SR and NSR treatments, but mean TSS was significantly lower and mean $N0_3$-N was significantly higher in the SR treatment (Table 2). Nitrate-nitrogen, the primary form of inorganic nitrogen in the rearing tanks, increased from approximately 10.5 mg/L to 161.9 mg/L and 94.3 mg/L in the SR and NSR treatments respectively. Likewise, TP increased from 0.1 mg/L in both treatments to 14.9 mg/L (SR) and 33.3 mg/L (NSR) by the end of the experiment. Potassium concentrations in the SR and NSR tanks were similar throughout the study and increased over time (SR, 3.2-131.1 mg/L; NSR, 3.2-131.4 mg/L). By the end of the experiment, the TSS concentration in the NSR tanks was 1250 mg/L compared to 368 mg/L in the SR tanks. The lowest concentrations of DO were 3.4 mg/L (SR) and 4.1 mg/L (NSR), both observed on day 147. Mean concentrations of TP, TSS and chlorophyll *a* were approximately 15, 49 and 34 times higher in the sludge than in the SR rearing tanks.

"Results from the two pak choi trials indicate that rearing tank water and sludge from tilapia tank culture may be used to obtain yields comparable to commercial fertilizer application."

In the first trial, pak choi fertilized weekly with sludge were significantly larger than plants fertilized with granular fertilizer or water from either the SR or NSR rearing tanks (Table 3). Similar results were observed in the second trial. In both trials, yields of pak choi fertilized with rearing tank water or sludge had total yields similar to or higher than those fertilized with the inorganic fertilizers.

Ammonia, the primary metabolic waste product of most fish, is toxic to fish at low concentrations and must be removed from intensive fish culture systems. Most recirculating aquaculture systems rely on bacteria to convert ammonia to nitrite, which is also toxic to fish at low concentrations, and then to nitrate, which is toxic only at high concentrations. This process is called nitrification and is usually accomplished by recirculating the water through a fixed-film biofilter. The biofilter is a means of increasing surface area for bacterial growth. Water quality results from this study indicate that nitrification occurred in the water column of both SR and NSR systems as seen by the increase of NO_3-N over time.

Relatively high concentrations of TP, TSS and chlorophyll *a* (algae) in the sludge compared with concentrations in the SR fish rearing tanks indicate that the clarifiers were effective in removing these substances from the system. In addition, the ability of the clarifier to remove solids was demonstrated by much higher concentration of TSS in the NSR tanks compared to the SR tanks. Fish production results show that solids removal increases tilapia

Table 3. Mean size and yield of pak choi fertilized with waste water generated from tilapia tank culture and commercial inorganic fertilizers. Within columns for each experiment, means followed by the same letter are not significantly different using Duncan's Multiple Range Test, (P>0.05).

	Size (g)	Total Yield (t/ha)
Experiment 1		
SR rearing tank water	288b	19.28b
NSR rearing tank water	300b	20.03b
sludge (0.5 cm once/wk)	393a	26.10a
sludge (0.5 cm 2-3x/wk)	353ab	23.38ab
sludge (adapter)	333ab	22.15ab
fertigation	320ab	21.23ab
band	300b	19.93b
Experiment 2		
SR rearing tank water	614ab	41.03ab
NSR rearing tank water	653a	43.63a
sludge (0.5 cm once/wk)	791a	47.40a
sludge (0.5 cm 2-3x/wk)	662a	44.20a
sludge (adapter)	612ab	40.88ab
fertigation	674a	45.03a
band	527b	35.20b

"As demand for fresh water increases, particularly in arid and semiarid regions, the development of techniques for water conservation and reuse are essential."

production in outdoor tanks without fixed-film biofiltration.

Results from the two pak choi trials indicate that rearing tank water and sludge from tilapia tank culture may be used to obtain yields comparable to commercial fertilizer application. In addition to providing a nutrient source for crop production, repeated application of aquaculture effluents could improve soil fertility by increasing organic matter.

As demand for fresh water increases, particularly in arid and semiarid regions, the development of techniques for water conservation and reuse are essential. Intensive aquaculture systems conserve water by increased yield per unit volume. As the aquaculture industry grows and fish farming practices intensify, the disposal of effluents is becoming an environmental concern. Crop irrigation with nutrient-rich aquaculture effluents is an example of sound resource management through the reuse of water and the recycling of nutrients.

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Promising Bulb Onion Varieties for Commercial Production in the U.S. Virgin Islands

Manuel C. Palada, Stafford M.A. Crossman and Jacqueline A. Kowalski

Onion (*Allium cepa* L.), one of the major vegetable crops in the world, ranks fifth in terms of production area and volume. In the U.S., onion ranks fourth in terms of area of production and value. Although the U.S. is one of the leading countries producing onions, imports have been steadily increasing since 1970. This is because the per capita consumption and demand for onions have been increasing for the past two decades. Onion is also one of the top ten vegetable imports of the U.S. Virgin Islands. In 1993, a total of 3.8 million pounds of onion worth $3.3 million was shipped from the U.S. mainland to the Virgin Islands. This value represents the second highest after potatoes. In addition, the Virgin Islands also imported onions from other regions outside the U.S. totalling $1.3 million.

Although the Virgin Islands is not self-sufficient in vegetable production including onions, vegetable imports can be reduced by encouraging local production. The climate and soils of the Virgin Islands are suitable for growing onions on a commercial scale provided growers use improved production technology such as microirrigation. However, successful onion production depends on the type of cultivars being grown. Growing onions for bulbs is mainly determined by the response of cultivars to daylength and temperature. These factors in turn determine the type of onion cultivars.

Daylength or photoperiod is an important factor which influences production of bulb onions. The critical daylength varies from 11-16 hours. Onion cultivars are classified according to the approximate photoperiod necessary to induce bulb formation. Based on bulbing response to photoperiod, onion cultivars are grouped into: short day (>12-13 hr); intermediate (>13.5-14 hr); long day (>14.5-15 hr); and very long day (>16 hr). Bulb formation occurs when the photoperiod is longer than the minimum daylength characteristic for the cultivar. Temperature also influences bulbing and interacts with daylength. Onions require high temperatures to trigger their reaction to the effect of long daylength on bulb formation. Tropical onion cultivars can grow at temperatures between 22-30°C (72-86°F). High temperatures seem to shorten the time necessary for the bulbing response, but very high temperatures can retard bulbing. In contrast, cool temperatures and adequate soil moisture favor early growth and establishment of onions. This is essential in providing maximum vegetative growth desired before bulb formation is initiated. Bulb size and total yield are determined by plant size at the start of bulb formation; hence, the bigger the plant the more likely that good and excellent bulb yields will be produced. As the plant matures and bulbs attain full size, hot and dry conditions are preferred for ripening and harvesting.

Most onion cultivars are very sensitive to daylength and temperature; therefore, their range of adaptation is very limited. Consequently, cultivars should be developed for a particular region, and, generally, shortday cultivars are preferred for the tropics. Introduction of new cultivars should be preceded by local checks to ensure that their optimal growing temperature and photoperiod requirements are compatible with local climatic conditions. It is essential that cultivars be carefully tested under local

Table 1. Bulb diameter and height of onion cultivars in St. Croix, U.S. Virgin Islands, 1994-95.

Cultivar	Bulb Diameter (mm)			Bulb Height (mm)		
	1994	1995	Mean	1994	1995	Mean
Contessa	73.4a	80.1b	76.8	71.4ab	67.7c	69.6
Granex 33	69.6a	96.1ab	82.9	60.4b	70.8c	65.6
Granex 429	77.4a	88.9ab	83.2	64.8ab	72.2bc	68.5
Texas Grano 502	74.7a	89.3ab	82.0	76.0a	83.2b	79.6
Texas Grano 1015	74.3a	100.8a	87.6	74.8ab	95.2a	85.0
Texas Grano 1025	75.9a	87.2ab	81.6	72.6ab	76.6bc	74.6
Year Mean	74.2	90.4	82.3	70.0	77.6	

For each column, means followed by similar letters are not significantly different (P>0.05) by Duncan's Multiple Range Test.

conditions to evaluate their horticultural adaptation.

Short day onion cultivars are best suited for the Caribbean region, and seed companies are making progress in breeding them. There are cultivars adapted to tropical areas which develop bulbs during increasing daylight conditions of 11-13 hours, or that are almost completely day-neutral. Cultivars recommended for the tropics include 'Granex' and 'Texas Grano'. The objective of this study was to evaluate onion cultivars suitable for commercial production in the Virgin Islands.

Seeds of six onion cultivars ('Contessa,' 'Granex 33,' 'Granex 429,' 'Texas Grano 502,' 'Texas Grano 1015' and 'Texas Grano 1025') were sown in speedling trays (Speedling Mfg., FL) containing Pro Mix BX (Premier Brands, PA) in October 1993 and 1994. Seedlings were transplanted into the field at 47 days after sowing for both trials. The field trials were replicated four times in a randomized complete block design. Plots consisted of three rows 3.6 m (11.8 ft) long, with a spacing of 0.3 m (11.8 in) both between plants and rows. A drip irrigation system was installed consisting of 1.27 cm (0.5 in) poly-hose (Hardie Irrigation, CA) as the submains and 15 mil Hardie New Tape with laser drilled orifices 0.3 m (11.8 in) apart as the laterals. Soil moisture levels were maintained at field capacity until the crop approached maturity. Fertilizer was band-applied at rates of 150 kg N, 100 kg P and 200 kg K per ha (134 lb N, 89 lb P and 179 lb K per acre), using ammonium sulfate, triple superphosphate and sulfate of potash, respectively. All plots were hand-weeded as required and no pesticides were applied, even though sporadic infestations by defoliators were observed during the growing season.

"The climate and soils of the Virgin Islands are suitable for growing onions on a commercial scale, provided growers use approved cultivars and improved production technology."

Onions were harvested when plant leaves began to fall over (or necks were broken). Two harvests were performed in both trials because some cultivars matured earlier than others. Data collected were diameter, height and weight of onion bulbs. All data were analyzed using the GLM procedures of SAS (SAS Institute, Cary, NC).

The mean maximum daytime temperatures during the 1994 growing season ranged from 28.8°C (83.9°F) in February to 30.1°C (86.1°F) in April. Temperatures during the 1995 growing season ranged from 28.9°C (84.1°F) in March to 31.3°C (88.3°F) in May. During the 1994 trial, Granex onion cultivars produced bulbs with the largest ('Granex 429,' 77.4 mm) and the smallest ('Granex 33,' 69.6 mm) diameters (Table 1). Bulb height varied from 60.4 to 76.0 mm with Texas Grano cultivars producing bulbs which were higher than other cultivars (Table 1). 'Texas Grano 1015' produced a yield (32.3 t/ha) which was significantly higher than 'Texas Grano 502' (25.1 t/ha) and 'Granex 33' (18.7 t/ha) as shown in Table 2. 'Granex 33' was the earliest maturing cultivar, harvested at 81 days after transplanting. However, this cultivar produced the lowest yield and the smallest bulbs.

