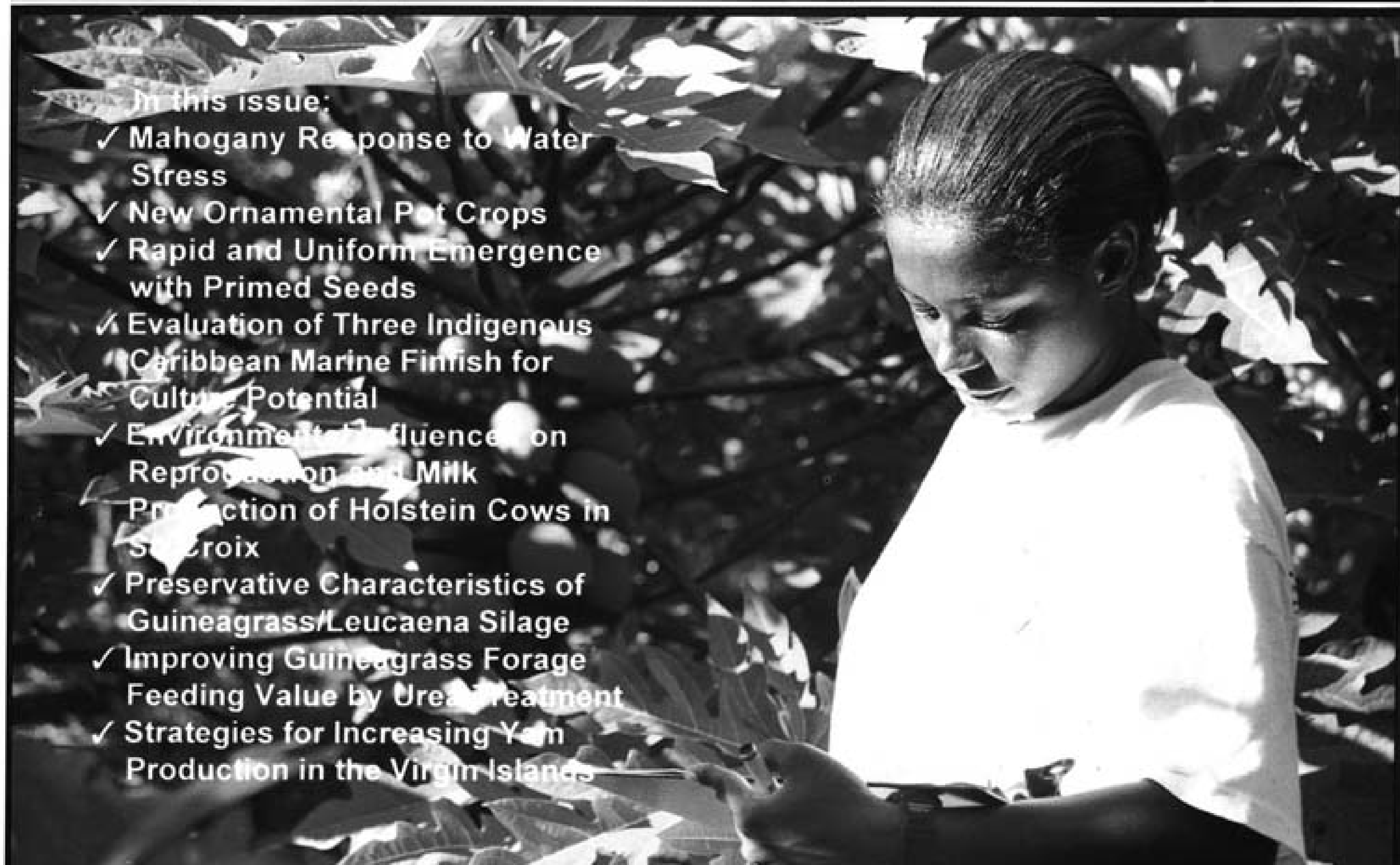
UVI Food and Agriculture

# RESEARCH

University of the Virgin Islands Agricultural Experiment Station Volume 6, 1994



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UVI Food and Agriculture

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# New Ornamental Pot Crops

## Chris Ramcharan

A number of colorful plants can be found growing throughout the landscape in the Caribbean, like *Hibiscus, Bird Pepper* and *Christmas Snowflake (See UVI Research 4:17-19)*. Others are relatively new, like *Mussaenda* from the Philippines and Africa and the *Lipstick plant* from Central and Tropical America.

But these plants all have one thing in common. Each can now be produced as an ornamental pot crop for the Virgin Islands and the Caribbean employing techniques such as pruning and the use of plant growth regulators (PGR). Recent research at the Fruit and Ornamental section of UVI-AES has demonstrated that many common and not-so-common garden species can now be tailored for pot crop production, adding to the list of potted plants for the home and augmenting the number of crops local nurseries can now offer to the consumer.

Most tropical species actively grow throughout the year due to the absence of the climatic changes that limit temperate species. This year-round growth often makes it difficult to grow ornamental species in pots where they may have added attraction by being easily moved around the land- or interiorscape.

Until now, continuous pruning was the only technique for adapting such plants to a pot environment. But this also meant continually destroying the stem tips where blooms are formed as in *Hibiscus* and *Christmas Snowflake* or colorful and edible fruits as in the *Bird Pepper*. A unique group of PGRs, called plant growth retardants (GR), have now made it possible to overcome this problem. By physiologically slowing growth through the inhibition of natural growth promoters, GRs (when applied in very controlled amounts to many potted plants) inhibit vegetative growth while either maintaining or promoting flower production. Hence, a much smaller but more floriferous plant adapted to a pot environment often results from GR treatments.

An example is *Mussaenda*, also called 'Satin Plant,' a member of the Coffee family - Rubiaceae. It is a spectacular flowering shrub grown for its showy bract-like sepals ranging from the deep 'Ashanti Red' of Africa to the 'Snow White' of the Philippines and the pink of the hybrid Dona Luz cultivar. The plant is covered with a delicate pubescence that imparts a soft satiny texture and has shiny deep green leaves, hence its common name.

*Mussaenda* grows well in pots larger than two inches in diameter and can be kept as a patio plant in cool to moderate climates but grows well as a small shrub in warmer climates. In Southeast Asia, Hawaii and south Florida *Mussaenda* is an established outdoor ornamental. It has an indoor postharvest life of three to four weeks or longer.

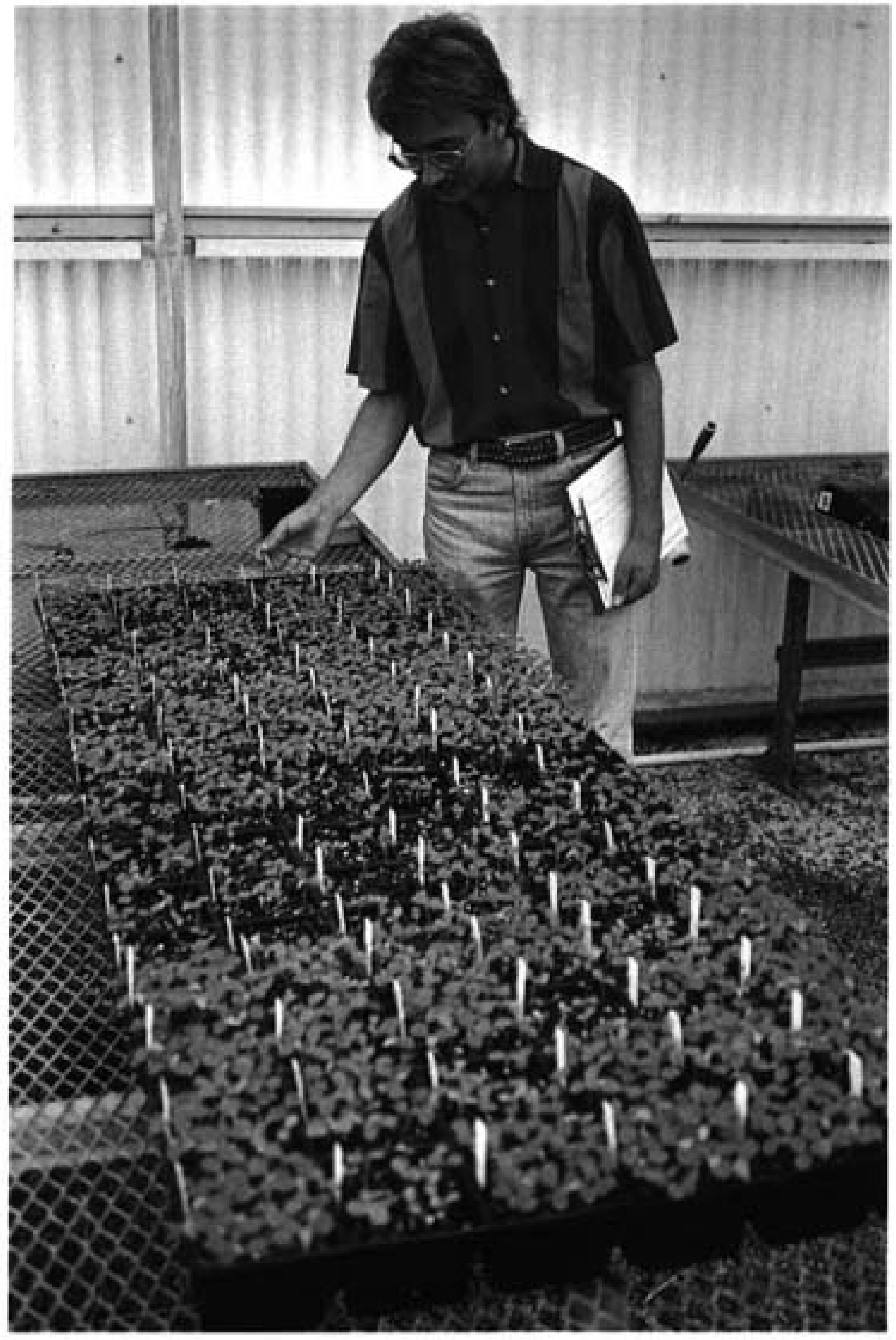
Untreated plants bloom in one to two years in the landscape, after which they must be pruned back for further growth and flowering. *Mussaenda* will not tolerate high-pH soils, thus severely limiting its culture in calcareous islands like St Croix. However, started from a soft wood cutting, *Mussaenda* can be forced to flower in a six-inch pot within five months through the application of 2500 ppm sprays of the GR - Alar or B9. After about two months of flowering, the plant can be pruned, repotted and similarly forced again within the next six months, thus producing its attractive blooms twice in one year. Because they are non-photoperiodic, they make an excellent flowering pot crop at virtually any time of the year. Additionally, they are almost pest-free and could therefore become a good substitute for poinsettias, which are highly seasonal and very susceptible to pests.

At UVI-AES, *Mussaenda* is just one of the many native and exotic flora species being investigated for their potential as new pot crops. Many will augment the arsenal of the nurseryman's range of crops, add color and variety to the local landscape and make potentially valuable import substitutes to help improve the economies of many Caribbean Basin island states.

This research was supported in part by the Caribbean Basin Advisory Group (CBAG) Project No. 91-34135-6173.

# Rapid And Uniform Papaya Emergence With Primed Seeds

Thomas W. Zimmerman



Papaya seeds have been attributed with poor germination in the propagation of papaya. Poor germination has been associated with growth inhibitors present in the sarcotesta, the gelatinous membrane surrounding the seed, as well as the seed coat itself. Seed priming is a system of soaking seeds in a solution for a given period of time prior to planting.

Seed priming is commercially used to reduce germination time and increase the uniformity of the seedling stand (see the home recipe for priming salts on page 6). Uniform plant emergence allows for the full growth potential of every seedling. When seedlings emerge unevenly over a period of time, the first to emerge shade the latter emerging seedlings and develop ahead of them.

Seed germination is divided into three phases: imbibition, lag phase and radicle emergence. Imbibition is the physical uptake of water by a seed. Imbibition is not an indication of seed viability because even dead seeds will draw up water and swell. The lag phase is the time during which the cell membranes are repaired and the metabolic processes in the cell are reinitiated. Radicle emergence occurs when the root protrudes from the seed due to cell elongation and cell division.

The purpose of seed priming is to promote the first two phases of seed germination, imbibition of water and restoration of cellular biochemical activity—but to inhibit the final phase— radicle emergence. Once the radicle has emerged, seeds are considered germinated and dehydration is lethal. Either salt solutions or water can be used for priming. When using water to prime seeds, priming should be terminated before radicle emergence. The osmotic potential is the key factor in developing salt solutions for seed priming. Osmotic potential,measured in megapascals (MPa), is an indication of how strongly a solution will hold water and inhibit it from being absorbed by the seeds.

This is different from molar concentration which indicates the amount of salt dissolved in a solution. An osmotic potential of -1 MPa will allow proper seed priming and yet inhibit radicle emergence. The objective of this study was to use K or Ca salt solutions to develop a system for reducing the time required for papaya seed germination and seedling emergence. Seedling emergence was determined when both the hypocotyl and the seed cotyledons broke through the potting mix surface.

Seeds were collected from mature fruits of four open-pollinated papaya varieties, 'Cariflora', 'Puerto Rico Red', 'Solo 64' and 'Waimanalo 162'. Seeds were washed to remove the gelatinous sarcotesta and any floating seeds were discarded. Floating seeds often contain aborted embryos or under developed embryos that are nonviable. Cleaned seeds were air-dried and stored in a refrigerator at 5°C until used. The priming solution treatments were developed to be -1 MPa as determined by a Decagon psychrometer.