During the second year of study (1995), 'Texas Grano 1015' (Table 1) produced bulbs with a significantly larger diameter (100.8 mm) than 'Contessa' (80.1 mm). 'Texas Grano 1015' also produced bulbs with a height of 95.2 mm, and was significantly higher than the other cultivars (Table 1). Even though 'Granex 33' was harvested earlier (127 days after transplanting) than the 'Texas Grano' cultivars, the bulb diameter (96.1 mm) and yield (49.2 t/ha) of 'Granex 33' ranked second among all cultivars.

All cultivars produced yields of over 39 t/ha in 1995, with mean yields ranging from 39.3 t/ha for 'Granex 429' to 53.2 t/ha for 'Texas Grano 1015' (Table 2). 'Texas Grano 1015' produced the greatest yield of bulb onions in both years with mean yield of 44.3 t/ha (Table 2). Yields were generally higher during the 1995

Table 2. Yield of onion cultivars grown in St. Croix, U.S. Virgin Islands, 1994-95.

Cultivar	Yield (t/ha)		Mean Yield (t/ha)
	1994	1995	
Contessa	27.6ab	39.4a	33.5
Granex 33	18.7c	49.2a	33.9
Granex 429	30.1ab	39.3a	34.7
Texas Grano 502	25.1b	43.8a	34.5
Texas Grano 1015	32.3a	53.2a	44.3
Texas Grano 1025	26.6ab	41.5a	34.1
Year Mean	26.7	44.4	

For each column, means followed by similar letters are not significantly different (P>0.05) by Duncan's Multiple Range Test.

Table 3. Days from planting to harvest of onion cultivars grown in St. Croix, U.S. Virgin Islands.

Cultivar	Cropping Season	
	1994	1995
Contessa	100	127
Granex 33	81	127
Granex 429	110	127
Texas Grano 502	110	154
Texas Grano 1015	110	154
Texas Grano 1025	110	154
Mean	104	141

"The early maturity characteristic of 'Granex 33' can have a significant economic benefit for commercial growers, since it will be available early and can have a premium price until the other cultivars are ready for market."

season compared to 1994. Average yield was 26.7 t/ha in 1994 compared to 44.4 t/ha in 1995. The difference in yield between years can be attributed to the length of the cropping season (Table 3). The average number of days from transplanting to harvest in 1994 was shorter (104 days) than in 1995 (141 days). Higher rainfall in 1995 from January to March (165 mm) compared to 127 mm for the same period in 1994 may have extended the growing season and maturity of the crop in 1995. Harvesting was therefore delayed during 1995, since it took longer time for onions to dry in the field because of relatively high moisture.

Onions are sensitive to small environmental changes which can affect a cultivar's performance not only from location to location, but also within the same location from year to year. Yields obtained from these trials are comparable to yields from other Caribbean countries.

Bulb appearance and characteristics of some onion cultivars are shown in Figure 1. 'Contessa' is a white-skinned cultivar, and, as such, can be marketed as a specialty onion. 'Granex 33' produced very good yields in 1995, compared to low yields in 1994. The performance of this cultivar in 1995 merits further evaluation regarding its potential as a recommended cultivar. It is the earliest maturing of all the cultivars tested, harvested one month earlier than Texas Grano cultivars in both years. The early maturity characteristic of 'Granex 33' can have a significant economic benefit for commercial growers, since it will be available early and can obtain a premium price until the other cultivars are ready for market. Other advantages in growing the early maturing cultivar are less labor, especially for weeding, required to produce the crop and less water use for irrigation. Furthermore, early harvest will leave the land available for the grower to produce another crop.

These evaluation studies have clearly demonstrated the potential for commercial onion production in the Virgin Islands. Growers will have the option of producing early or late maturing cultivars depending on their overall production and economic goals. Both Granex and Texas Grano cultivars are ideal and suitable for growing, and adopting these cultivars will help growers realize their goals for successful onion production.

This research was supported in part by the U.S. Department of Agriculture under Hatch Grant No. 0158036.

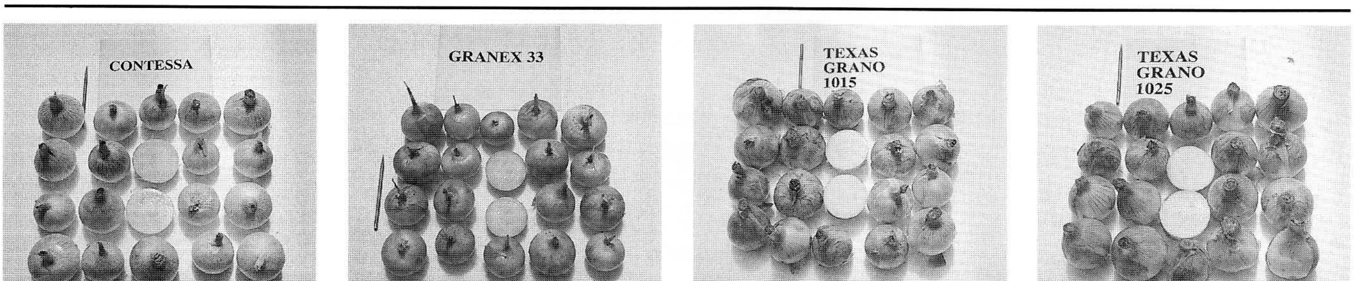


Figure 1. From left, bulb appearance and characteristics of onion cultivars 'Contessa,' 'Granex 33,' 'Texas Grano 1015,' and 'Texas Grano 1025' from the 1994 cropping season.

Sheep Grazing Pressure Effects on Productivity of Guinea Grass Pasture

Optimum post-graze guinea grass stubble height should be approximately 0.3 m.

Martin B. Adjei, Terry J. Gentry and Robert W. Godfrey

The ruminant livestock industry in the Virgin Islands and the Caribbean at large is supported primarily by grazing native pastures. These pastures are dominated by guinea grass *(Panicum maximum)* and the browse legume leucaena *(Leucaena leucocephala)* in productive sites. Native pastures also usually contain some herbaceous legumes such as desmanthus *(Desmanthus virgatus)* and teramnus *(Teramnus labialis)*, and can, if properly managed, satisfy much of the nutritional requirement of ruminant livestock. However, guinea grass is not drought tolerant and its inability to produce forage in a cyclic dry season is perhaps its chief limitation. Pasture overgrazing, especially during the dry season, has resulted in widespread range deterioration in the Virgin Islands to less productive associations of hurricane grass *(Bothriochloa pertusa)* and the spiny woody legume casha *(Acacia* spp.). Under conditions of extreme overgrazing, a number of broadleaf weeds such as maran *(Croton astroites)*, side *(Sida carpiniifolia)*, man-batter-man *(Achyranthes indica)*, thistleroot *(Argemone mexicana)*, physic nut *(Jatropha curcas)*, hollow stalk *(Leonotis nepetoefolia)*, castor bean *(Ricinus communis)*, stinging nettle *(Tragia volubilis)* and even bare ground become dominant.

This experiment was conducted to determine the carrying capacity of native, predominantly guinea grass, pasture for sustainable sheep production in the Caribbean based on an evaluation of (1) dynamics of pasture botanical composition and (2) animal performance.

The experiment was conducted at the sheep research facility of the University of the Virgin Islands Agricultural Experiment Station. Each of four levels of herbage allowance (HA) [4, 7, 10 and 13 kg DM 100-kg^{-1} body weight (BW)] were assigned to three 0.2-ha fields of renovated native pasture in a randomized complete block design. Each pasture replicate was subdivided into three 0.07-ha paddocks that were grazed in rotation of 14 days of grazing, followed by 28 days of rest to give a grazing cycle of 42 days. Two tester weaned lambs (approximately 16 kg initial BW) and additional grazer animals, to meet prescribed HA, were allowed to graze a pasture 24 h d^{-1}, beginning in February, 1992. All sheep were weighed at 14-day intervals in order to make adjustments in grazers to meet prescribed HA. Animals were given free access to shade, mineralized salt and water. Testers were replaced when their BW reached approximately 30 kg and grazing was continued rotationally through 1993 and 1994. There were nine grazing cycles in each season (378 d). Weight changes of testers were used to calculate average daily gain (ADG) for each 42-day grazing cycle and also for the entire season. Stocking rate (kg BW ha^{-1} d^{-1}) was calculated using both tester and grazer animals. Gain ha^{-1} was calculated as the product of

Figure 1. Annual stocking rate associated with grazing native pasture at different levels of herbage allowance.

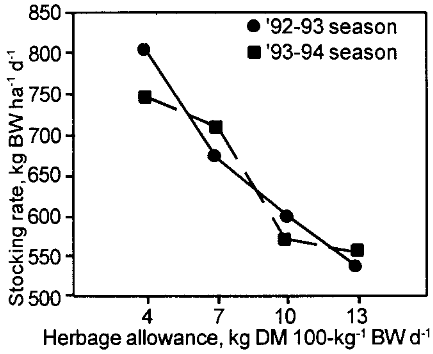
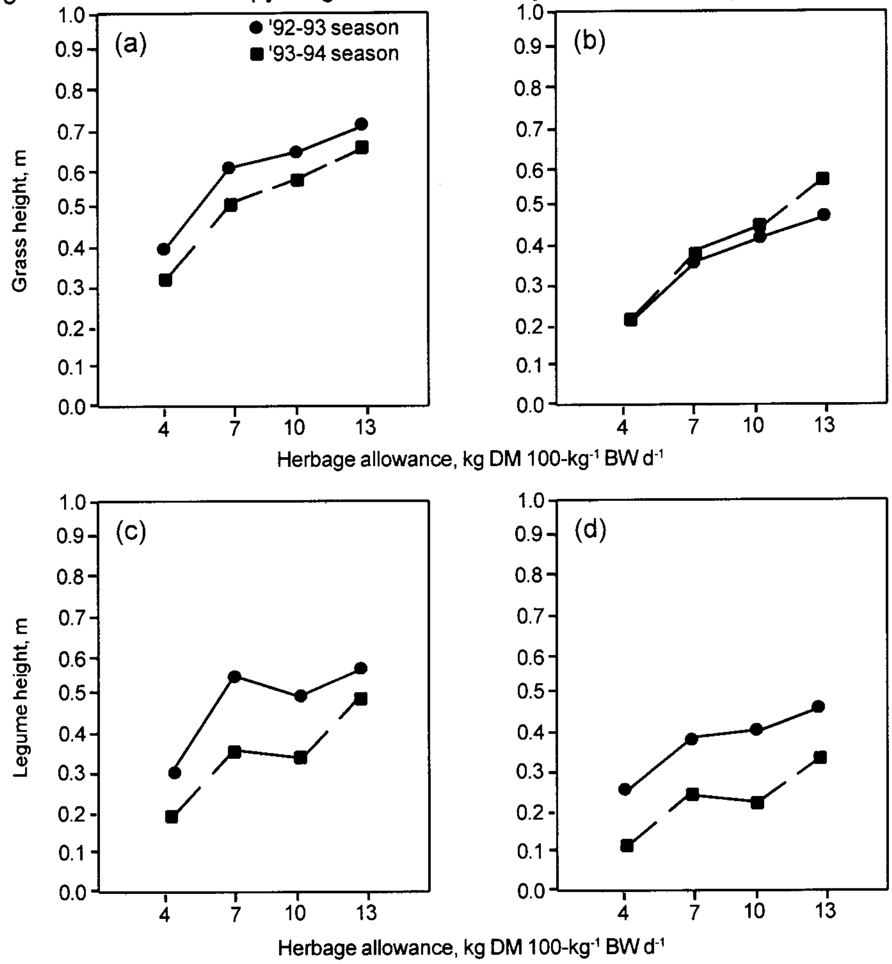


Figure 2. Pre- (a) and post- (b) graze guineagrass; and pre- (c) and post- (d) graze leucaena canopy heights as affected by levels of herbage allowance.



ADG, stocking rate adjusted for the average tester BW and the number of grazing days.

Herbage mass (HM), an instantaneous measure of total weight of herbage per unit area of ground at the start (pre-graze) and end (post-graze) of each grazing in a paddock was estimated by clipping forage in six 0.5 m^2 randomly selected plots to 7.5 cm stubble height. Subsamples were dried at 60 °C to constant weight for dry HM ha^{-1}. Pre-graze and post-graze herbage canopy heights were measured for guinea grass and leucaena from six random spots in each paddock. Dried pre-graze herbage was composited across paddocks within a pasture for each 42-day grazing cycle, ground and analyzed for crude protein (CP) and in vitro organic matter digestion (IVOMD), but these data are not presented here.

Frequency of plant species (guinea grass, hurricane grass, leucaena, desmanthus, teramnus, casha and broadleaf weed) occurrence was measured at the beginning of the trial and then annually (June-July), using a modified line transect and point method. The point consisted of a 0.325 m square quadrat. Lines were laid at 5.0 m intervals across the width of a paddock and quadrat was dropped every 1.0 m along the line, making 1.0 x 5.0 m^2 grids on each paddock. Plants with canopy falling within the quadrat were recorded as present. Bare ground was also recorded when it covered more than 50% of the quadrat.

Carrying capacity (stocking rate at optimum herbage allowance) of the native pasture was determined by regressing HA separately on ADG and botanical data using the REG procedure of SAS.

The two-year mean seasonal stocking rate associated with prescribed levels of herbage allowance ranged from 540 to 775 kg BW ha^{-1} d^{-1} (Figure 1). Given that an average mature St. Croix White sheep weighs approximately 35 kg, these values corresponded with 15 to 22 mature sheep ha^{-1} for the highest and lowest HA, respectively. This represented a linear ($P<0.0001$) decline in SR with increasing HA.

Both the pre- and post-graze guinea grass canopy heights were positively related to HA. Pre-graze guinea grass canopy height increased in a curvilinear pattern ($P<0.001$) from 0.35 m to 0.65 m as HA was increased (Figure 2a). Post-graze grass canopy height increased from 0.2 m to 0.45 m with increasing HA (Figure 2b). In both cases, the greatest increase in canopy height occurred between the 4 and 7% HA, followed by marginal increments as HA was increased further.

Changes in leucaena canopy height were characterized by significant linear ($P<0.0001$), quadratic ($P<0.01$) and cubic ($P<0.03$) effects of HA (Figure 2c and 2d). Analysis conducted using orthogonal contrasts showed no statistical difference in pre- or post-

"Although short-term high animal production is obtainable with high stocking rates, the results from this experiment provide direct evidence of rapid guineagrass pasture deterioration to undesirable plant species under that type of management."

graze canopy height between the 7 and 10% HA for any season.

Pre- and post-graze herbage mass provided the best overall relationship to HA across all grazing cycles (seasonal R^2 =0.61, P<0.0001). Pre-graze herbage mass increased linearly from 1.0 to 2.5 Mg ha^{-1} as HA was increased from 4 to 13% (Figure 3a). Post-graze herbage mass increased curvilinearly from 0.7 to 2.0 Mg ha^{-1} with no statistical difference between values for the 7 and 10% HA (Figure 3b).

Guinea grass frequency of occurrence prior to initiation of grazing in 1992 was approximately 95%. This frequency remained practically unchanged under all HA during the first year of grazing. However, the frequency of guinea grass occurrence decreased to 75% following two-year rotational grazing at the 4% HA compared with 85-95% at the remaining HA (Figure 4a). By contrast, the proportion of leucaena present in the original pasture decreased by 20-30% after two-year grazing, regardless of HA (Figure 4b). Visual observation indicated selective leucaena grazing by sheep and greater grass competition at the higher HA treatments which probably contributed to the lack of response of leucaena frequency to HA. Of the other important pasture legumes, the frequency of teramnus, which initially was 12%, decreased to 2.5-7% in an inverse linear relationship to HA after two-year grazing (data not shown). Desmanthus also showed increased frequency of occurrence under heavier grazing pressure. Its initial frequency prior to 1992 grazing was 26%. Desmanthus frequency at the end of two-year grazing was 23, 31, 29 and 39% for the 13, 10, 7 and 4% HA treatments, respectively.

Among the pasture weeds, the original frequency of hurricane grass occurrence was 3%. At the end of two-year grazing, the incidence of hurricane grass on pasture had increased to 15-24% (Figure 5a). However, the effect of HA on hurricane grass population dynamics was not clear-cut. This was partly due to the confounding effect from a large shade tree (*Swietenia mahagoni*) in one replicate of the 10% HA treatment. Sheep congregated in shaded areas and also in areas adjacent to alleyways which created pockets of overgrazed sites even at the higher (7-13%) HA treatments. Therefore, whereas the sixfold increase in hurricane grass incidence at the liberal HA was restricted to overgrazed microenvironments, the increase at the 4% HA was widespread throughout the entire pasture.

Casha (*Acacia* spp.) frequency of occurrence, which initially stood at 1%, increased independently of HA to 1.5-3% after two-year grazing (data not shown). However, HA had a negative linear effect on other broadleaf weed (BLW) incidence following two-year grazing. The initial 1992 pregrazing frequency of BLW occurrence was 17%. That

Figure 3. Forage dry matter on-offer at pre- (a) and post- (b) grazing as affected by herbage allowance.

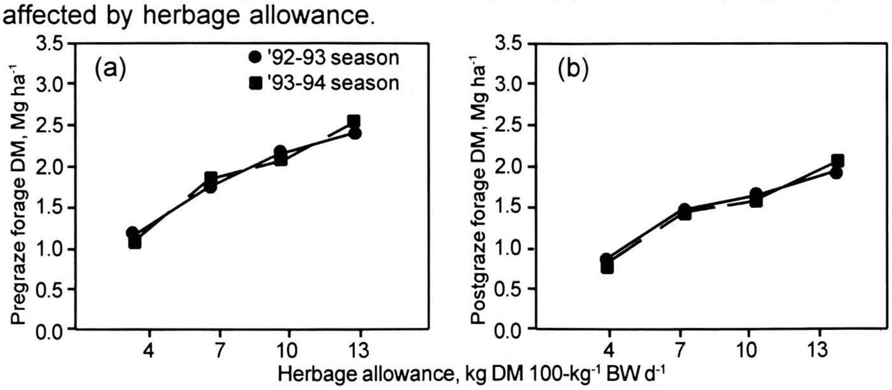


Figure 4. The frequency of occurance of guineagrass (a) and leucaena (b) relative to their initial 1992 pregrazing occurances (95% and 45%, respectively) as affected by levels of herbage allowance.