The salts chosen for priming solutions were: $CaCl_2$ (173 mM), $Ca(NO_3)_2$ (173 mM), KCl (232 mM) or $KNO_3$ (232 mM). A distilled $H_2O$ and a control (no priming treatment) were also included. Twenty-five seeds were placed in each half of 100 x 15 mm divided petri dishes to which 8 ml of priming solution was added. Each treatment was replicated four times. Seeds were primed for five days at room temperature (20°C) with a change of fresh solution after

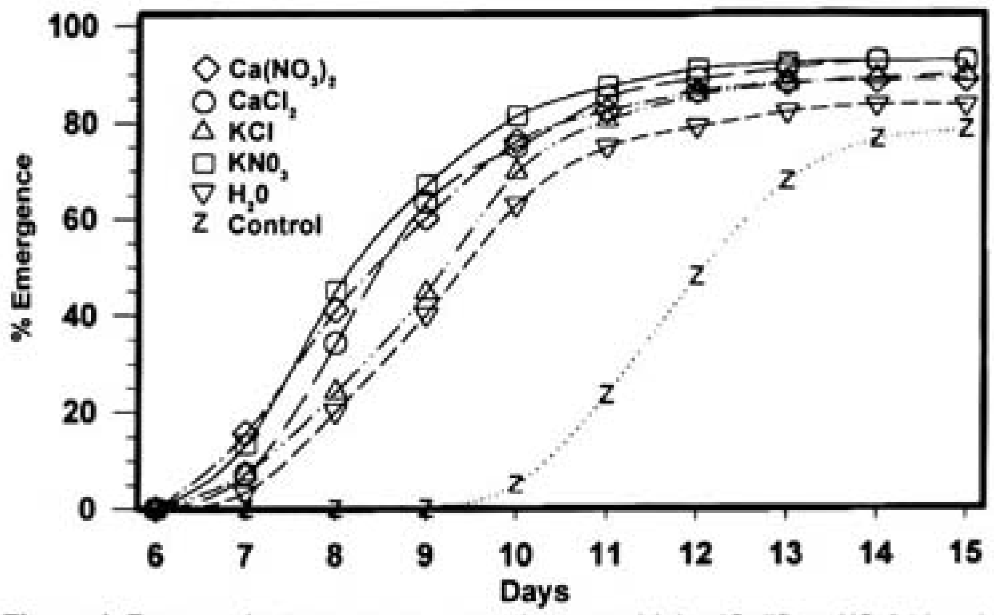



**Figure 1.** Papaya plant emergence over time, combining 'Califlora,' 'S-64,' and 'Waimanalo,' as influenced by the salt solutions used in seed priming. The 'PR Red' data was significantly different ($P = 0.05$) from the other three varieties and isn't included.

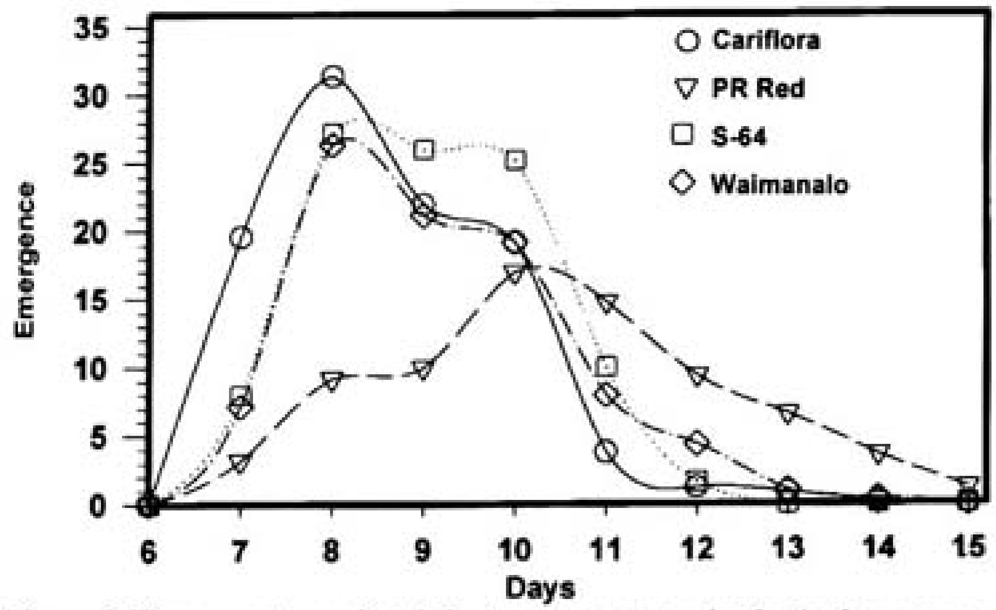



**Figure 3.** The percentage of total plant emergence per day for the four papaya varieties.

> **"Seed priming was shown in this study to enhance the total seed germination and seedling stand establishment for slow germinating varieties or varieties with reduced viability. The benefit of seed priming was to reduce the average seedling emergence time and increase the uniformity of plant emergence."**

48 hours. After five days of priming, seeds were rinsed with distilled water and air dried two days prior to planting under greenhouse conditions in mid April at a 1 cm depth in 1:1 (v/v) Pro Mix : sand potting mix. Emergence was recorded when the hypocotyls forced the seed cotyledons above the potting mix surface.

During imbibition the cell membranes have not yet been repaired from the damage incurred during dehydration of the mature ripening seed. The cells are therefore leaky and cell contents which dissolve with the uptake of water can be lost from the cell until the membrane is repaired. The loss of cell contents or electrolytes can be measured by conductivity.

Conductivity readings provide an indication of the seeds passing from imbibition to the lag phase. The conductivity from all the priming solutions were the highest after the first two days and decreased by the fifth day of priming (data not presented). This indicated that the seeds were viable and able to repair the cell membranes upon imbibition of water. Dead seeds are unable to repair damaged membranes caused by dehydration and would have continuous electrolyte leakage over time. The conductivity readings indicate that the priming solutions did allow imbibition and activation of cellular membrane repair.

The effect of priming solution on total plant emergence over time was similar for all salt solution and significantly different from the control over time. The salt solutions used for seed priming provided better emergence over time than the water treatment or the control. While plant emergence began on the seventh day for all priming treatments, the start of plant emergence was delayed until the tenth day for the controls (Figure 1). All priming treatments significantly reduced the average emergence time over the controls for all four varieties. Priming solutions containing either $KNO_3$ or $Ca(NO_3)_2$ had the greatest overall effect of reducing the average emergence time (Figure 2).

The varieties selected did provide a range of response for plant emergence. Seedling emergence began on the seventh day and leveled off for 'Cariflora', 'Solo 64' and 'Waimanalo' by the twelfth day. Total plant emergence on the fifteenth day among these varieties ranged between 85-95 percent and was not significantly different. Total 'PR Red' emergence was lower at 70 percent but stabilized by day 15. The greatest total daily emergence for 'Cariflora', 'S-64' and 'Waimanalo' was on day 8, while 'PR Red' was similar for both day 10. The greatest average daily emergence for 'Cariflora', 'Solo 64', 'Waimanalo' and 'PR Red' was 31.4, 29.2, 26.4 and 17 respectively (Figure 3).

These data presented are averages of the priming solution treatments without the control. Seed priming with one of the four salt solutions increased the total plant emergence for 'Cariflora', 'Waimanalo' and 'PR Red' than was possible with priming in water or no priming at all. The priming solutions had no effect on the total germination of 'Solo 64' (Figure 4).

Seed priming was shown in this study to enhance the total seed germination and seedling stand establishment for slow germinating varieties or varieties with reduced

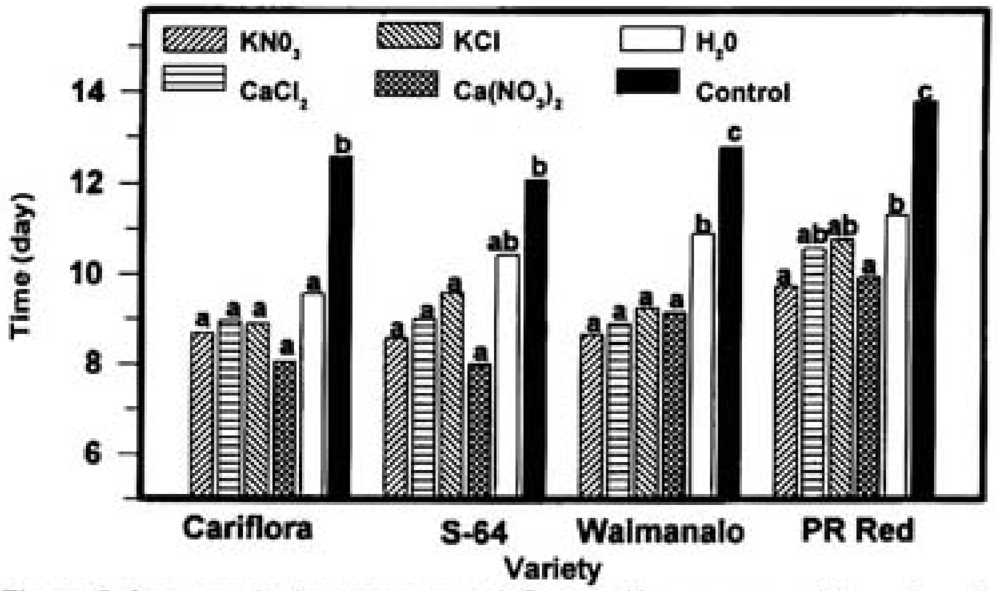



Figure 2. Average plant emergence as influenced by papaya variety and seed priming treatment. Different letters indicate significant differences between treatments within a variety. Mean separation test based on LSD P = 0.05.

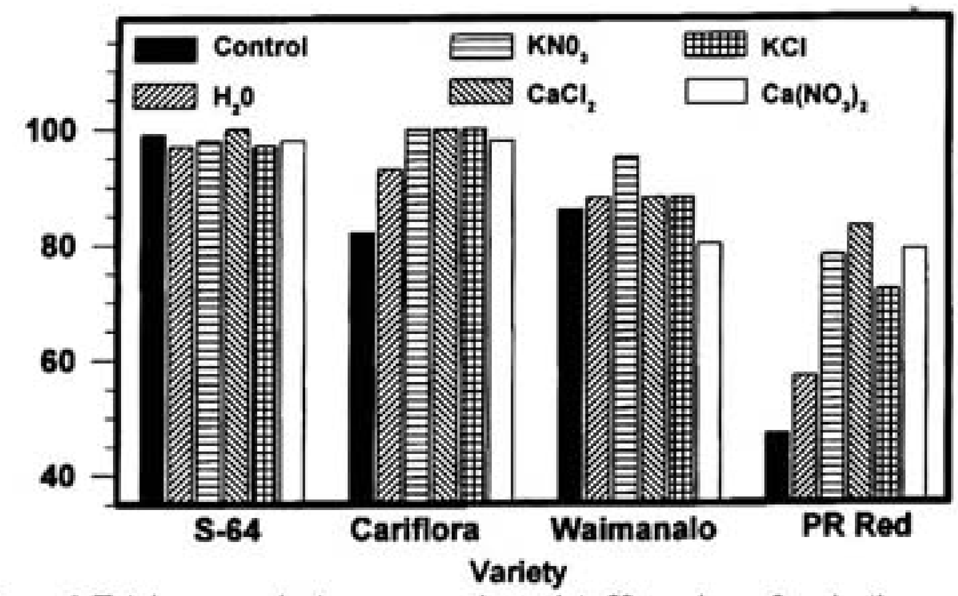



Figure 4. Total papaya plant emergence by variety fifteen days after planting as influenced by seed priming treatment.

viability. The benefit of seed priming was to reduce the average seedling emergence time and increase the uniformity of plant emergence.

Priming papaya seeds in water or one of the four salt solutions examined benefited seedling stand establishment.One of the beneficial effects of seed priming may be to leach some of the plant growth inhibitors from the seed coat and internal seed tissues.

Using a salt solution for seed priming of some papaya varieties can enhance the performance of seedling stand establishment over that obtained by water priming or unprimed seed.

The uptake of the nutrient salt during priming may increase metabolic activity during the priming process which can stimulate low vigor seeds to germinate. Pretreating papaya seeds with a salt solution can be used to enhance seed germination and provide uniform plant emergence in a shorter length of time than untreated seed.

Priming papaya seeds in a $KNO_3$ solution resulted in the greatest seedling emergence in the shortest length of time. Seed priming can be effectively used to promote better papaya seedling stand establishment.

This research was supported in part by Caribbean Basin Advisory Group (CBAG) Grant No. 94-34135-0280.

## *From the kitchen of...*

## A Home Recipe for Starting Papaya Seeds

**Seed priming can easily be done in a home or small-scale gardening situation:**

- ✓Put up to 50 mature and dried papaya seeds in a sandwich bag (Ziploc is best) or a small container.
- ✓Add 1/4 cup of bottled water or make a fertilizer solution made of 1 teaspoon $CaCl_2$ or $Ca(No_3)_2$ per cup of water or 1/2 teaspoon of KC1 or $KN0_3$ per cup of water). These salts are found in the commercial "Miracle Grow" plant food.
- ✓This should be enough solution to keep the seeds wet without submerging them. Seeds are living and require air, so be sure not to completely submerge them or they will drown.
- ✓Seal the bag but leave as much air in the bag as possible.
- ✓The solution will become dark from the tannins in the seed coat.
- ✓After two days, pour out the old solution and replace it with fresh, clear solution.
- ✓Allow the seeds to soak an additional three days. Now they are ready for planting.
- ✓The seeds may be planted 1/4 to 1/2 inch deep directly into pots or trays containing a loose potting soil with good drainage. Water the planted seeds and keep them in an area above 80° F during the day (you'll get very little or no plant emergence at temperatures below 75° F).
- ✓Seeds should start coming up in a week.

# Evaluation Of Three Indigenous Caribbean Finfish For Culture Potential

**Bill Cole and Kurt Shultz**

Worldwide fish harvests increased dramatically in the years following World War II, primarily due to improved fishing technology. Annual yields began to taper off in the late 1970s and it became evident that the ocean's fisheries resources were not inexhaustible. For the past several years the annual catch has hovered around 100 million metric tons (mt), a figure which many fishery biologists consider to be the ocean's maximum sustainable yield (MSY). MSY is the harvest of a particular stock or stocks of fish over time without causing a decrease in abundance. Today 13 out of 17 of the world's major fisheries are depleted or in serious decline. The remaining four are either fully utilized or over-exploited. Total catch has remained constant because of shifts in species composition that are harvested. The reasons for the decline in stocks include over-fishing, habitat destruction, pollution and climatic changes.