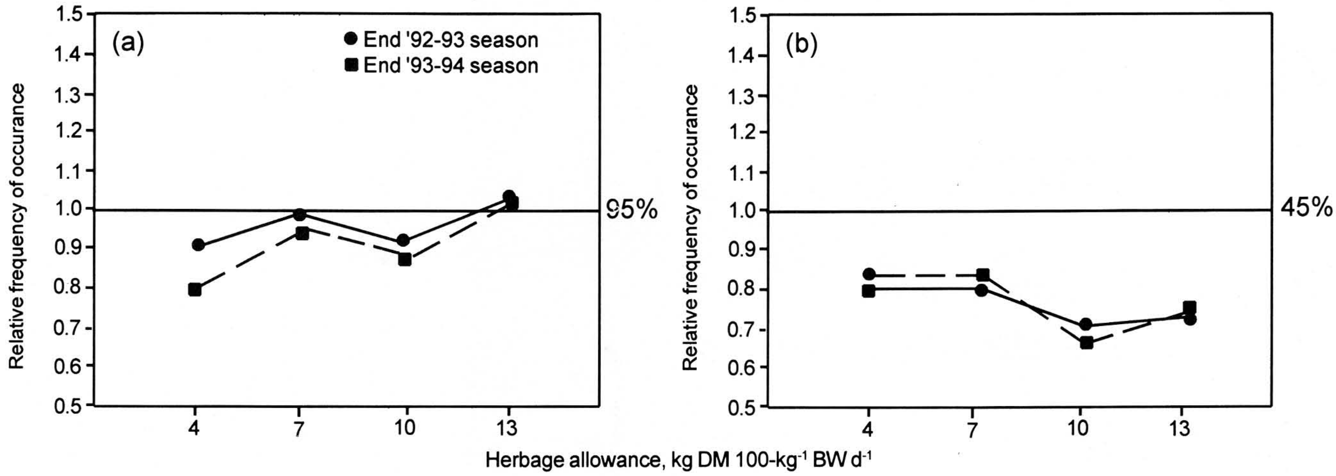
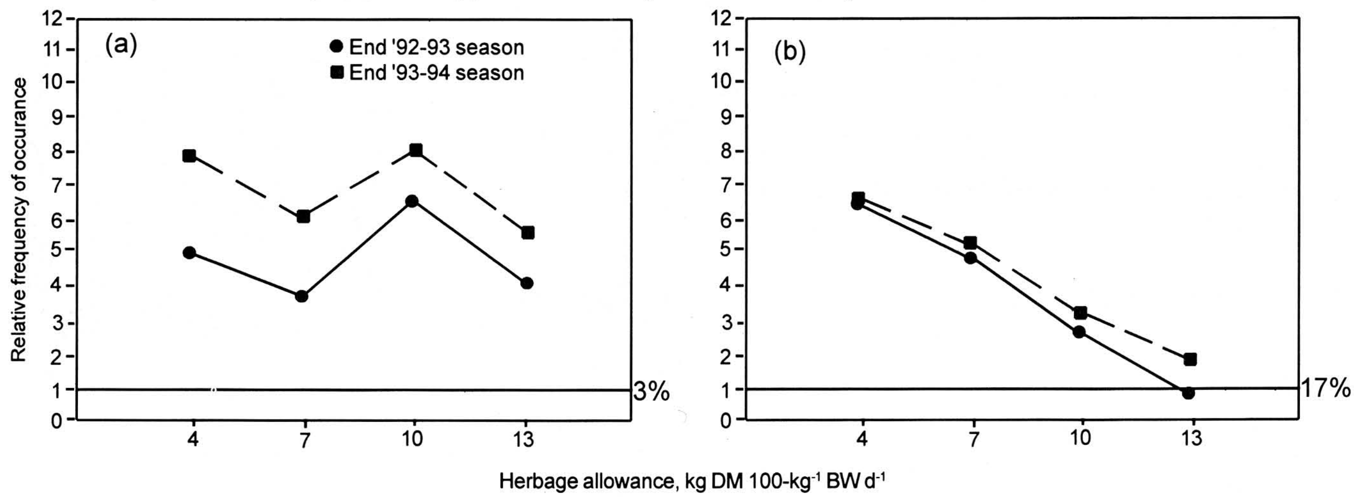


Figure 5. The occurance of hurricane grass (a) and broadleaf weeds (b) relative to their initial 1992 pregrazing occurances (3% and 17%, respectively) as affected by levels of herbage allowance.



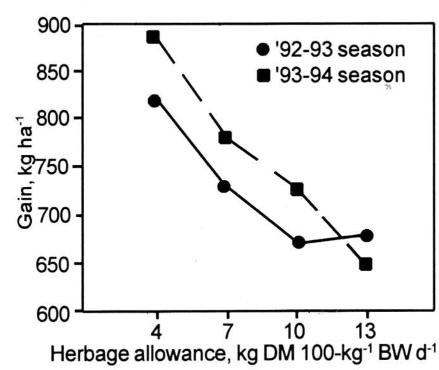
value remained constant under 13% HA treatment but increased linearly to approximately 100% as HA was reduced to 4% (Fig 5b).

Sheep average daily gain ranged between 0.071 and 0.076 kg and the effect of HA was not significant. However, as a result of major differences in animal stocking rates, sheep seasonal (378 d) liveweight gain increased from 660 kg ha^{-1} with 13% HA to 845 kg ha^{-1} with 4% HA treatment.

Although short-term high animal production is obtainable with high stocking rates, the results from this experiment provide direct evidence of rapid guinea grass pasture deterioration to undesirable plant species under that type of management. Minor differences in botanical parameters between the 7 and 10% HA treatments seem to indicate the locus of an optimum range. For a rotational grazing management system, this optimum will correspond with varying the stocking rate between 575 and 690 kg BW ha^{-1} d^{-1} depending on the rainfall situation. The concentration of hurricane grass weed on repeatedly grazed pockets even at liberal HA suggests a lower carrying capacity for a continuously grazed system. Further experiments are being conducted to compare pasture performance under a faster rotation with a continuous grazing system.

This research was supported in part by the U.S. Department of Agriculture under Hatch Grant No. 0159522.

Figure 6. Annual sheep liveweight gain per hectare as affected by herbage allowance.



Papaya Ringspot Virus, Symptoms and Control

Thomas W. Zimmerman and Jeanette A. Richards

Figure 1. Papaya stem and petioles with watersoaked streaks or lesions that are visible symptoms of PRV.

Papaya (*Carica papaya*) production throughout the world has been devastated by the papaya ringspot virus (PRV). This viral disease costs the papaya industry millions of dollars each year and can be a limiting factor to growing papaya in areas of Hawaii, Guam, Florida, the Caribbean, Africa, Australia and the Far East.

The Daily Gleaner newspaper from Jamaica last year reported that the Agriculture Ministry had ordered the destruction of 81 ha of papaya, valued at $600,000, that were suspected to have PRV. Each year in southeastern Mexico, 90% of the papaya in plantations die from PRV.

Papayas are now grown only as an annual crop, and production cannot meet local demand. The Virgin Islands was an exporter of papayas until the early 1980's.

Papaya production in the Virgin Islands is presently sporadic with few fruits being sold at local markets or roadside stands. However, the demand for papaya is high, both at the local markets and at the hotels and restaurants that cater to tourists.

Infection and Symptoms

Papaya ringspot virus is a member of the potyvirus group and multiple strains of PRV exist from varying tropical regions around the world. Papaya ringspot virus is closely related to PRV-W, which is also known as watermelon mosaic virus 1. The host range for PRV includes papayas, cucurbits such as pumpkin, squash, cucumbers and melons and relatives of beets in the Chenopodiaceae family. The virus is principally transmitted by aphids but can also be transmitted through wounds from contaminated tools or equipment. The virus spreads rapidly once it occurs in an orchard.

Symptoms of the virus include: water-soaked streaks or lesions on the stems and leaf petioles (Figure 1); ringspots on the fruit (Figure 2); mottled and distorted leaves (Figure 3); premature ripening and reduced flavor; reduced plant vigor, low fruit set and smaller fruits; and, finally, death of the plant.

Any plant stress caused by drought or the cooler temperatures experienced from December through February will amplify the development of the viral symptoms. Once introduced, PRV has never been successfully eradicated from a production region.

Control of PRV

Presently, 100% control of PRV is not possible. However, certain factors can delay the outbreak of the virus in a papaya orchard. First, locate the papaya field in an isolated area away from other established or diseased papayas. Planting a windbreak around the orchard can act as a natural barrier in isolating the orchard from the insect vector.

Do not grow other PRV host plants such as squash, melons, cucumbers or beets near the papaya. Inspect the orchard weekly for signs of the disease and remove infected plants. Fruit set on plants prior to infection with PRV will not develop the istotion or ringspot symptoms on the fruit.

Pest Control

Routine pest control will inhibit the aphid vector and delay the viral disease outbreak. Maintain a regular spray program for disease-carrying insects and pests. Apply adequate fertilizer for maximum growth and production in a short period of time. Growing strong healthy plants that have not been subjected to stress can delay disease symptoms in a papaya planting.

Varietal Selection

Natural resistance to PRV has not been found in *Carica papaya* after screening large collections of papaya lines and cultivars. Presently, there are no commercial papaya varieties that are resistant to PRV. However, some varieties, such as 'Cariflora,' have been developed with increased tolerance to PRV.

Papaya varieties that were screened at the Agricultural Experiment Station of the University of the Virgin Islands on St. Croix have indicated varying levels of tolerance to PRV (Table 1). The most tolerant varieties, after nine months in the field, include '356-3,' 'PR6-65' x 'Cariflora' and 'Cariflora.' An advantage found in planting 'Cariflora' is that flowering may occur within three months after planting while 'Sunrise' and 'Kapoho' took five and six months, respectively. The variety 'Kapoho' became infected with PRV prior to flowering. The solo 'Sunrise' related varieties are very susceptible to PRV (Table 1) with limited production potential for PRV infested areas.

Growers should plant the most tolerant papaya varieties available and avoid the most susceptible varieties. The use of ground covers in the papaya field can influence the spread of PRV. The papaya ringspot virus spread more quickly through a papaya field when mowed grass was used as a ground cover, as compared to a chipped wood mulch or tilled soil (Table 2). The grass may harbor the aphids that spread this viral disease. The wood chip mulch provided the greatest deterrent to the spread of PRV and also preserved the soil moisture.

Control of PRV through Cross Protection

Cross protection is a system in which plants infected with one strain of a virus are protected from the severe effects of a second related strain of the same virus. Under warm conditions, above 25 °C, papayas inoculated with the mutant PRV strains grow well and do not show conspicuous symptoms. The fruit of some plants had a few ringspots that became less apparent at maturity and did not affect the quality of the fruit. However, when temperatures drop below 20 °C, or during rainy and cloudy conditions, chlorotic spots appear on the leaves and small ringspots appear on fruit. As the temperatures rise above 25 °C, new developing leaves and fruit have less apparent viral symptoms. The mild symptoms may be repressed by applying more fertilizer to the trees.

Cross protection can only delay expression of severe symptoms; superinfection by persistent PRV strains can still occur. If cross protection breaks down before flowering, no economic benefit is gained. Cross protection, when tested in Puerto Rico, was not effective in

Table 1. Progression of PRV infection through a field of twelve papaya varieties over time.

	Total	PRV Infection					
		5 mo		7 mo		9 mo	
Papaya Varieties	Plants	Plants	%	Plants	%	Plants	%
Cariflora	65	1	2	17	26	28	43
SS x CFL F2	41	7	17	16	39	27	66
Washington	39	0	0	7	18	19	49
PR 6-65	35	1	3	6	17	15	43
PR 6-65 x CFL F2	32	0	0	6	19	11	34
Solo 64	25	2	8	7	28	18	72
Barbados Dwarf	23	0	0	10	44	15	65
Kapoho	23	2	9	16	70	20	87
Tainung-2	20	2	10	6	30	10	50
Yeun Nong-1	20	2	10	7	35	11	55
356-3	20	2	10	2	10	2	10
Exotica	18	0	0	9	50	17	94
Sunrise	13	0	0	5	39	13	100
Total	374	19	5.1	114	30.5	206	55.1

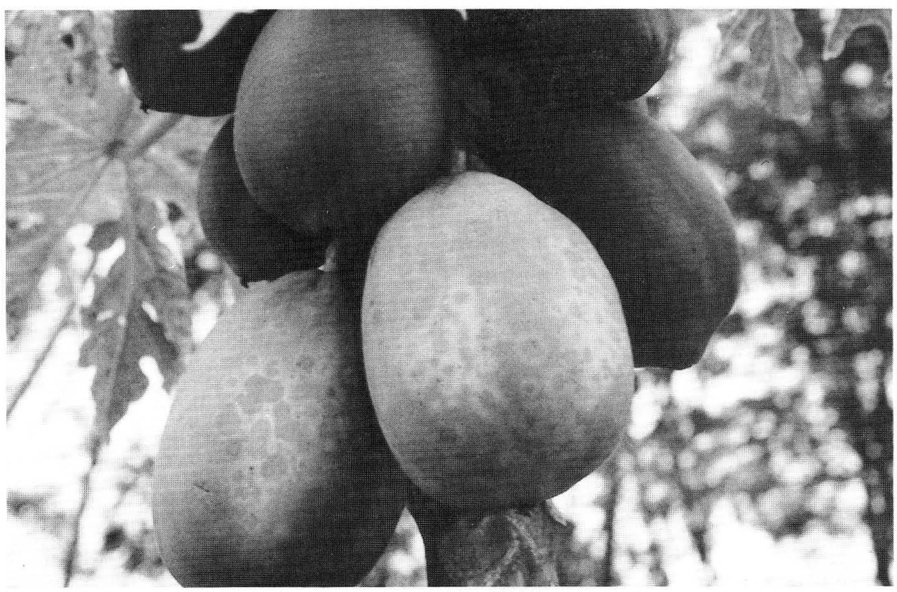


Figure 2. Developing papaya fruit with ringspots that are associated with PRV.

Table 2. The influence of ground cover in a papaya field and the spread of PRV infection over time.

	Total	5 mo		7 mo		9 mo	
Treatment	Plants	PRV	%	PRV	%	PRV	%
Grass	118	18	15.3	52	44.1	78	68.1
Mulch	120	6	5	28	23.3	61	50.8
Tilled	136	11	8.1	34	25	67	49.3

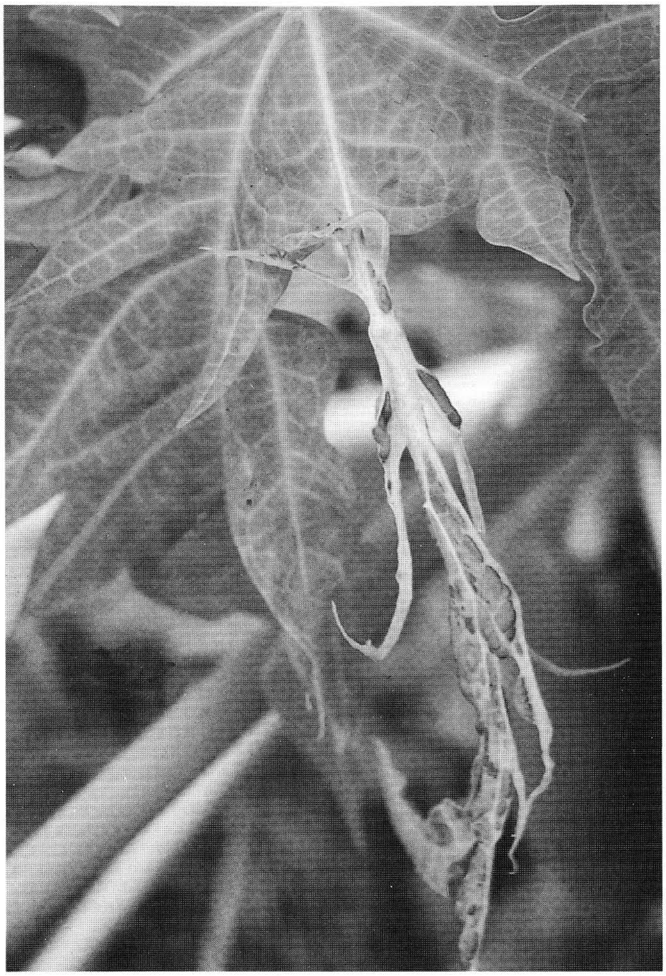


Figure 3. Mottled and distorted papaya leaves: signs of PRV.

"UVI-AES, in cooperation with the University of Puerto Rico and Cornell University, is working to bioengineer resistance to a local PRV strain into papaya cultivars grown in Puerto Rico and the Virgin Islands."

reducing or controlling the Caribbean strain of PRV.

Genetically Engineered Viral Resistance

Genetic engineering or transformation involves the transfer of genetic information for a specific trait or characteristic from one type of organism to another in a way that permits stable incorporation and expression of the foreign genes in the recipient organism. Researchers have demonstrated that the transfer of a gene for the viral coat protein (CP) into virus-susceptible plants can cause resistance to the viral disease. The presence of the Hawaiian PRV-CP gene in transgenic papaya plants has provided resistance to the Hawaiian strain of PRV. However, these transgenic papaya plants are susceptible to strains of the PRV found in other regions of the world, including the Caribbean.

Through a 1994 Caribbean Basin Administrative Group grant, UVI-AES, in cooperation with Dr. Bryan Brunner from the University of Puerto Rico and Dr. Dennis Gonsalves from Cornell University, is working to bioengineer resistance to a local PRV strain into papaya cultivars grown in Puerto Rico and the Virgin Islands.

Zygotic embryos, developing seeds from green fruit 90-114 days after flowering, are placed into a plant tissue culture system. A special tissue culture medium formulation has been successful for somatic embryogenesis on 16 papaya cultivars. Somatic embryogenesis is the regeneration of embryos or seed-like structures from unorganized cell clusters. Depending on the papaya cultivar, somatic embryos form within 4 to 8 weeks. After 8 weeks, somatic embryos are matured and germinated as a normal seed.

The first phase of the study has been completed with the successful tissue culture regeneration of 16 papaya varieties. The second phase of inserting the PRV resistance gene into papaya has begun. The final goal of having locally-grown papaya cultivars that are immunized against the Virgin Islands strain of PRV, by bioengineering transgenic papayas with the coat protein gene from PRV, is now on the horizon. The future for papaya production looks bright with the development of disease resistance in the local papaya varieties.

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Evaluation of Trees for Use as Hedgerows in Alley Cropping

J. J. O'Donnell, Manuel C. Palada, Jacqueline A. Kowalski, Aberra Bulbulla and Stafford M.A. Crossman

Alley cropping is an agroforestry system in which trees and crops are combined in a systematic manner in order to maintain a stable, sustainable environment for crop production. There are two main components in an alley cropping system: the hedgerow formed by trees or shrubs, and the alleys between the hedgerows. The main crop is planted in the alleys. The hedgerows, being deep-rooted, can take up nutrients from the subsoil and cycle them back to the soil surface through their prunings for use by the main crop.

In most alley cropping systems in the tropics, the hedgerows are continuously pruned and the prunings incorporated into the soil or applied as mulch to the soil surface. The prunings increase the organic matter content of the soil and provide nutrients to the crop, while decreasing competition between the hedgerow and crop.

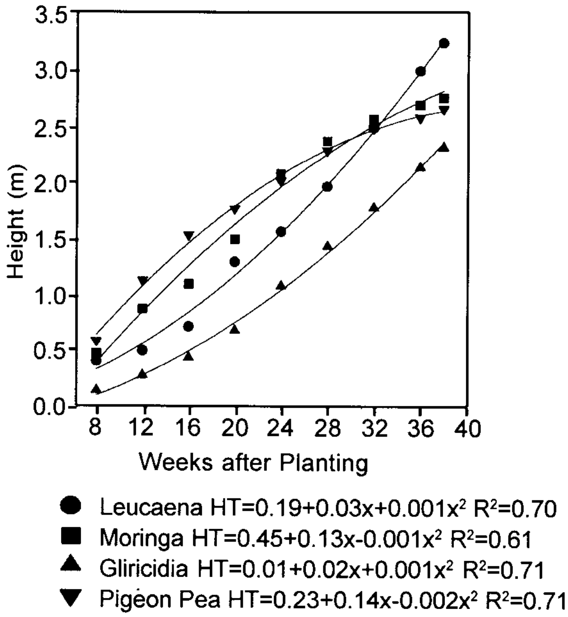
Alley cropping may be an alternative to traditional vegetable farming practices in the U.S. Virgin Islands for a number of reasons. The application of prunings to the soil could reduce the use of expensive fertilizers. The incorporation of the leaf material in the soil would build up the soil organic matter, thus increasing soil fertility and water-holding capacity. Use of pruning as a mulch would reduce evaporation of soil water and decrease the soil temperature resulting in more efficient water use. And hedgerows could serve as windbreaks to protect the crops from the damaging effects of the wind. On the other hand, hedgerows may compete with the crop for light, water, nutrients and land, possibly reducing crop yields.

As part of a long-term study of vegetable alley cropping systems for the USVI, the University of the Virgin Islands Agricultural Experiment Station has been evaluating the performance of four hedgerow species. The species being evaluated are gliricidia (*Gliricidia septum*), leucaena (*Leucaena leucocephala*), moringa (*Moringa oleifera*) and pigeon pea (*Cajanus cajan*). Some of the criteria used to evaluate hedgerow trees for alley cropping are ease of establishment, rate of growth, biomass production and the ability to withstand heavy pruning.

The four species were seeded in polyethylene bags (approximate volume 2.25 L) and grown for 19 weeks prior to planting in the field plots. Hedgerows were planted in December, 1992, using a randomized plot design with three replicates. Each plot consisted of three hedgerows 12 meters in length with 5 meters between hedgerows. Trees were planted 30 cm apart within hedgerows. The plants were drip-irrigated for four weeks to ensure good establishment.