The majority of the Caribbean Sea consists of deep, nutrient-poor waters that are characterized as a biological desert. Many islands are surrounded by shallow, narrow shelves, that, while productive, are extremely sensitive to over-fishing. Landings in the U.S. Virgin Islands have been declining since the late 1970s in spite of increased fishing effort. Despite the small human population relative to surrounding sea, Caribbean islands rely on imports to meet demand. A study published in 1984 found that annual seafood demand in the

Table 1. Composition of diets fed to juvenile white grunts for ten weeks. Protein, fat, fiber and ash are expressed as a percent of dry weight.

| DIET | %PROTEIN | %FAT | %FIBER | %ASH | %MOISTURE |
|---|---|---|---|---|---|
| Dry, salmonid[a] | 43 | 15 | 4 | 12 | 10 |
| Semi-moist, salmonid[a] | 43 | 15 | 3 | 11 | 18 |
| Marine finfish[b] | 55 | 11 | 2 | 11 | 7 |
| Non-formulated[c] | 82 | 8 | 2 | 7 | 80 |

Table 2. Composition of diets fed to juvenile schoolmaster for ten weeks. Protein, fat, fiber and ash are expressed as a percent of dry weight.

| DIET | %PROTEIN | %FAT | %FIBER | %ASH | %MOISTURE |
|---|---|---|---|---|---|
| Dry, salmonid[d] | 44 | 15 | 3 | 7 | 11 |
| Semi-moist, salmonid[d] | 43 | 15 | 2 | 7 | 21 |
| Marine finfish[b] | 55 | 11 | 2 | 11 | 7 |
| Non-formulated[e] | 72 | 5 | 2 | 13 | 78 |

Table 3. Composition of diets fed to palometa for 16 weeks. Protein, fat, fiber and ash are expressed as a percent of dry weight.

| DIET | %PROTEIN | %FAT | %FIBER | %ASH | %MOISTURE |
|---|---|---|---|---|---|
| Dry, salmonid[d] | 46 | 16 | 2 | 8 | 10 |
| Semi-moist, salmonid[d] | 44 | 16 | 3 | 9 | 21 |
| Floating, salmonid[f] | 41 | 11 | 2 | 13 | 10 |
| Marine finfish[b] | 61 | 15 | 1 | 8 | 10 |

[a]Moore-Clark Co., Inc., LaConner, WA.
[b]Formulated by John Tucker, Harbor Branch Oceanographic Institution, Fort Pierce, FL, and manufactured by Zeigler Brothers, Inc., Gardners, PA.
[c]Composed of 45% fish, 45% shrimp and 10% squid. The ingredients were ground, mixed and supplemented with vitamins and minerals.
[d]BioProducts, Inc., Warrenton, OR.
[e]Composed of 70% fish, 20% shrimp and 10% squid. The ingredients were ground, mixed and supplemented with vitamins and minerals.
[f]Integral Fish Foods, Inc., Grand Junction, CO.

Caribbean was approximately 775,000 metric tons (mt) which greatly exceeded not only the fish landings (88,947 mt), but also the estimated potential yield (193,785 mt). Local fishery landings account for approximately 30 percent of seafood consumed in the U.S. Virgin Islands. If seafood supply is to be increased, other methods of production must be explored.

Mariculture, which refers to the culture or farming of marine organisms, has the potential to increase seafood production, provide economic diversification, create employment, reduce dependence on fish imports and generate foreign exchange through exports. With careful planning and management, stock enhancement programs may be used to reestablish fisheries where over-fishing has occurred. The Caribbean has excellent possibilities for mariculture, but development is restricted by a number of factors including the lack of technical and biological information. For example, insufficient information has been gathered to describe growth, feed conversion and survival of indigenous finfish under culture conditions.

The University of the Virgin Islands Agricultural Experiment Station (UVI-AES) initiated a program to evaluate the culture potential of several near-shore Caribbean marine finfishes. In the first phase of the program, feeding trials are used to evaluate growth performance, feed conversion efficiency and survival of juveniles fed various diets.

Three species have recently been evaluated: white grunts (*Haemulon plumieri*), schoolmaster snapper (*Lutjanus apodus*) and palometa (*Trachinotus goodei*). The studies were conducted in a flow-through facility consisting of 12 2-m3 fiberglass tanks. Water was pumped directly from the ocean using a 1-horsepower (hp) pump. Each tank was covered with 80 percent shade cloth and a 1/2-hp air blower provided backup aeration.

Fish captured from the wild using traps and seine nets were trained to eat a formulated (pelleted) diet by incorporating the formulated feed with a fish/shrimp/squid mixture. Over several days the percent of formulated feed was increased in the daily ration until the fish consumed 100 percent pellets. The fish were stocked in the tanks at a rate of 5 fish/m3 and fed four diets for 10 to 16 weeks. Treatments were randomly assigned to tanks and replicated three times. Diet types included commercially-available salmonid diets, experimental diets formulated specifically for warm-water marine finfish, and non-formulated diets consisting of fish, shrimp and squid plus vitamins and minerals.

At the conclusion of each experiment growth rates, feed conversion ratios (FCR), survival and condition factors (CF) of fish in each diet treatment were compared. Absolute growth rate (g/d) was calculated by dividing weight gain (g) by time (days). Specific growth rate was determined by the formula:

$$\text{Specific growth rate (\%/d)} = (\text{Ln } W2 - \text{Ln } W1 / T) \times 100$$

where W1 was the initial mean weight (g), W2 was the final mean weight (g) and T was time (days). FCR values were obtained by dividing the total amount of feed administered (g) by the increase in fish weight (g). CF was calculated by the formula:

$$CF = 105 \text{ X } W2 / TL23$$

where TL2 was the final mean total length (mm).

Mean values for growth rates, FCR, survival and CF were compared by one way analysis of variance and pairwise multiple comparisons were made using the Student-Newman-Keuls method. Differences among treatment means were considered significant at the 0.05 level of probability.

Juvenile white grunts (mean initial weight = 53 g) and schoolmaster (mean initial weight = 53 g) were fed three formulated, sinking diets and a non-formulated diet (Tables 1 and 2) for 10 weeks. Feed was administered once daily at rates of 10 percent of biomass for grunts and 3-4 percent of biomass for schoolmaster. Fish were sampled and feed rations adjusted accordingly by weighing all fish from each tank at two-week intervals. A second eight-week experiment was conducted using the semi-moist diet to compare growth of schoolmaster (mean initial weight = 78 g) fed once per day with those fed continuously during daylight hours. Continuous feeding was achieved using spring-operated belt feeders. Palometa (mean initial weight = 85 g) were fed four formulated diets (Table 3) for 16 weeks. Feed was administered four times daily, initially at a rate of 5 percent of biomass which was gradually reduced to 2 percent of biomass. Sampling occurred at four-week intervals.

Grunts fed the dry salmonid diet had significantly lower growth rates and a significantly higher FCR than fish fed the other diets (Table 4). The FCR of grunts fed the non-formulated diet was significantly lower than fish of the other treatments. There were no significant differences in condition factors for grunts fed each diet. In the first schoolmaster experiment, fish fed the non-formulated diet had the highest growth rates and the lowest FCR followed by fish fed the marine finfish diet, the semi-moist salmonid diet and the dry salmonid diet (Table 5). Pairwise comparisons of growth rates and FCRs indicated significant differences among all treatment means except between the two salmonid diets. The final condition factors were nearly identical for fish fed each diet. In the second schoolmaster study, there were no significant differences in growth rates among fish fed once per day at 4 percent of biomass (0.24 g/d, 0.26 %/d), fish fed continuously at 4 percent of biomass (0.33 g/d, 0.38 %/d), and fish fed continuously at 8 percent of biomass (0.27 g/d, 0.32 %/d). Absolute growth rate, specific growth rate, FCR

**Table 4.** Mean values for absolute growth rate, specific growth rate, feed conversion ratio and condition factor of juvenile white grunts fed three formulated diets and a non-formulated diet for ten weeks. For each column, values followed by the same letter are not significantly different ($p<0.05$).

| DIET | ABSOLUTE GROWTH RATE (g/d) | SPECIFIC GROWTH RATE (%/d) | FEED CONVERSION RATIO | CONDITION FACTOR | SURVIVAL (%) |
|---|---|---|---|---|---|
| Dry, salmonid | 0.20a | 0.76a | 10.9a | 1.84a | 100a |
| Semi-moist, salmonid | 0.27bc | 0.94b | 8.6b | 1.93a | 100a |
| Marine finfish | 0.29b | 1.02b | 8.4b | 1.92a | 100a |
| Non-formulated | 0.26c | 0.92b | 2.0c | 2.13a | 100a |

**Table 5.** Mean values for absolute growth rate, specific growth rate, feed conversion ratio and condition factor of juvenile schoolmaster fed three formulated diets and a non-formulated diet for ten weeks. For each column, values followed by the same letter are not significantly different ($p<0.05$).

| DIET | ABSOLUTE GROWTH RATE (g/d) | SPECIFIC GROWTH RATE (%/d) | FEED CONVERSION RATIO | CONDITION FACTOR | SURVIVAL (%) |
|---|---|---|---|---|---|
| Dry, salmonid | 0.28a | 0.45a | 7.9a | 1.67a | 100a |
| Semi-moist, salmonid | 0.30a | 0.48a | 7.4a | 1.68a | 100a |
| Marine finfish | 0.48b | 0.70b | 5.1b | 1.74b | 100a |
| Non-formulated | 0.58c | 0.81c | 3.5c | 1.74b | 100a |

**Table 6.** Mean values for absolute growth rate, specific growth rate, feed conversion ratio and condition factor of palometa fed four formulated diets for 16 weeks. For each column, values followed by the same letter are not significantly different ($p<0.05$).

| DIET | ABSOLUTE GROWTH RATE (g/d) | SPECIFIC GROWTH RATE (%/d) | FEED CONVERSION RATIO | CONDITION FACTOR | SURVIVAL (%) |
|---|---|---|---|---|---|
| Dry, salmonid | 2.79a | 1.38a | 2.15a | 2.93ab | 93a |
| Semi-moist, salmonid | 2.85a | 1.39a | 2.13a | 3.04a | 100a |
| Floating, salmonid | 2.78a | 1.83a | 2.16a | 2.83b | 97a |
| Marine finfish | 2.81a | 1.39a | 2.16a | 3.05a | 100a |

[a]Moore-Clark Co., Inc., LaConner, WA.

[b]Formulated by John Tucker, Harbor Branch Oceanographic Institution, Fort Pierce, FL, and manufactured by Zeigler Brothers, Inc., Gardners, PA.

[c]Composed of 45% fish, 45% shrimp and 10% squid. The ingredients were ground, mixed and supplemented with vitamins and minerals.

[d]BioProducts, Inc., Warrenton, OR.

[e]Composed of 70% fish, 20% shrimp and 10% squid. The ingredients were ground, mixed and supplemented with vitamins and minerals.

[f]Integral Fish Foods, Inc., Grand Junction, CO.

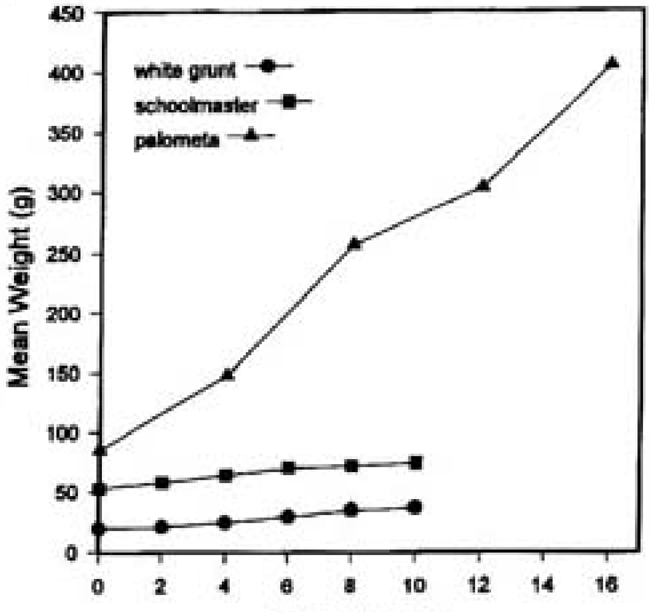



**Figure 1.** Mean weights of white grunts, schoolmaster and palometa fed semi-moist salmonid diets for 10 or 16 weeks.

Although both white grunts and schoolmaster snapper responded well to handling and no diseases were observed, growth rates obtained in these studies were lower than the range desired for commercially-cultured finfish. This is also true for the feed conversion ratios obtained for both species, with the exception of grunts fed the non-formulated diet. Continuous feeding of schoolmaster did not significantly improve growth. Absolute growth rates, which tend to increase with fish size, decreased throughout each schoolmaster study. A better understanding of these species nutritional requirements and behavior in confined conditions may improve growth and feed conversion. These studies indicate that white grunts and schoolmaster are not suitable candidates for food fish culture under these experimental conditions.

Although direct comparison between species can not be made due to variation in diets and initial weights, Figure 1 illustrates increases in mean weight for grunts, schoolmaster and palometa fed semi-moist diets of similar composition. Growth rates and feed conversion ratios exhibited by palometa fed each diet compare favorably to commercially-cultured finfishes. Palometa fed the lower protein salmonid diets grew as rapidly and had similar feed conversion as those fed the high-protein marine finfish diet. The floating diet was readily accepted. Mortalities were due to parasitosis (*Neobenedenia melleni*). Parasites were controlled by a one-hour bath treatment of 167 ppm formalin and subsequent three-minute dips in freshwater at four-week intervals. This parasite has been problematic with other cultured warm water marine species and practical methods of control will have to be developed for commercial operations.

Juvenile feeding experiments are only one step in UVI's program to evaluate the mariculture potential of indigenous finfish. Species, such as the palometa, which appear to have mariculture potential, require further research. Grow-out systems (i.e., tanks and cages) need to be evaluated as well as spawning and larval rearing techniques. Nutritional and environmental requirements of potential species have to be determined. Practical disease prevention and control methods must be developed before commercial mariculture is possible.

Cultured seafood production will increase in the future because of the shortfall of ocean fisheries, an increasing world population and developments in mariculture technology. Total aquaculture (freshwater and marine) production in 1990 was 12.1 million metric tons (mt) and the projected aquaculture production in the year 2000 is between 20 and 22 million mt. More than 50 percent of aquaculture production comes from brackish and marine environments. The Caribbean, which has excellent potential for mariculture, could play a role in future seafood production. To help meet these needs, UVI-AES will continue to pursue mariculture research.

This research was supported in part by the U.S. Department of Agriculture under Hatch Project No. 0220530.

# Environmental Influences On Reproduction And Milk Production Of Holstein Cows On St. Croix

**Robert W. Godfrey and Peter J. Hansen**

The dairy industry is one of the major animal-related agribusinesses in the U.S. Virgin Islands, but the industry has been unable to consistently meet local demand. A consistent supply of fresh milk for consumption or processing into dairy food items could minimize the use of imported or reconstituted milk for human consumption in the USVI.

Several factors, including nutrition, genetics and the environment can influence milk production and reproductive efficiency of dairy cattle. Dairy farmers in the Caribbean have the least amount of control over the environment when compared with nutrition or genetics.

Two components of the Caribbean environment have high potential to influence dairy cattle. The first is ambient temperature. The ability of cattle to maintain thermoneutrality is more difficult when they are exposed to elevated ambient temperatures. When ambient temperature rises above the upper limit of the thermoneutral zone (80°F) it is more difficult for cattle to maintain their normal body temperature (101°F). When this occurs the animal will experience some degree of heat stress.

The second environmental component is solar radiation. Studies have shown that dairy cattle in sub-tropical and tropical environments have depressed reproductive and productive traits. This suppression was most noticeable during the warmer months of the year. The amount of solar radiation plays a major role in determining the ambient temperature, and may also be involved in suppressing the reproduction and production of dairy cattle.

It has been known for many years that darker colors absorb more solar radiation which leads to elevated temperatures of dark colored objects. Recently, there has been interest in determining the relationship between hair coat color and production and reproduction in Holstein cows in hot, humid climates with high amounts of solar radiation, based on the theory that darker cows will absorb more solar radiation which could lead to elevated body temperatures and increase the incidence of heat stress.

The objectives of this study were: 1) to evaluate if there are seasonal influences on reproduction and milk production of Holstein cows on St. Croix, and 2) to determine if there is a relationship between percent black hair coat and milk production or reproductive traits of Holstein cows on St. Croix. The project was conducted in retrospect by examining herd records from a commercial dairy farm covering the period from 1960 through 1986. The herd consisted of both registered and commercial grade Holsteins. Information obtained directly from the herd records included milk production during the first lactation (lb), length of first lactation (days) and calving dates. Calving interval was calculated as the number of days between consecutive calving dates for an individual cow. Cows were bred by natural service using Holstein bulls and were exposed to the bulls at all times of the year during the time frame that the records cover. Cows were milked two times a day during lactation and maintained on guinea grass pastures.

Percent black hair coat (BHC) was determined by using the identification pictures on the record sheets for the cows.

**Table 1.** Number of observations collected from dairy herd records of 520 Holstein cows covering a 25-year period.

| Data Type | n |
|---|---|
| Calves born | 1293 |
| Calving intervals | 767 |
| Percent black hair coat | 462 |
| First lactation levels | 456 |

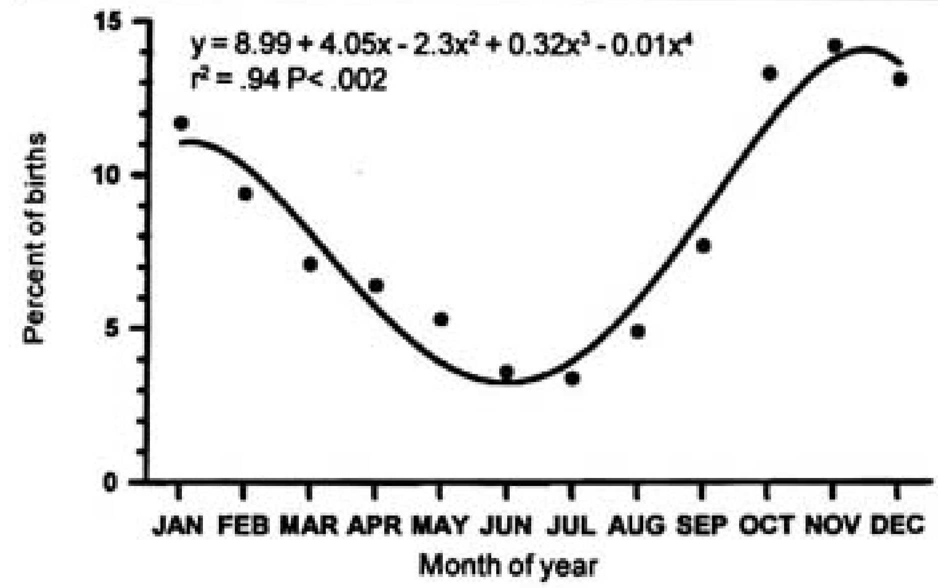



**Figure 1.** Distribution of calvings throughout the year in Holstein cows (n = 1293 calves).

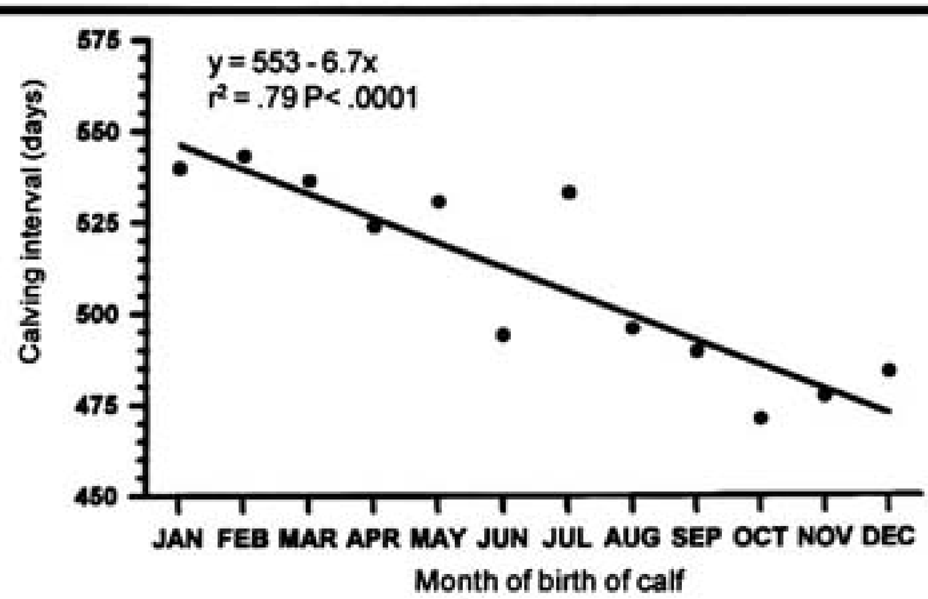



**Figure 2.** Relationship of calving interval and month of calving in Holstein cows (n = 767).

**"Cows that calve and begin lactating during the late part of the year when grass is abundant and the temperature is decreasing have more efficient reproduction and higher milk production than cows that calve during the summer when grass is sparse and the temperature is elevated."**

A transparent grid was placed over the left and right profile drawings of the cow and the number of points that fell on areas of black hair were counted. Percent BHC was calculated by dividing the number of points that were over areas of black hair on both the left and right sides of the cow by the total number of points over the entire left and right sides of the cow. The number of cows and observations for the various traits analyzed are shown in Table 1.

To evaluate the effect of time of year on reproduction and milk production, the year was divided into four seasons based on rainfall on St. Croix. The first dry season included January through April (DRY-1). May is considered a rainy period (WET-1), and June through September is the second dry season (DRY-2). The second rainy season (WET-2) occurs from October through December. Based on data collected from 1987 through mid-1994, the average monthly rainfall during DRY-1, WET-1, DRY-2 and WET-2 was 2.1, 4.9, 3.6 and 5.1 inches, respectively, and the average daily high temperature was 86.7, 88.7, 90.3 and 89.9° F, respectively.

The calving distribution throughout the year exhibited a definitive seasonal pattern (Figure 1). Greater than 50 percent of the calves were born during the winter months (October through January) while less than 8 percent were born during the summer (June and July). By back calculating from calving dates, it was determined that the majority of conceptions occurred during the months of January through April. This coincides with the first dry season (DRY-1), which is also the coolest time of the year on St. Croix. The combination of relatively cooler temperatures and adequate levels of forage during the first two months of the year, due to the previous rainy season (WET-2), enhanced the conception rate of the cows during the early months of the year. Conception rate is related to both temperature and humidity in a negative fashion, which may explain why the majority of the conceptions occurred during a cooler, dry period of the year (DRY-1). Nutritional status may also have been improved since the cows were receiving adequate nutrition from the forage available in the pastures.

Calving interval was influenced by the time of year when the calf was born. Cows that gave birth early in the year had a longer calving interval than cows that gave birth during the later months of the year (Figure 2). A similar pattern was observed when the data were analyzed using the wet and dry seasons as a time frame (Table 2). Cows that gave birth during DRY-1 had a 61-day longer calving interval than cows that gave birth during WET-2. The cows that gave birth during the last three months of the year (WET-2) were exposed to decreasing temperatures, higher rainfall and higher levels of forage availability than at other times of the year. This combination may have improved conception rate at first service after calving and shortened the postpartum interval due to the increased plane of nutrition provided by the forage. This may also explain why the majority of conceptions occurred during the early part of the year. The cows had shorter postpartum intervals and were bred sooner than cows that calved during other times of the year, both of which led to a shorter calving interval.

Milk production during the first lactation exhibited a pattern similar to that of calving distributions (Figure 3). Cows that began lactating in the middle of the summer (July) had the lowest milk production compared to cows that began lactating in either the early or late part of the year. The length of lactation was not different among cows

**Table 2.** Calving interval (CI), first lactation milk production and length of first lactation (DAYS) of Holstein cows on St. Croix that either gave birth or began their first lactation in a dry or wet season.

| Season[a] | n | CI, days | n | Milk, lb | DAYS |
|---|---|---|---|---|---|
| DRY-1 | 260 | 524[c] | 179 | 10,750[c,d] | 294 |
| WET-1 | 33 | 504[c,d] | 22 | 10,121d | 285 |
| DRY-2 | 136 | 485[c,d] | 113 | 9,877d | 291 |
| WET-2 | 338 | 466d | 142 | 11,576c | 308 |
| Combined[b] | | | | | |
| WET | 371 | 469[c] | 164 | 10,849 | 298 |
| DRY | 396 | 511[d] | 292 | 10,314 | 293 |

[a]DRY-1 = January-April, WET-1 = June-September, WET-2 = October-December.
[b]WET = WET-1 + WET-2, DRY = DRY-1 + DRY-2.
[c,d]Values within a trait with different superscripts differ ($P < .05$).