During the establishment phase hedgerows were measured for height growth every four weeks with initial measurements made at 8 weeks after planting. At the end of the establishment period measurements of total plant height and diameter at 50 cm above ground were taken. The initial cutting of the hedgerows was at 40 weeks after outplanting. All four species were cut at 50 cm above ground. Prunings (except for pigeon pea) were separated into leaves and stem, and fresh weight for both components taken. Subsamples were taken from both components, weighed and then dried at 80°C until a constant weight was obtained. The dried samples were ground and analyzed for nitrogen (N),

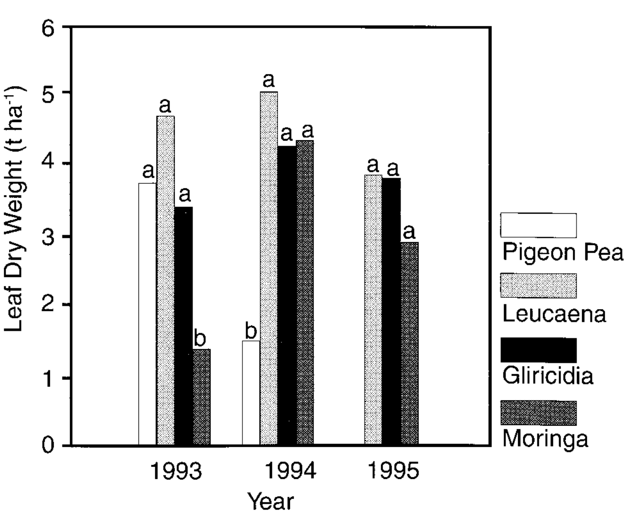
Figure 1. Hedgerow height growth during the establishment phase.



phosphorus (P) and potassium (K). After the initial cutting, hedgerows were pruned periodically in preparation for planting the alleys or, as needed, to lessen the competition with the vegetable crop. At each pruning the hedgerows were cut to 50 cm height and weight data recorded as described previously. Moringa, gliricidia and leucaena were pruned seven times, and pigeon pea twice. All data were collected from the middle hedgerow.

Pigeon pea had the fastest rate of growth during the first two measuring periods. Pigeon pea growth then began to slow and in the later measurements leucaena and moringa had the fastest rate of growth (Figure 1). Overall, leucaena had the greatest height growth (341 cm), followed by moringa and pigeon pea (287 cm). Moringa had the largest stem diameter (3.8 cm) at the end of the establishment period. Mean plant survival for all species was 97%.

Figure 2. Annual biomass production by the four hedgerow species. Bars for each year with the same letter are not significantly different. (Duncan's Multiple Range Test, P=0.05).



In the initial cutting of the four hedgerow species, leaf biomass ranged from 3.7 t ha^{-1} for pigeon pea to 0.6 t ha^{-1} for moringa. Leucaena produced the largest amount of total (leaf + stem) biomass (8.5 t ha^{-1}). Leucaena also produced the greatest stem biomass (5.4 t ha^{-1}).

Leucaena and gliricidia consistently produced the greatest amount of leaf biomass annually from pruning (Figure 2) Leucaena responded well to pruning, although its yield was suppressed somewhat due to defoliation by the leucaena psyllid (*Heteropsylla cubana*). Gliricidia was slower to establish and required a longer recovery time in the early prunings. In the later prunings gliricidia produced as much leaf biomass as leucaena or moringa. Moringa produced the largest amount of total biomass from the prunings (23 t ha^{-1}). Moringa also produced the greatest stem biomass from the prunings, 15 t ha^{-1} compared to a mean of 5.25 t ha^{-1} for gliricidia and leucaena. It also responded well to pruning and in the second and third years produced as much leaf biomass as leucaena and gliricidia. Pigeon pea did not respond well to pruning, produced the smallest quantity of total biomass (1.5 t ha^{-1}) and died out after its second pruning.

Total leaf biomass production from all cuttings (initial cutting + prunings) over the three-year time period ranged from 13.6 t ha^{-1} for leucaena to 5.2 t ha^{-1} for pigeon pea (Figure 3). Leucaena and moringa produced the largest total biomass (Figure 4). Moringa also produced the greatest amount of stem biomass (17.3 t ha^{-1}). There were no differences in the foliar-N concentration of leucaena, gliricidia and moringa (mean=37.5 g N kg^{-1}). Pigeon pea foliar-N concentration (26.3 g N kg^{-1}) was lower than the other species. Leaf concentrations of K and P varied between species. Concentrations of K in the leaf biomass were highest in gliricidia (20.5 g K kg^{-1}) and lowest in pigeon pea (9.9 g K kg^{-1}). Moringa had the highest concentrations of foliar-P (2.3 g P kg^{-1}). Calculated from leaf nutrient concentrations and biomass production, the incorporation of prunings or their application to the soil as mulch resulted in the equivalent nutrient yield of 558, 26 and 236 kg NPK ha^{-1} for leucaena, 389, 20 and 220 kg NPK ha^{-1} for gliricidia; 301,16 and 158 kg NPK ha^{-1} for moringa; and 138, 10 and 52 kg NPK ha^{-1} for pigeon pea, over the 36-month study period.

Although the hedgerow species are still being evaluated, it appears that the two species to be recommended for use in alley cropping systems on St. Croix are leucaena and gliricidia. Leucaena can establish a hedgerow quickly, produces large quantities of high-N

Figure 3. Leaf biomass production from hedgerow species for all cuttings over the three-year time period. Bars with the same letter are not significantly different. (Duncan's Multiple Range Test, P=0.05).

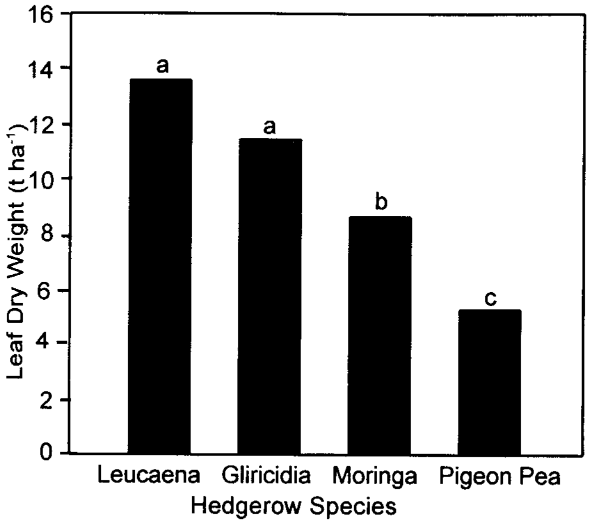
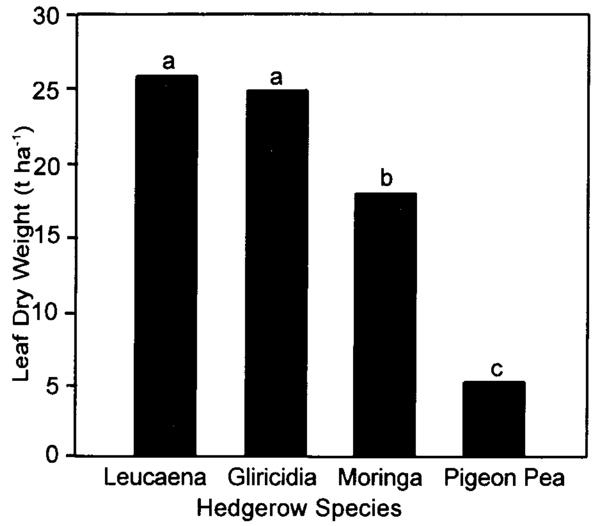


Figure 4. Total hedgerow biomass (leaf + stem) production for all cuttings over the three-year time period. Bars with the same letter are not significantly different. (Duncan's Multiple Range Test, P=0.05).



leaf biomass and withstands frequent prunings. The variety used in this trial (St. Croix Native) proved susceptible to attack by the leucaena psyllid, which reduced yields. This variety also has a tendency to flower and produce seed early, although by weeding and soil cultivation we were able to keep it from spreading. Gliricidia required a longer time to establish, but proved a good biomass producer once established. It is tolerant of frequent prunings, is high in N and its low spreading form lessens competition for light with the vegetable crop. Moringa's foliar-N concentrations were equal to both gliricidia and leucaena, which is surprising since moringa does not fix N as do gliricidia and leucaena. This may indicate that moringa is an efficient scavenger of soil nutrients. The greater stem production for moringa resulted in a much higher stem-to-leaf ratio for this species (1.9) as compared to gliricidia (0.48) and leucaena (0.56). Moringa's rapid growth and upright form caused excessive shading of the vegetable crop. Pigeon pea initially grew the fastest, produced a hedgerow rapidly and in the first cutting had the greatest leaf biomass. But, its inability to withstand pruning makes it a poor choice for use as a hedgerow.

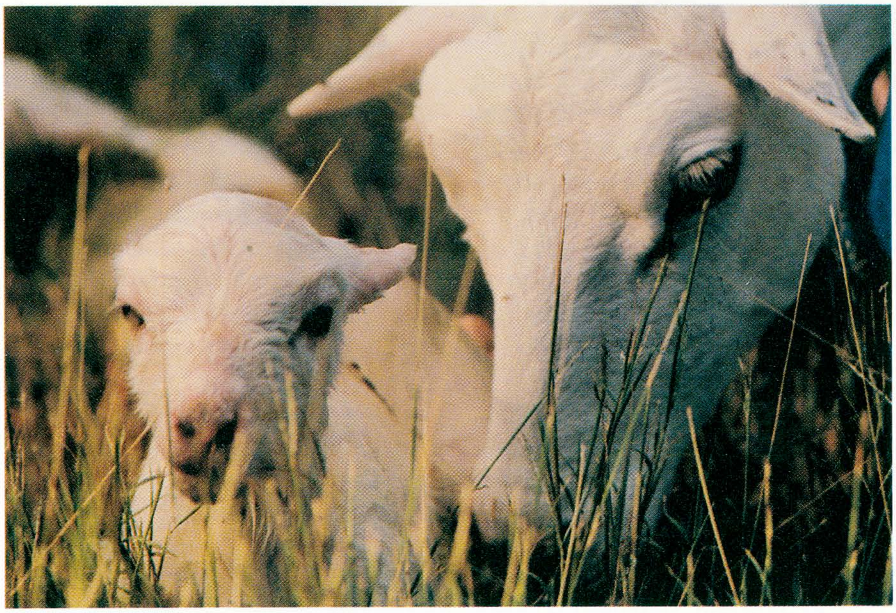
Although these four species were evaluated for use as hedgerows in alley cropping, the biomass data are indicative of their production potential for other uses. It is possible that under a more intensive pruning regime biomass production would be greater. Both leucaena and gliricidia could be used for cut and carry forage production and as a high protein supplement for livestock. These two species could be planted on marginal land for use as a biomass bank for mulch and green manure for crop production. Leucaena stems can be used for tomato and yam stakes, firewood and charcoal production. Gliricidia also produces stakes which can be used for cuttings and posts for live fences. The rapid growth and upright form of pigeon pea and moringa would make them excellent for windbreaks along the margins of farm plots and fields. Pigeon pea hedgerows may be beneficial in cases where a quick windbreak is needed to protect a crop. It also produces a secondary crop (peas and pods) which can be harvested during hedgerow establishment and while the main crop is maturing. Moringa stems root readily if planted directly in the ground and it makes an excellent live fence. Depending on the desired use and end product, all four of these species have potential as hedgerows.