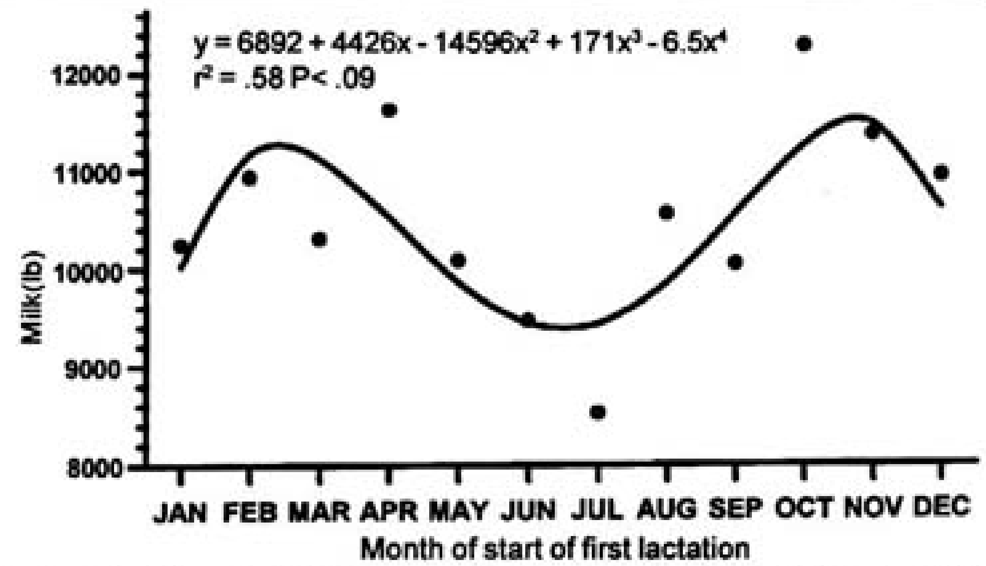


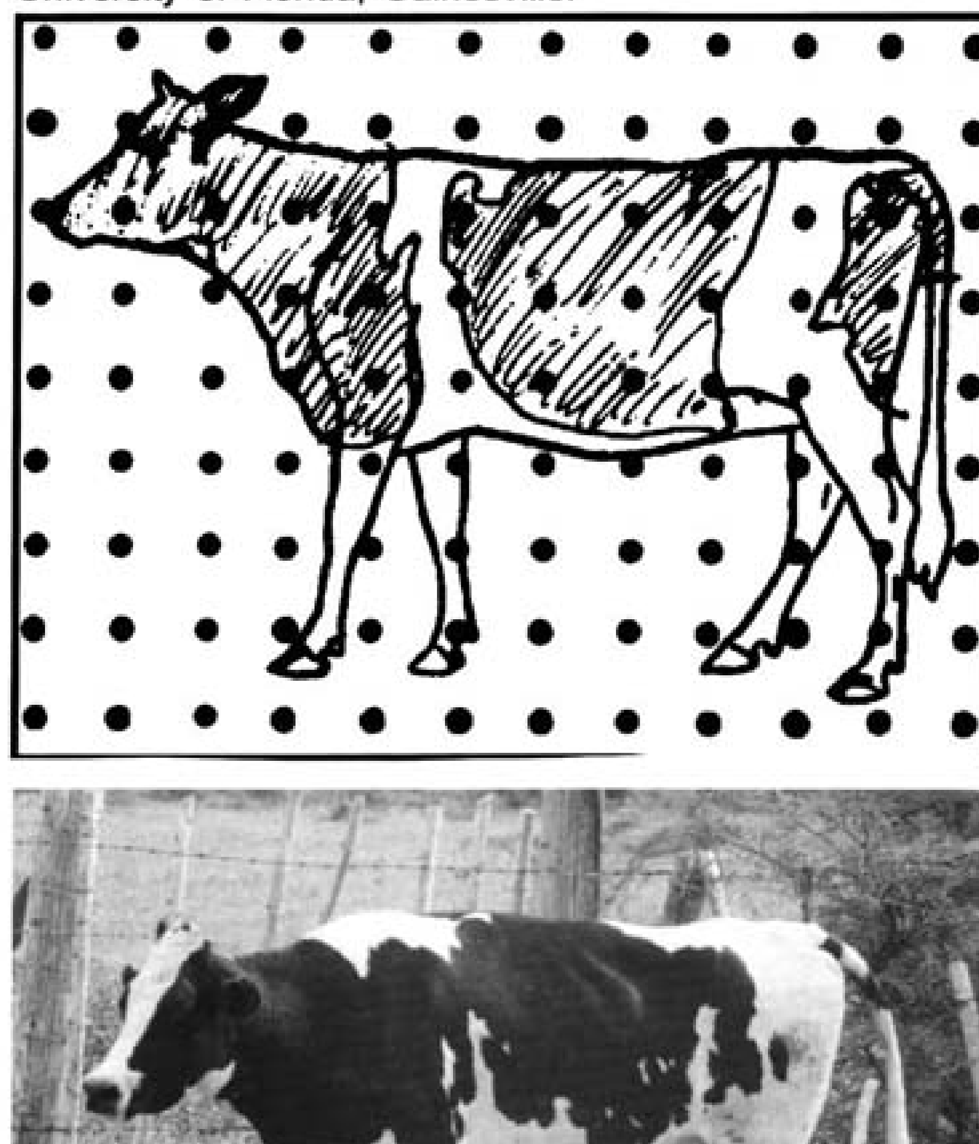

**Figure 3.** Milk production during first lactations that bagan at different months of the year (n = 456).

that began lactating at different times of the year (Table 2), which means that the pattern of milk production is most likely caused by other factors, such as the environment and/or nutrition. Cows that began lactating during WET-2 produced approximately 1700 lbs. more milk than those that began in DRY-2 (Table 2). Cows that began lactating in July (DRY-2) did so at a time of year when the temperature was increasing and rainfall was low, while those that began in DRY-1 or WET-2 were exposed to either cooler temperatures or increased rainfall, respectively. Holstein cattle spend less time grazing and more time seeking shade during the hottest time of the day. This could mean that the difference in milk production is partially due to nutrition, since lactation increases the nutrient requirements of cattle. There are higher levels of forage available during the rainy season of WET-2 than during the dry season of DRY-2 and the cows are in a better nutritional status during the rainy season.

The population of cows was skewed towards a darker-colored animal with an average percent BHC of 74.1 percent from a range of 12 to 100 percent. This description of the population of cows is in agreement with results of other researchers who described populations of cows in Florida. There was no relationship found between BHC and calving interval or milk production in the present study. It may take analysis of larger numbers of cows before any correlation between hair coat color and either production or reproduction can be established. Since the average high temperature on St. Croix is 89°F, cattle may be constantly in a state of heat stress of varying degrees throughout the year. Any influence of coat color and heat absorption on reproduction/production traits may be masked by the effects of the consistently high ambient temperature on St. Croix.

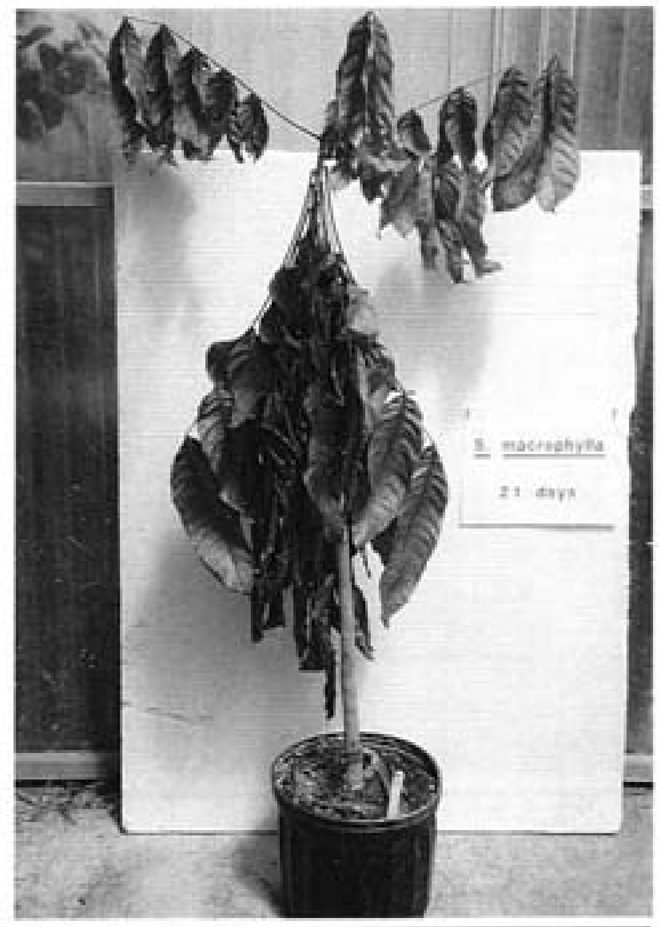
The results of the present study indicate that reproductive efficiency and milk production of Holstein cows on St. Croix are influenced by season of the year, when determined by rainfall and temperature. Both reproduction and milk production are negatively influenced by the hot and dry times of the year when forage availability is low. Cows that calve and begin lactating during the late part of the year when grass is abundant and the temperature is decreasing have more efficient reproduction (shorter calving intervals) and higher milk production than cows that calve during the summer when grass is sparse and the temperature is elevated.

The authors would like to thank Mrs. Caroline Gasperi of Castle Nugent Farms, St. Croix, for providing access to the animal records. This project was supported by CBAG Project 9204572 in collaboration with Dr. Peter J. Hansen, Professor, Department of Dairy and Poultry Sciences, University of Florida, Gainesville.



# Mahogany Response To Water Stress

## Jim O'Donnell




**"Both the big-leaf and medium-leaf mahoganies exhibited severe defoliation at the 7- and 21-day watering intervals."**

Mahogany is a precious wood, highly prized by woodworkers and furniture makers for its color, strength, working qualities and durability. The mahogany genus includes three species (*Swietenia mahagoni, S. macrophylla,* and *S. humilis*) and at least one interspecific hybrid.

Small-leaf or West Indies mahogany (*S. mahagoni*) is native to the Greater Antilles (except Puerto Rico), the Bahamas and southern Florida. It has since been introduced to other islands in the West Indies and is now naturalized throughout the Caribbean. Small-leaf mahogany ranges in habitat from lowland, tropical moist to tropical dry forest formations. It is noted for its ability to grow on dry sites with shallow soils.

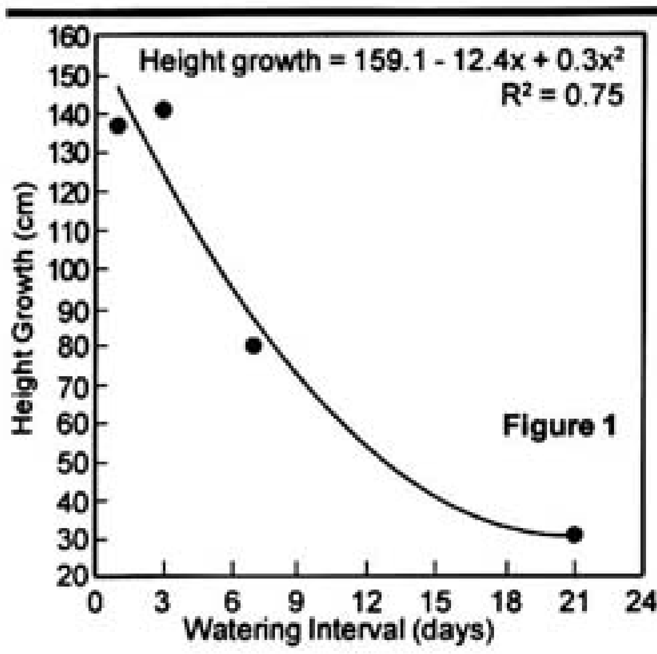
The big-leaf or Honduras mahogany (*S. macrophylla*) is a lowland, moist to humid tropical species that has a native range from southern Mexico through Central America to the Amazon basin of Brazil, Peru and Bolivia. It has become the most widely used mahogany due to the depletion of the small-leaf mahogany wood supply.

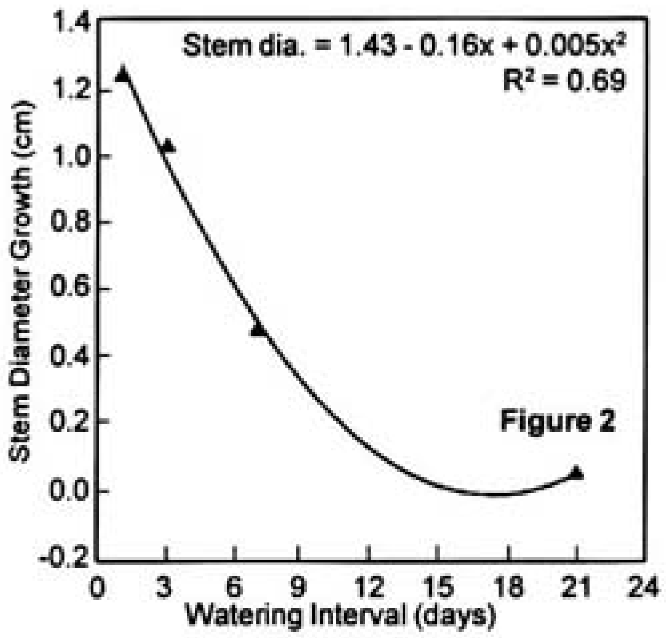
As a result of adjacent plantings of these two mahogany species a natural hybrid was produced. This hybrid is referred to as medium-leaf or hybrid mahogany (*S. macrophylla* x *mahagoni*). Medium-leaf mahogany, as the name implies, is intermediate between its two parents in leaf and seed capsule size. It is thought to grow faster than the small-leaf mahogany and be more drought tolerant than big-leaf mahogany. Its wood is of better quality than big-leaf mahogany and produces a straighter stem than the small-leaf.

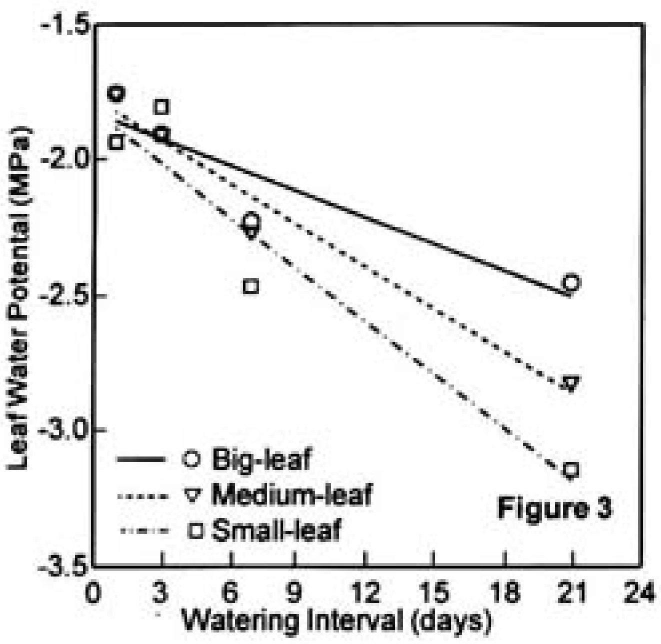
Small-leaf mahogany was probably brought to the U.S. Virgin Islands as early as 1770. It was widely planted as a shade tree along roads and driveways and was grown for use in furniture making. It has become naturalized on St. Croix and can now be found in nearly all parts of the island. Big-leaf mahogany was introduced much later on St. Croix for use in species trials. Although not as common as small-leaf, it is found planted along roadsides and in public areas in the Virgin Islands. The medium-leaf mahogany began to appear in St. Croix as a result of cross-pollination of big-leaf and small-leaf mahoganies in adjacent plantings. After a number of growth studies, the U.S. Forest Service recommended that the medium-leaf mahogany be used in forest plantations for timber production on St. Croix. This has resulted in increased planting of the medium-leaf.

Studies of survival and growth of the three mahoganies common to St. Croix have indicated that these species are susceptible to drought conditions, especially in the seedling and sapling stages. Since many potential areas for forest plantings on St. Croix are marginal sites with shallow or rocky soils, water stress can be a recurring problem. In order to evaluate the effect of water stress on mahogany an experiment was conducted at UVI-AES. The three mahogany species common to St. Croix (*S. macrophylla, S. mahagoni,* and *S. macrophylla* x *mahagoni*) were subjected to four watering intervals (1, 3, 7, and 21 days) for a period of 37 weeks. Two-year old trees were grown in 28-cm plastic pots (11-L volume) with a growing medium composed of potting media, field soil and river sand in a 2:1:1 ratio. All trees received fertilizer and pots maintained at field capacity prior to the initiation of the experiment. The study was conducted in a greenhouse with a plant spacing of 0.5 m within rows and 1 m between rows.

At the beginning of the experiment total tree height and stem diameter were measured. Tree height was measured from the soil surface to the top of the terminal bud with a measuring pole. Stem diameter was measured at the soil surface with calipers. After imposition of watering regimes, observations were made on leaf abscision, changes in leaflet color and branching. Leaf water potential (LWP) was measured every 21 days with a J-14 leaf press (Decagon Devices, Inc., Pullman, WA). Three 2-cm leaf discs taken from the most recent fully expanded leaves were used for leaf water potential measurements.



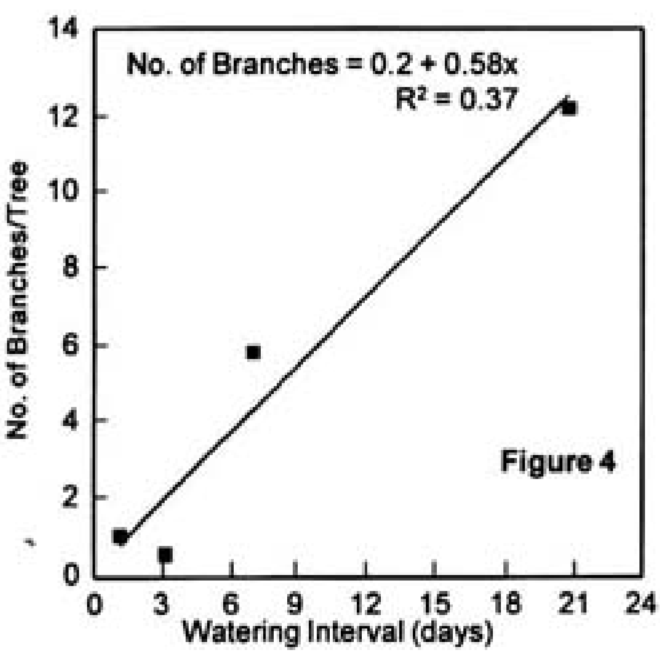




**Figure 1.** Relationship between mahogany height growth and watering interval.

**Figure 2.** Relationship between mahogany diameter growth and watering interval.

**Figure 3.** Relationship between mahogany leaf water potential and watering interval.

**Figure 4.** Influence of watering interval on branching in big-leaf mahogany.

Pressure was applied via the leaf press until a color change was observed, and the pressure noted. Measurements of LWP were made between 10:00 a.m. and 2:00 p.m. At the end of the experiment total tree height and stem diameter were again measured.

There were no differences in total height or stem diameter growth between the three types of mahogany; however, watering interval did have a significant effect on both height and diameter growth. Greatest height (Figure 1) and diameter (Figure 2) growth occurred at the three-day watering interval and lowest growth for both parameters at the 21-day interval. Height growth ranged from 137.2 cm at the three-day watering interval to 30.5 cm at the 21-day interval. The 21-day watering interval resulted in a diameter growth of 0.05 cm as compared to 1.24 cm of diameter growth at the three-day interval. The 21-day watering interval resulted in dieback of the terminal bud in 50 percent of both the big-leaf and medium-leaf mahoganies. Fifty percent of the big-leaf mahoganies also had terminal bud dieback at the seven-day watering interval. In addition, one small-leaf and one medium-leaf mahogany died in the 21-day watering treatment.

There were no differences in LWP between species, but watering interval did affect overall LWP. Leaf water potential responded linearly to watering interval, with highest LWP at the one-day watering interval and lowest LWP at the 21-day interval (Figure 3). The absence of variation in LWP between species may indicate that maintenance of LWP is not a specific mechanism of drought tolerance in mahogany. Although no differences in LWP were found, distinct responses to water stress were observed. Both the big-leaf and medium-leaf mahoganies exhibited severe defoliation at the seven- and 21-day watering intervals. Leaf abscision is a drought avoidance mechanism. Since both of these species have much larger leaves than the small-leaf mahogany, their transpirational losses would be greater, thus necessitating leaf abscision to reduce water loss during times of stress. The small-leaf, on the other hand, did not demonstrate any large scale leaf abscision, but did reorient its leaves from a horizontal to a vertical position at the higher watering intervals. This is also a drought avoidance technique for reducing transpirational losses by decreasing the interception of solar radiation. In both cases, the reduction of leaf area for the interception of solar radiation and the subsequent decrease in photosynthesis could have been a factor in the reduced growth of mahogany at the higher watering intervals.

Branching was much more pronounced in the small-leaf mahogany (28/tree) than the other two species (6/tree), although there was no correlation between branching and watering interval for the small-leaf. Small-leaf mahogany has a tendency to produce more branches and to branch at an earlier age than either big-leaf or medium-leaf mahogany. Branching in big-leaf mahogany was affected by watering interval with a linear increase in branching with increasing watering interval (Figure 4). The increased branching in big-leaf mahogany was probably due to the dieback of the terminal bud and loss of apical dominance.

Under the environmental conditions encountered on St. Croix—shallow soils, extended dry periods and high solar radiation—water stress may be an important factor in the survival and growth of mahogany. Although older trees with well-established root systems can withstand extended periods of low water availability, trees in the seedling and sapling stage may be more susceptible to water stress. This study demonstrates the effect water stress has on mahogany height and diameter growth. Additionally, the increased branching exhibited by big-leaf mahogany, and the dieback of the terminal bud in both medium-leaf and big-leaf mahogany at the higher watering intervals suggest that water stress may also influence stem growth and bole formation and, ultimately, lumber quality.

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# Preservative Characteristics Of Guineagrass/ Leucaena Silage Compared To Sorghum Silage

**Martin B. Adjei and S. Josephat**

The dairy cattle industry on the Virgin Islands requires high quality feed year-round to sustain production of milk and milk products for the public. The industry is largely supported by native pastures dominated by guineagrass and leucaena (tan-tan) which grow well on the islands and produce large quantities of highly nutritious forage during the rainy season. However, in the dry season, the mature guineagrass stops growing and loses quality. Stockpiling guineagrass in the field during the growing season for use in the dry months can help overcome the lack of forage caused by dry weather. When stockpiled, however, guineagrass and leucaena lose digestibility and, in turn, lower the animal's intake of essential nutrients. As an alternative to stockpiling, nutritive value of native forage can be preserved by ensilage. Indeed, some dairy farmers on the Virgin Islands have contemplated harvesting surplus native guineagrass on a large scale during the growing season for conservation as silage. As part of the on-going evaluation of forage conservation systems in the Caribbean, a pilot experiment was conducted at UVI-AES to evaluate the preservative characteristics of guineagrass/leucaena forage when ensiled without or with molasses addition at 3 percent of forage biomass. Leucaena leaf meal inclusion was varied at 0, 5, 10 and 20 percent of forage mass before ensiling. In a second experiment, silage characteristics of guineagrass were compared with those of sorghum and millet-elephantgrass hybrids which are known to be good silage crops.

Knowledge of the ensilage process is an essential first step towards adoption of good ensilage practices. During ensilage, soluble carbohydrates, such as sugars and starch that are present in forage material, get fermented to fatty acids. The two essential acids produced are lactic and acetic. They reduce the pH of the forage material which kills micro-organisms present and thereby pickles the forage for long term preservation. However, as long as oxygen is present, plant enzymes and oxygen-utilizing (aerobic) micro-organisms will use up the sugars through respiration and generate carbon dioxide and heat which is capable of causing a considerable rise in temperature of the material. Therefore, if forage is not finely chopped and well packed in the silo after filling, air will remain in the material and cause excessive overheating with a consequent depletion of the same soluble carbohydrates needed for conversion into acids.

In addition to the possible breakdown of carbohydrates to carbon dioxide through respiration, approximately 60 percent of the proteins in forage are broken down even in well preserved material during ensilage. In well preserved silage, where a rapid fatty acid type of fermentation occurs and a satisfactory degree of acidity is produced, the end-products of protein breakdown are mainly amino acids. However, in badly preserved material, the amino acids are further degraded by micro-organisms into ammonia gas which may be lost from the silo. As a result of these chemical changes, gaseous losses (mainly of carbon dioxide and ammonia) occur during ensilage. The amount of dry matter lost in gaseous form may vary from 2-30 percent of the original forage depending on the type of chemical changes induced. Since these losses are caused by a breakdown of soluble and highly digestible nutrients, it follows that the higher the gaseous losses, the lower will be the feeding value of the silage.

Two problems associated with ensiling forage grasses are their low concentrations of dry matter (DM) and fermentable carbohydrates. Wilting of forage and the addition of carbohydrates such as cane molasses to forage material before ensilage may be beneficial. The objectives of our study were to characterize guineagrass/leucaena silage as influenced by wilting and molasses additive, and to compare it with sorghum silage.

The field of guineagrass used for our experiment was mowed back to a 6-inch stubble on May 13, 1993, and allowed to regrow for 40 days. Leucaena leaves, including young green branches, were pruned from an established field on the 17th of June 1993, chopped through a shredding machine into a meal and partially dried in a forced-air oven at 140°F (60°C) for 48 hours. The 40-day guineagrass regrowth was approximately four feet in height and at the early flowering (boot) stage of maturity. It was harvested with a sickle bar mower on the 22nd of June, 1993, and chopped. Approximately 13 lbs of chopped guineagrass forage was mixed

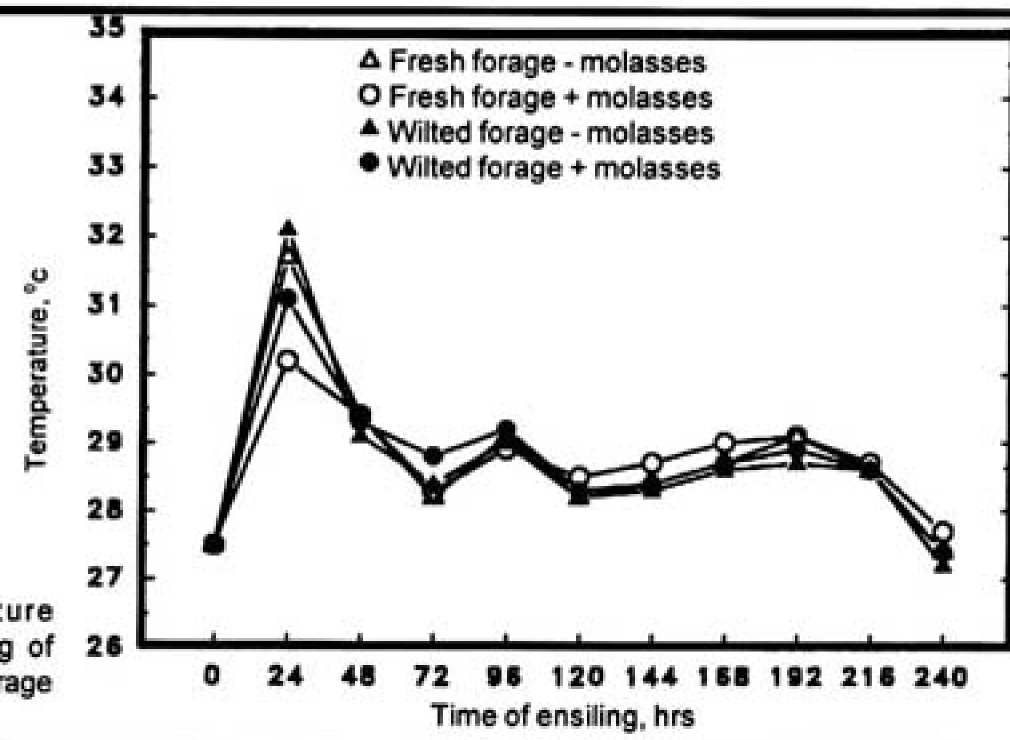



Figure 1. Temperature changes during ensiling of guineagrass/leucaena forage on St. Croix.

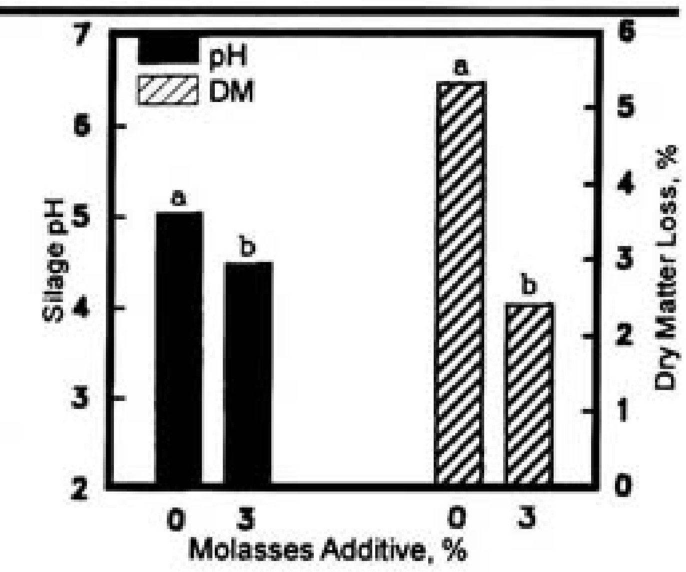



Figure 2. Effect of molasses additive on the final pH and dry matter losses of guineagrass/leucaena silage on St. Croix. Average over fresh and wilted treatments.

with all possible combinations of 0, 5, 10 or 20 percent of the partially dried leucaena leaf meal and 0 or 3 percent molasses, on fresh weight basis. The molasses was diluted with an equal weight of water to facilitate mixing. Treated forage was thoroughly mixed, hand-packed in 5-gallon plastic buckets and weighed. There were three replicates (buckets) for each treatment. Fresh forage subsamples were dried in oven at 60°C (140°F) to determine dry matter (DM) content. Filled plastic buckets were covered first with a 6 mil plastic sheet and then with a lid that had a rubber seal around the rim to keep out air. In addition to ensiling fresh grass, some guinea grass was left to wilt in the field for approximately three hours before it was subjected to similar chopping, leucaena and molasses treatments and ensiled. A 3-ft copper-constantan thermocouple was inserted through a hole drilled in the center of the plastic lid into the bucket to help monitor temperature changes during the fermentation process. The hole in the lid around the thermocouple was sealed with an epoxy resin (diethylene triamine). Temperatures were read at 24 hour intervals on a digital thermometer for 10 days during ensilage. Filled buckets were stored at room temperature (approximately 27°C or 80°F) in a shed for 28 days after which period, they were reopened and reweighed. Following visual determination of color, subsamples of ensiled forage were removed for DM, pH and volatile fatty acid (VFA) determinations. Color was rated on a scale of 1 to 5 (green=1 greenish brown=2.5; brown and moldy=5).