"Although the hedgerow species are still being evaluated, it appears that the two species to be recommended for use in alley cropping systems on St. Croix are leucaena and gliricidia."

This research was supported in part by a special grant in tropical and subtropical agricultural research, CBAG Grant No. 92-34135-7299, and the U.S. Department of Agriculture under McIntire-Stennis Grant No. 0162363.

An Evaluation of Two Methods of Estrous Synchronization in Sheep

Robert W. Godfrey, Joni R. Collins and Mark L. Gray



Estrous synchronization of sheep can be accomplished using several methods. Prostaglandin F2α (PGF) has been used successfully to synchronize estrus in sheep when given as two injections 10 days apart. Another method of synchronizing estrus involves the administration of progesterone by injection, as a feed additive or intravaginal sponges. The length of time the progesterone needs to be administered makes the injection method less desirable: ewes need to be injected daily for up to 10 days.

Progesterone can be fed to animals for a period of time, and after the treatment is stopped the ewes will exhibit estrus. One drawback to this method is that it is difficult to control the amount of progesterone each animal consumes unless the animals are fed individually, which is not practical on most farms. The development of alternative methods of administering progesterone such as vaginal sponges has made the procedure less labor intensive.

Recently a new device for administering progesterone for estrous synchronization has been developed. The controlled internal drug release (CIDR) device is a nylon core surrounded by silicone that has been impregnated with progesterone. The CIDR is placed in the vagina of the ewe for 12 days, and after it is removed the ewe will come into estrus. Presently CIDRs are only available for research purposes in the U.S., but it is hoped they will be commercially available in the near future.

The objectives of this study were (1) to evaluate the efficacy of CIDR devices to synchronize estrus in hair sheep and the fertility of the synchronized estrus, and (2) to compare CIDRs and PGF for synchronizing estrus in hair sheep.

Two trials were conducted using St. Croix White, Barbados Blackbelly hair and Florida Native wool ewes. In Trial 1 all three breeds were used. One group of ewes (n = 27) were treated with CIDRs for 12 days, and 29 ewes were not treated (CONTROL). The CIDRs were removed on the same day that intact rams of the same breeds, equipped with marking harnesses, were placed with the ewes. Ewes were monitored three times a day for estrus (day 0). On day 6, laparoscopies were performed on one half of the ewes in each treatment group to count the number of ovulation sites on the ovaries.

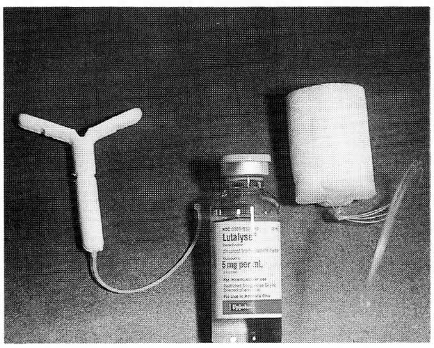
In Trial 2, 14 St. Croix White ewes were treated with CIDRs the same as in Trial 1 and 14 St. Croix White ewes were given 2 i.m. injections of 15 mg PGF 10 days apart. Intact rams, equipped with marking harnesses, were placed with the ewes on the day of CIDR removal or the second PGF injection. Estrus detection was conducted in the same manner as in Trial 1.

Ram breeds used in Trial 2 were St. Croix White, Florida Native and Suffolk. The wool breed rams were being used to produce crossbred lambs for another study. In both Trial 1 and Trial 2 a jugular blood sample was taken from each ewe on day 10 and assayed for progesterone concentration to monitor the function of the corpus luteum formed after the synchronized estrus.

Time to estrus after ram introduc-

Table 1. Interval to estrus, ovulation rate, conception rate, number of lambs born and progesterone on day 10 of ewes after estrous synchronization with either CIDR or PGF. Within rows, means followed by the same letter are not significantly different using Student-Newman-Kuels multiple range test or chi-square, ($P<0.05$).

	Trial 1		Trial 2	
	CONTROL	CIDR	CIDR	PGF
Time to estrus (days)	6.3 ± .7a	1.7 ± .8b	1.4 ± .4b	2.9 ± 4c
Ovulation rate	1.61 ± .2a	1.4 ± .2a	---	---
Conception rate (%)	76a	72a	100a	86a
Lambs born	1.4 ± .2a	1.2 ± .2a	2.2 ± 2b	1.9 ± 2b
Progesterone (ng/ml)	8.4 ± .7a	6.8 ± .6a	10.8 ± .8a	10.4 ± .8a



From left, CIDR-G device, prostaglandin F2α and progesterone sponge.

tion in Trial 1 was four days shorter in CIDR treated than CONTROL ewes (Table 1). Within three days of ram introduction 100% of CIDR ewes but only 37.9% of CONTROL ewes had been in estrus. Conception rate at the first estrus after ram introduction was 74.1% overall, and was not different between treatments, but days to conception after ram introduction was shorter in CIDR-treated than CONTROL ewes (3.6 ± 1.3 vs 12.2 ± 1.3 days, respectively).

Neither ovulation rate, determined by laparoscopy, nor number of lambs born, were different between CIDR and CONTROL ewes (Table 1). The CIDR ewes lambed earlier in the lambing season than CONTROL ewes (9.5 ± 1.3 vs 15.1 ± 1.3 day of lambing, respectively).

In Trial 2, the CIDR ewes exhibited estrus 1.5 days earlier than PGF-treated ewes (Table 1). The time to estrus after ram introduction was similar between CIDR-treated ewes in both Trials 1 and 2. Synchrony response was higher in CIDR than in PGF ewes (100% vs 71.4 % in estrus within three days of ram introduction, respectively). The conception rate at the synchronized estrus was not different between CIDR and PGF ewes. Progesterone concentration on day 10 after synchronized estrus was not different among CONTROL, CIDR and PGF-treated ewes.

These results show that estrus synchronization can be used successfully in hair sheep breeds in the tropics. The shorter time to estrus and the higher synchrony response of the CIDR-treated ewes, when compared to the PGF group, indicates that the CIDR devices may be a more efficacious method to use. The higher level of synchrony would be critical if the sheep were being bred by artificial insemination or used in an embryo transfer program.

There was no detrimental effect of either CIDRs or PGF on fertility at the synchronized estrus as shown by the conception rates in Table 1. In fact, all of the CIDR ewes in Trial 2 became pregnant at the synchronized estrus. Even though there was no treatment effect on the number of lambs born, the ewes in Trial 2 had more lambs/ewe than the ewes in Trial 1. This may have been due in part to the fact that the ewes in Trial 2 were on a slightly higher plane of nutrition prior to breeding than the ewes in Trial 1. The progesterone levels on day 10 indicate that none of the treatments had a detrimental influence on ovarian function after estrus.

Even though sheep on St. Croix can breed year round, it is still advisable to manage the animals in a way that imposes designated breeding and lambing seasons. By doing this, the breeding and lambing seasons can be scheduled to take advantage of seasonal variations in forage availability or the demand for lambs.

Through estrous synchronization, the ewes will be bred within a short period of time (2-3 days), and the subsequent lambing will also take place over a short time period. This will allow producers to plan for labor input and feed resources and provide a more uniform lamb crop for sale to the consumer. Another benefit of estrous synchronization is that it will allow producers to utilize other advanced breeding techniques, such as artificial insemination or embryo transfer.

By using these procedures, sheep producers in the U.S. Virgin Islands will have the opportunity to access genetic material from sheep breeds not found locally without having the expenses associated with importing live animals. Subsequent studies are being conducted by the Animal Science Program at UVI to use these results to develop procedures for artificial insemination of sheep in the tropics.

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Current Research Projects

Evaluation of Forage Conservation Systems in the Caribbean.
Evaluation of Integrated Mechanical and Chemical Control of Casha (*Acacia* spp.) on Native Pasture.
Improving Forage Feeding Value by Urea Treatment.
Breeding and Biotechnology for Forage Yield, Quality and Persistence of *Pennisetums*.
Evaluation of Native Pasture and Agro-By-Product-Based Systems for Market Lamb Production.
Herbage Allowance and Pasture Rotation Systems for Animal and Forage Production on Tropical Pasture.
Developing an Integrated Forage-Livestock Feeding System for the Caribbean.
Increased Efficiency of Sheep Production.
Reducing Effects of Heat Stress on Reproduction in Dairy Cattle.
Studies on the Production of Tilapia in Marine Cages.
Evaluation of the Culture Potential of Selected Caribbean Fishes.
Integration of Tilapia and Hydroponic Vegetable Production in Recirculating Systems.
Economic Analysis of Integrated Recirculating Systems.
Integrating Tilapia Culture in Tanks with Field Production of Vegetable Crops.
Micro-Irrigation of Horticultural Crops in Humid Regions.
Horticultural and Economic Evaluation of Vegetable Varieties in the U.S. Virgin Islands.
Alley Cropping Systems for Sustainable Vegetable Production in the U.S. Virgin Islands.
Improving Crop Management Systems for the Production of Culinary Herbs in the U.S. Virgin Islands.
Evaluation of Horticultural Practices for Enhancing Root Crop Production in the Virgin Islands.
Evaluation of Cultural Practices for Sweet Potato Weevil Control.
Evaluation of Integrated Production Methods for Tropical Fruit Crops.
Evaluation of Minor Tropical and Subtropical Fruits and Nuts for Production in the U.S. Virgin Islands.
Evaluation of Trees for Agroforestry in the U.S. Virgin Islands.
Potential for Ornamental Pot Crops in the Virgin Islands Using Growth Regulators.
Bioengineering Plants with the Rolc gene to Improve Water Use Efficiency and Drought Tolerance.
Bioengineering Papaya Ringspot Virus Resistance in *Carica papaya* for the Caribbean.
Transformation and Regeneration of Hibiscus and Bougainvillea.
Effects of Bioherbicides on Competitive Ability of Nutsedge.
Biochemical Basis of Resistance of Nutsedge Biotypes and Species to Nutsedge Rust.

Recent Publications

Adjei, M.B. 1995. Productivity of guineagrass pasture as influenced by sheep grazing pasture. Agronomy Abstracts:46. (abstract).

*Adjei, M.B. 1995. Component forage yield and quality of grass-legume cropping systems in the Caribbean. Tropical Grasslands 29:142-149.

Adjei, M.B. and T.J. Gentry. 1995. Forage growth performance of lablab bean in the semi-arid tropics. Proceedings of the Caribbean Food Crops Society, Christ Church, Barbados, West Indies. 31:(in press).

Adjei, M.B. and T.J. Gentry. 1995. Forage growth performance of lablab bean in the semi-arid tropics. Agronomy Abstracts:31. (abstract).