In the other experiment, fresh and wilted guineagrass, Puerto Rico 5BR forage sorghum (PR 5BR) and a millet-elephantgrass hybrid (M-E) forages were chopped, mixed with 0 or 10 percent leucaena leaf meal and 0 or 3 percent molasses additive and ensiled as described above.

The results of the guineagrass/leucaena experiment were as follows. The maximum observed temperatures occurred within the first few hours of ensiling and ranged between 30 and 32°C (86-90°F) depending on treatment (Figure 1).

> "For proper fermentation and long term preservation of guineagrass/leucaena silage, the results suggest that molasses or other energy additive are necessary."

Although minimal, the rise in temperature was affected ($P<0.01$) by molasses additive and the condition of guineagrass (fresh vs. wilted). Maximum temperature was greater in forage without molasses additive and for wilted over fresh guineagrass (Figure 1). This might have been caused by differences in rates of fatty acid production and hence rates of containment of aerobic microbial activity under the different treatments. Following the initial increase, temperatures declined sharply as entrapped air became depleted. Apparently, fermentation was completed in 8 days (192 hours) beyond which time a further decline in forage temperatures was observed for all treatments (Figure 1). It is generally accepted that an early temperature rise above 55°C (130°F) of forage material in the silo is undesirable. In our experiment, temperature rise caused by the initial aerobic respiration was minimal; probably because forage was firmly packed to exclude air and sealed in the plastic bucket silos.

The initial pH of fresh or wilted guinea grass forage before ensiling was 6.1 and that for the partially dried leucaena meal was 6.2. The pH of silage was significantly affected by molasses additive and leucaena inclusion (Figures 2 and 3). The final pH of ensiled forage averaged 4.5 when molasses was added but 5.1 without molasses (Figure 2). A pH of about 4.2 is generally recommended for long term preservation of silage. The final pH of silage was generally elevated by the inclusion of leucaena meal (Figure 3) probably because of the high buffering capacity of protein from the legume.

Dry matter content of the fresh and wilted guinea grass before ensilage averaged 20 and 25 percent, respectively. The dried leucaena leaf meal was 83 percent DM. Thus, inclusion of leucaena at the 0, 5, 10 and 20 percent of fresh weight on an ensiled basis corresponded to 0, 18, 32 and 51 percent DM inclusion for fresh guinea grass and 0, 13, 25 and 43 percent DM inclusion for wilted guinea grass, respectively.

In our experiment, DM losses during the 28 day storage ranged from 1 to 6.8 percent and was significantly influenced by molasses addition and leucaena inclusion (Figures 2 and 4). The DM losses, when averaged over leucaena treatments, were 2.4 and 5.2 percent for

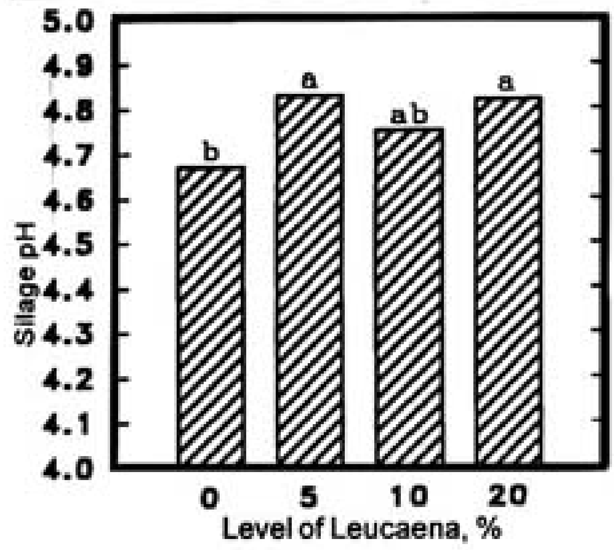



**Figure 3.** Effect of level of leucaena inclusion (fresh weight basis) on the final pH of guineagrass/ leucaena silage on St. Croix.

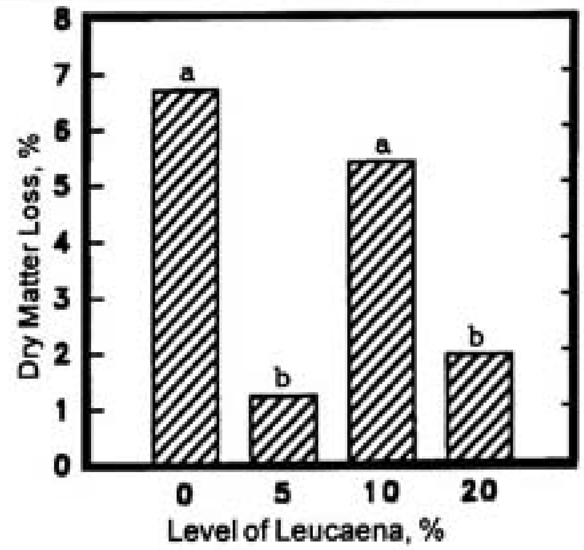



**Figure 4.** Effect of level of leucaena inclusion (fresh weight basis) on dry matter losses of guineagrass/ leucaena silage on St. Croix.

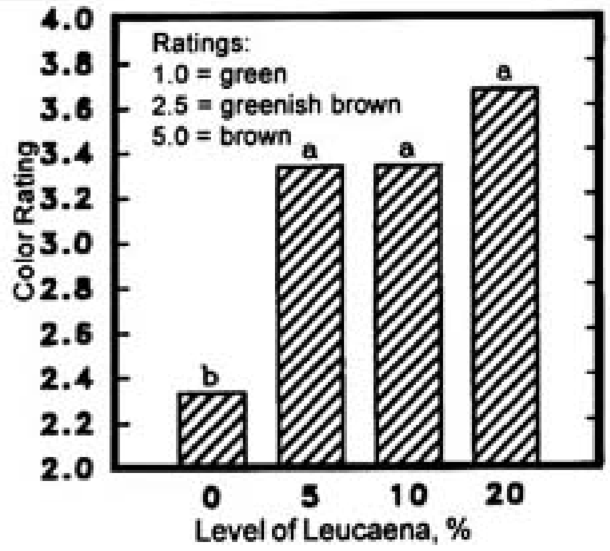



**Figure 5.** Effect of level of leucaena inclusion (fresh weight basis) on the final color of guineagrass/ leucaena silage on St. Croix.

forage ensiled with and without molasses, respectively (Figure 2). However, the effect of leucaena inclusion on DM losses (Figure 4), was inconclusive. Dry matter losses during ensilage was highest at 0 percent level of leucaena inclusion and lowest at the 5 and 20 percent levels of inclusion.

In well preserved silage, where the temperature has not risen to any appreciable extent, the carotene (pigment) content should be similar to that of the original crop. Large amounts of carotene can be lost, however, in overheated silage changing the color to brown. Although color is sometimes used to classify the quality of silage, the color of silage produced in our experiment was largely controlled by leucaena inclusion. The addition of dried leucaena meal (which was brownish green in color) generally modified the greenish color of guinea grass silage towards a brownish color (Figure 5).

In the second experiment, the level of leucaena inclusion (0 vs. 10%) did not have any marked effect on measured traits. The final silage DM for the sorghum, wilted guineagrass and M-E hybrid ranged from 28 to 30 percent but only 23 percent for the fresh guineagrass (Figure 6). The sorghum and M-E hybrid silage contained lower ($P<0.01$) acetic acid but higher levels of lactic acid than guineagrass (Figure 7). A higher level of lactic acid is the ideal situation since acetic acid is less stable. It has been suggested elsewhere that a deficiency of lactic acid bacteria may lead to high concentration of acetic acid in silages from tropical grasses. The final pH of M-E hybrid and sorghum silages were 4.04 and 3.85, respectively. These levels of pH were not affected ($P>0.05$) by molasses additive (Figure 8). Apparently, grains in the sorghum and sugars in the M-E hybrid forage provided sufficient fermentable carbohydrates during ensilage. On the contrary, molasses additive was essential to lowering ($P<0.01$) the final silage pH of guineagrass from 5.0 to 4.5, whether or not the forage was wilted initially.

Our preliminary experiment has demonstrated the possibility of preserving guineagrass/leucaena forage as silage in the Caribbean for use during the dry period. Temperature rise, DM losses and final silage pH were minimal when molasses was added to forage prior to ensilage. Therefore, for proper fermentation and long term preservation of guineagrass/ leucaena silage, the results suggest that molasses or other energy additive will be necessary. The concentration of acetic acid in guineagrass silage was greater than lactic acid which suggests a possible lactic acid bacteria deficiency. Future studies will evaluate the efficacy of bacteria inoculant and the level of molasses additive required to obtain a pH in the range of 3.8 to 4.2. We also intend to assess the effect of leucaena inclusion on the nutritive value of the silage.

This research was supported in part by Hatch Project No. 0156333.

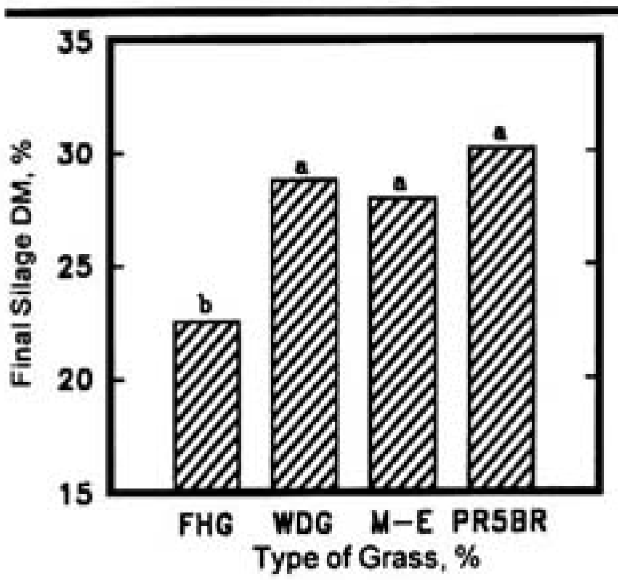



**Figure 6.** Effect of grass type on the final dry matter content of silage. FHG = fresh guineagrass; WDG = wilted guineagrass; M-E = millet-elephant grass hybrid; and PR5BR = Puerto Rico 5BR forage sorghum.

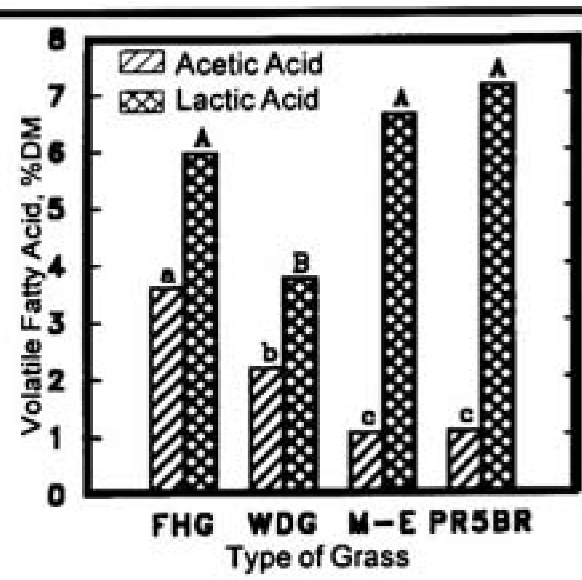



**Figure 7.** Effect of grass type on the final acetic acid and lactic acid content of silage.
A, a: comparison within acid at P = 0.05

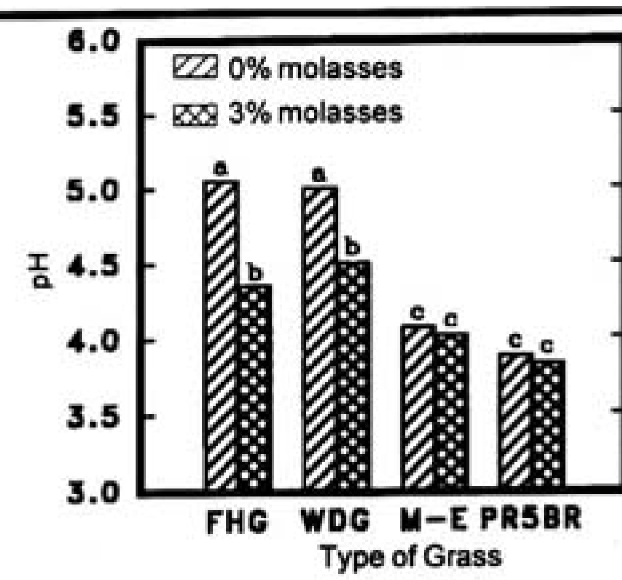



**Figure 8.** Effect of grass type and molasses addition on the final pH of silage.
Grass x molasses interaction P < 0.01.