*Adjei, M.B., W.F. Brown and T.J Gentry. 1994. The effects of moisture, urea level and method of application on the chemical composition and digestibility of native grass hay in the Caribbean. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:186-198.

*Adjei, M.B., T.J. Gentry, S.C. Schank and A. Sotomayor-Rios, 1994. Forage yield, quality and persistence of interspecific Pennisetum hybrids in the Caribbean. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:163-172.

Adjei, M.B. and T.J. Gentry. 1994. Improving guineagrass forage feeding value by urea treatment. UVI Research, Agricultural Experiment Station, University of the Virgin Islands, 6:18-21.

Adjei, M.B. and S. Josephat. 1994. Preservative characteristics of guineagrass/leucaena silage compared to sorghum silage. UVI Research, Agricultural Experiment Station, University of the Virgin Islands, 6:15-17.

Bailey, D.S., W.B. Peter, J.E. Rakocy and R.W. Moore. 1995. Marketing locally-produced tilapia products on a subtropical semiarid island: the St. Croix case. World Aquaculture Society, Book of Abstracts:53.

Brown, W.F. and M.B. Adjei. 1995. Urea treatment to improve the nutritional value of tropical forages. Proceedings of the International Conference on Livestock in the Tropics. IFAS, University of Florida, Gainesville, Florida, 71-77.

Brown, W.F. and M.B. Adjei. 1995. Urea ammoniation effects on the feeding value of guineagrass (*Panicum maximum*) hay. Journal of Animal Science 73:3085-3093.

*Brown, W.F., M. Gray, M.B. Adjei and R. Godfrey. 1994. Growth response of hair sheep fed urea-ammoniated guineagrass (*Panicum maximum*) hay. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:173-179.

Cole, W.M. and K.A. Shultz. 1994. Evaluation of three indigenous Caribbean finfish for culture potential. UVI Research, Agricultural Experiment Station, University of the Virgin Islands 6:6-9.

Cole, W.M., J.E. Rakocy, K.A. Shultz and J.A. Hargreaves. 1995. The effects of four formulated diets on the growth, feed conversion and condition factor of palometa (*Trachinotus goodei*). World Aquaculture Society, Book of Abstracts: 87.

Crossman, S.M.A., M.C. Palada and J.A. Kowalski. 1995. Irrigation affects yield and sweet potato weevil [*Cylas formicarius elegantus* (Summers)] infestation on sweet potato. HortScience 30:829 (abstract).

Crossman, S.M.A., M.C. Palada and l.A. Kowalski. 1995. Germplasm evaluation of onion for growth and yield characteristics in the Virgin Islands. Proceedings of the Caribbean Food Crops Society, Christ Church, Barbados, West Indies. 31:(in press).

*Crossman, S.M.A., C.D. Collingwood, M.C. Palada and J.A. Kowalski. 1994. The effect of varying rates of nitrogen and irrigation on yam (*Dioscorea alata* L.) production. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:65-72.

Crossman, S.M.A., C.D. Collingwood, M.C. Palada and J.A. Kowalski. 1994. Strategies for increasing yam production in the Virgin Islands. UVI Research, Agricultural Experiment Station, University of the Virgin Islands, 6:22-24.

Gloger, K.C., J.E. Rakocy, J.B. Cotner, D.S. Bailey, W.M. Cole and K.A. Shultz. 1995. Contribution of lettuce to wastewater treatment capacity of raft hydroponics in a closed recirculating fish culture system. Pages 272-300 *in* M.B. Timmons, ed. Aquacultural Engineering and Waste Management, NRAES-90, Northeast Regional Agriculture Engineering Service, Ithaca, New York.

Gloger, K.C., J.E. Rakocy, J.B. Cotner, D.S. Bailey, W.M. Cole and K.A. Shultz. 1995. Waste treatment capacity of raft hydroponics in a closed recirculating fish culture system. World Aquaculture Society, Book of Abstracts: 126.

Godfrey, R.W., J.R. Collins and M.L. Gray. 1995. Lamb growth and ewe milk production of hair and wool sheep in a tropical environment. Journal of Animal Science 73 (Suppl. 1):245.

Godfrey, R.W., J.R. Collins and M.L. Gray. 1995. The effect of ambient temperature on sexual behavior of rams in a tropical environment. Journal of Animal Science 73 (Suppl. 1):132.

Godfrey, R.W., M.L. Gray and J.R. Collins. 1995 Estrus synchronization of sheep in the tropics using either controlled internal drug release (CIDR) dispensers or prostaglandin F2∝ (PGF). Journal of Animal Science 73 (Suppl. 1):232.

Godfrey, R.W., M.L. Gray and J.R. Collins. 1995. Lamb growth and milk production of hair and wool sheep in a semi-arid tropical environment. Small Ruminant Research (in press).

*Godfrey, R.W. and P.J. Hansen. 1994. Effects of coat color on production and reproduction of dairy cattle on St. Croix. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:180-185.

Godfrey, R.W. and P.J. Hansen. 1994. Environmental influences on reproduction and milk production of Holstein cows in St. Croix. UVI Research, Agricultural Experiment Station, University of the Virgin Islands, 6:10-12.

Kowalski, J.A., M.C. Palada and S.M.A. Crossman. 1995. Germplasm evaluation of snap beans for growth and yield characteristics in the Virgin Islands. Proceedings of the Caribbean Food Crops Society, Christ Church, Barbados, West Indies. 31:(in press).

*Kowalski, J.A. and M.C. Palada. 1994. Response of selected vegetable crops to saline water in the U.S. Virgin Islands. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:232-246.

O'Donnell, J.J., M.C. Palada and A. Bulbulla. 1995. Canopy growth and light interception by three hedgerow species for alley cropping in St. Croix. Proceedings of the Caribbean Food Crops Society, Christ Church, Barbados, West Indies. 31:(abstract, in press).

O'Donnell, J.J., M.C. Palada, J.A. Kowalski, A. Bulbulla and S.M.A. Crossman. 1995. Productivity and nutrient content of hedgerow species for alley cropping in St. Croix. Agronomy Abstracts, 44.

O'Donnell, J.J. 1994. Mahogany response to water stress. UVI Research, Agricultural Experiment Station, University of the Virgin Islands, 6:13-14.

*O'Donnell, J.J., C. Ramcharan and A. Bulbulla. 1994. The minor tropical and sub-tropical fruit project on St. Croix. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:385-386.

*Palada, M.C., S.M.A. Crossman and C.D. Collingwood. 1995. Improving vegetable production using microirrigation in the Virgin Islands. pp. 502-509 *in* Freddie Lamm, ed. Microirrigation in a Changing World: Conserving Water Resources/Preserving the Environment. Proceedings of the Fifth International Microirrigation Congress, Orlando, Florida. American Society of Agricultural Engineers 4-95.

Palada, M.C., S.M.A. Crossman and J.A. Kowalski. 1995. Organic and synthetic mulches affect yield of basil under drip irrigation. Proceedings of the Caribbean Food Crops Society, Christ Church, Barbados, West Indies. 31:(in press).

Palada, M.C., S.M.A. Crossman and J.A. Kowalski. 1995. Water use and yield of basil as influenced by drip irrigation levels and mulching. Proceedings of the Caribbean Food Crops Society, Christ Church, Barbados, West Indies. 31:(in press).

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Palada, M.C., W.M. Cole, S.M.A. Crossman, J.E. Rakocy and J.A. Kowalski. 1995. Fish culture water and sludge applied via drip irrigation improves yield of pak choi (*Brassica rape* L. Chinensis). HortScience 30:885 (abstract).

*Palada, M.C., S.M.A. Crossman and J.A. Kowalski. 1994. Growth and yield response of thyme (*Thymus vulgarus* L.) to sources of nitrogen fertilizer. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:58-64.

*Rakocy, J.E. 1994. Aquaponics: the integration of fish and vegetable culture in recirculating systems. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:101-108.

Rakocy, J.E. 1995. The role of plant crop production in aquacultural waste management. Pages 349-364 *in* M.B. Timmons, ed. Aquacultural Engineering and Waste Management, NRAES-90, Northeast Regional Agriculture Engineering Service, Ithaca, New York, U.S.A.

Rakocy, J.E., D.S. Bailey, W.M. Cole and K.A. Shultz. 1995. Effect of continuous light on the growth of *Oreochromis niloticus* using demand feeders. World Aquaculture Society, Book of Abstracts: 193.

Rakocy, J.E., J.A. Hargreaves and D.S. Bailey. 1995. Tilapia culture in small cages. World Aquaculture Society, Book of Abstracts: 193.

Ramcharan, C., J.J. O'Donnell and A. Bulbulla. 1995. Preliminary trials with two FHIA banana cultivars on St. Croix, U.S.V.I. Proceedings of the Caribbean Food Crops Society, Christ Church, Barbados, West Indies. 31:(in press).

Ramcharan, C. 1994. Bird pepper growth and fruiting response to uniconazole sprays. Proceedings of the Interamerican Society for Tropical Horticulture, Campeche, Mexico: (in press).

Ramcharan, C. 1994. Growth and flowering responses of culantro (*Erynguim foetidum* L.) to Pro-Gibb sprays. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:384.

Ramcharan, C. 1994. New ornamental pot crops. UVI Research, Agricultural Experiment Station, University of the Virgin Islands, 6:2.

*Ramcharan, C. 1994. Potential for pot crop production using growth retardants in the USVI. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:380.

Zimmerman, T.W. 1995. Effect of Timentin for controlling agrobacterium tumefaciens following cocultivation on select plant species. In Vitro Cellular and Developmental Biology 31:70A.

Zimmerman, T.W. 1995. The effect of papaya ringspot virus on production and future means of possible control. Proceedings of the Caribbean Food Crops Society, Christ Church, Barbados, West Indies. 31:(in press).

Zimmerman, T.W. and C. Ramcharan. 1994. A preliminary investigation into breadfruit micropropagation. Tropical Fruits Newsletter 13:5.

*Zimmerman, T.W. 1994. Effect of exposure to plant growth regulators on cellular differentiation. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:377.

*Zimmerman, T.W. 1994. Priming papaya seeds reduces seed germination time. Proceedings of the Caribbean Food Crops Society, St. Thomas, U.S.V.I. 30:329-332.

Zimmerman, T.W. 1994. Rapid and uniform papaya emergence with primed seeds. UVI Research, Agricultural Experiment Station, University of the Virgin Islands, 6:3-5.

*An asterisk in front of an entry indicates that it has been previously listed, but was in press. Now the entry is complete.

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