# Improving Guineagrass Forage Feeding Value By Urea Treatment

**Martin B. Adjei and Terry J. Gentry**

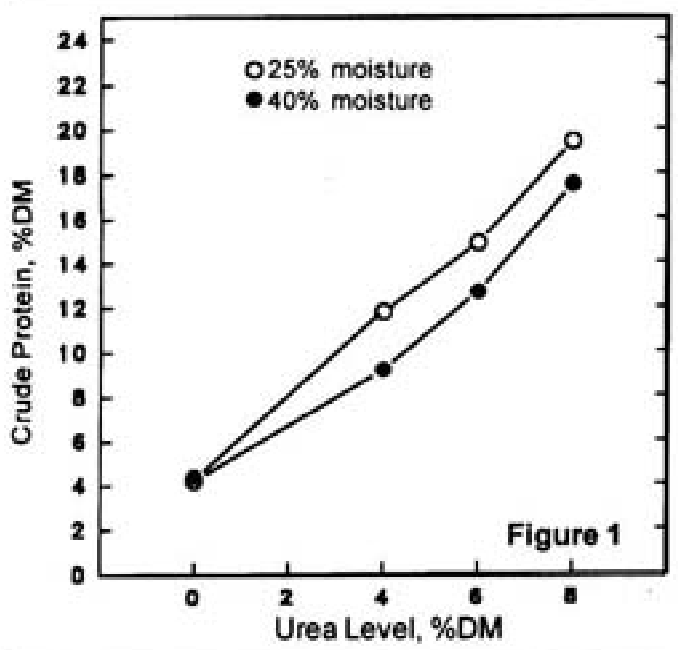
Efficiency of ruminant livestock production in the Caribbean Basin is severely hampered by seasonal deficiencies in the quantity and quality of available forage, resulting in recurrent livestock body weight losses. The inability of native pastures to produce quality forage during cyclic dry periods has been known for many years since the work done by A.J. Oakes in 1966 and 1969 on St. Croix. He reported that crude protein content of predominant pasture grasses on St. Croix normally ranges between 3 and 6 percent of dry matter (DM) during the dry season, with digestibilities of 36 to 43 percent. According to the Animal Nutritional experts, any forage crude protein content below 8 percent of DM will reduce forage intake and adversely affect livestock performance.

In 1989, a survey conducted by personnel of the Cooperative Extension Service of the University of the Virgin Islands also showed that hay produced for dairy farms on St. Croix was low in crude protein (5.2 to 6.5% DM) and total digestible nutrients (51 to 59%). This poor feeding value of hay necessitated the use of dairy rations that contained more than 60 percent of DM from imported concentrates at an estimated monthly cost of $24,000 to the three major dairies in St. Croix alone during the severe 1989-90 dry season. The huge expense of importing grains and oilseed products, which compete with human and nonruminant livestock consumption, limits the widespread use of concentrate supplements in the region. Forage conservation either through hay or silage production provides a viable option for many Caribbean Islands; however, advanced maturity of many stored forages and crop residues results in low feeding value.

Chemical treatment to improve the feeding value of low quality forage offers another opportunity to utilize large amounts of low quality grasses and crop residues. There is some evidence that alkali treatment of forages results in increased forage digestibility, feed intake and animal performance. Among the chemicals, ammonia, in either the aqueous or anhydrous form, has received the greatest attention because of its dual capability to increase both crude protein and fiber digestibility in forages. Ammoniation of hay has been adopted rapidly by farmers in North America and Europe because of its high economic return. However, limited availability of ammonia, lack of pressurized equipment to handle it, high cost and increased Federal regulation of transportation of anhydrous ammonia have prevented its use in the tropics including the Caribbean.

The use of feed grade urea as a source of ammoniation to improve forage quality has greater application in the tropics where it is widely available. For it to be effective, urea must first be converted to ammonia under air-tight conditions such as a plastic cover. This conversion requires the presence of urease enzyme and water. Most urea treatment studies have been conducted with wilted or reconstituted cereal straws stored by ensiling. Very little information is available concerning urea treatment of tropical grass hay. The objectives of our study were to investigate the effectiveness of urea-ammoniation for improving guineagrass hay and measure sheep growth performance when fed urea-treated hay. Factors including final moisture content, urease addition, urea application method and urea treatment level were studied.

Experiments were conducted at the Agricultural Experiment Station of the University of the Virgin Islands (UVI-AES) on St. Croix, under tropical forage-livestock production system. In each experiment, hay was purchased from the local Department of Agriculture which supplies most of the hay used by local farmers. The hay was composed of greater than 90 percent of guineagrass (*Panicum*



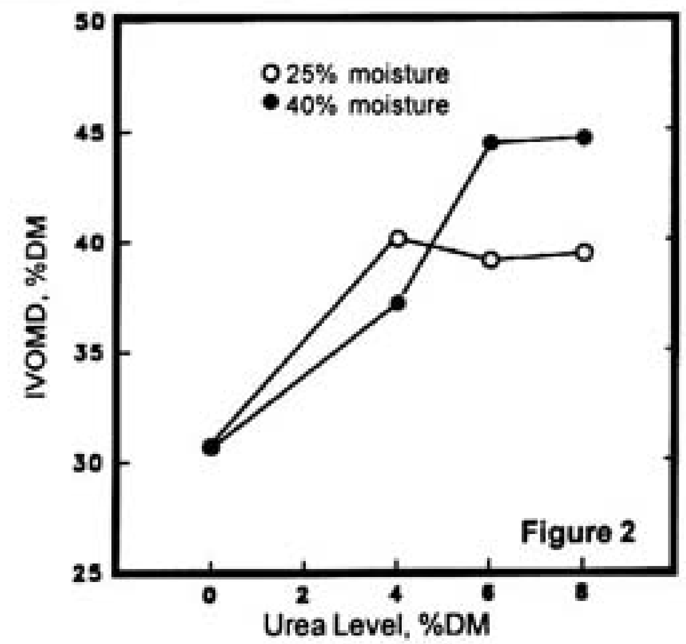




**Figure 1.** Effect of urea treatment level on crude protein content of guineagrass hay in Experiment 1.

**Figure 2.** Effect of urea treatment level on in vitro organic matter digestion of guineagrass hay in Experiment 1.

*maximum*), with small quantities of leucaena (*Leucaena leucocephala*), johnsongrass (*Sorghum halepense*), casha (*Acacia* spp.) and hurricane grass (*Bothriochloa pertusa*). Initial hay DM content was consistent across experiments and averaged 87 percent.

Two laboratory-scale experiments were conducted using 5 kg portions of hay to determine the effects of final forage moisture content, urea treatment levels and urease application on hay quality.

Treatment factors and levels for Experiment 1 were as follows:

| Factor | Levels |
|---|---|
| 1) Forage final moisture content | 25% or 40% |
| 2) Urea treatment level | 0, 4, 6 or 8% DM |
| 3) Urease | With or without |

All possible combinations of factor levels were studied. Urea and urease were mixed with the appropriate volume of water to reconstitute the hay to the desired final moisture concentration, and then sprayed onto the hay. There were three replicates of each treatment combination. Forage was then packed into individual plastic bags and stored air-tight at room temperature (approximately 78°F) for 60 days.

In Experiment 2, urea treatment level was deliberately confounded with final forage moisture content by using a 15% (w/v) urea solution to obtain all urea application levels.
Treatment factors and levels for Experiment 2 consisted of:

| Factor | Levels |
|---|---|
| 1) Urea treatment level | 0, 4, 6 or 8% DM |
| 2) urease | With or without |

Urease was added to an appropriate quantity of the 15 percent urea solution to yield the appropriate urea treatment level, sprayed onto the hay and stored as described above.

After 60 days storage, bags in Experiments 1 and 2 were opened and the contents of each bag were thoroughly mixed. Subsamples were dried, ground and analyzed for dry matter, organic matter (OM) and crude protein according to the Association of Official Analytical Chemists method. Cell wall fiber components including hemicellulose (HC), cellulose, neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined by the procedure of Goering and Van Soest. In vitro OM digestion (IVOMD) was determined by the modified Tilley and Terry procedure described by Moore and Mott.

Two field-scale experiments were also conducted using large round bales of approximately 32 kg (700 pounds) each.
Experiments 3. Treatment factors and levels follow:

| Factor | Levels |
|---|---|
| 1) Final moisture content | 25% or 40% |
| 2) Urea treatment level | 0, 4 or 6% DM |
| 3) Application method | Sprayed-on or injected |

Urea was dissolved in an appropriate volume of water to reconstitute each bale of hay to 25 or 40 percent final moisture. The urea solution was applied by either spraying from watering cans onto both flat surfaces of the bales, or by low pressure (10 psi) injection at five sites on each flat surface. Each treatment combination was applied to three bales. Each bale was stored separately in slip-on, 6-mil plastic bags for 60 days. After storage, each bale was sampled with a core sampler at approximately 20 sites. Forage samples were processed and analyzed for quality measures as described above.

The second field experiment (Experiment 4) was designed to confound moisture content and urea treatment levels by using a 15 percent (w/v) urea solution. The appropriate quantity of the 15 percent urea solution was either sprayed onto or injected into bales and stored as described. Bales were sampled and analyzed for quality as described.

Large round bales described above for Experiment 3 from the 0, 4 and 6 percent urea treatment levels where the urea solution was sprayed on the hay at 25 percent forage moisture content were used to determine the effect of urea-treatment level on the digestibility and growth performance of sheep fed guineagrass hay.

In the growth trial (Experiment 5), 30 St. Croix white hair weaned lambs of approximately 18 kg (40 pounds) initial body weight were assigned to six pens, resulting in five head per pen and fed for 50 days. Two pens were assigned to each 0, 4 and 6 percent urea-treated hay. Sufficient feed grade urea was applied at feeding time to the 0 and 4 percent urea-treated hay to equal

Table 1. The effect of urease addition on the chemical composition and in vitro digestion of guineagrass hay in Experiment 1.

| Urease | CP[1] | NDF | ADF | Cellulose | HC | ADL | IVOMD |
|---|---|---|---|---|---|---|---|
| Without | 11.4 | 75.1 | 48.1 | 26.8 | 38.1 | 10.1 | 38.9 |
| With | 12.0 | 74.9 | 48.1 | 26.8 | 38.1 | 10.0 | 37.1 |

[1]CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre; HC = hemicellulose; ADL = acid detergent lignin; IVOMD = in vitro organic matter digestion.

Table 2. The interactive effects of method of application, forage moisture and urea treatment levels on the crude protein content guineagrass hay in Experiment 3.

| Application | Moisture | Urea, %DM (U) 0 | 4 | 6 | Mean | U Effect |
|---|---|---|---|---|---|---|
| | | CP, %DM | | | | |
| Spray | 25 | 5.3 | 7.8 | 10.5 | 7.4 | L** |
| | 40 | 5.9 | 6.8 | 8.1 | | |
| Inject | 25 | 5.3 | 6.7 | 8.1 | | |
| | | | | | 6.1 | NS |
| | 40 | 5.7 | 5.7 | 6.4 | ** | |

Application x moisture x urea interaction P<0.05.
L, NS = Linear or non-significant urea effect.
** = Significance at P<0.01.

the crude protein content of the 6 percent urea-treated hay. Dehydrated alfalfa pellets (14% CP) were fed to all sheep at a daily rate of 1 percent of body weight. Water was provided free-choice. Total feed offered was recorded and total feed refused was collected and weighed. Dried and ground subsamples of feed and refusals were analyzed as described above.

In the digestion trial (Experiment 6), six wether lambs, similar to those used in the growth trial, were used to determine the digestibility of the same diets as those in the growth trial. Sheep were fitted with fecal collection bags and housed in individual crates. Each of the three feeding periods consisted of a 10-day dietary adjustment phase followed by a 5-day collection phase. Two animals were assigned to each treatment diet during a feeding period and animals were rotated among diets between periods. Following total recording of feed or collection and weighing of refusals and feces, subsamples were processed for quality analyses as described above.

Applied Questions:

1) Did urease addition, forage moisture content and urea treatment level affect quality of small hay samples in the laboratory study?

Results in Table 1 indicate that urease addition did not influence any forage quality measure nor did it interfere with the quality response to urea treatment level. This was probably due to the presence of adequate amounts of urease enzyme in or on the hay that was treated. However, as urea treatment level was increased from 0 to 8 percent of forage DM, crude protein (CP) content of forage increased in a linear manner from 4.3 to 18 percent as shown in Figure 1. The improvement in forage CP due to urea treatment was greater for the 25 percent than for the 40 percent moisture contents.

Additionally, urea treatment improved organic matter digestibility of forage by an average of 35 percent as shown in Figure 2. Also, acid detergent lignin concentration in Experiment 1 and hemicellulose concentration in experiment 2 decreased in a linear manner to increasing urea treatment level (data not shown).

> **"Our results have provided evidence that urea treatment will significantly improve forage crude protein content, digestibility and overall feeding value of locally produced hay."**

2) Did forage moisture content, urea treatment level and application method affect the quality of guineagrass bales of hay?

The response of forage quality to urea treatment level depended on forage moisture and application method. In both Experiments 3 and 4, greatest increase in forage crude protein content due to urea treatment was found when the urea solution was sprayed onto the hay and when the final forage moisture content of 25 percent was used as shown in Tables 2 and 3. Also in both experiments, forage organic matter digestibility was only moderately improved when the solution was injected into the bales. When the urea solution was sprayed onto the hay, forage digestibility was increased by approximately 15 percent in both Experiments 3 and 4 (Tables 3 and 4). In addition, cell wall components such as ADL and HC were reduced when the solution was sprayed onto the hay but were not affected when the solution was injected into the hay.

3) Did urea treatment level affect hay digestibility and growth performance in hair sheep?

In the digestion trial, hay intake increased in a quadratic manner with increasing urea treatment level (Table 5). Apparent organic matter digestibility was not affected by urea treatment, but, due to increased hay intake, digestible organic matter intake increased in a quadratic manner with increasing urea treatment level. Apparent digestible fiber fractions increased in a linear manner due to urea treatment.

In the growth trial, hay intake also increased in a quadratic manner (Table 6). The results show that daily gain (17, 51, 48 g) and feed efficiency (.013, .032, .033) increased in a linear manner with increasing urea treatment level from 0, 4 to 6 percent DM.

Our results have provided evidence to support the fact that urea treatment will significantly improve forage crude protein content, digestibility and overall feeding value of locally produced hay. The fact that urease addition had no effect on urea-ammoniation has an important practical implication. Since synthetic urease is an expensive input item, the need for it would adversely affect the cost/benefit ratio of the treatment.

In the laboratory experiments where the quantity of water required to reconstitute the hay to the appropriate forage moisture content was thoroughly

**Table 3.** The interactive effects of method of application and urea treatment level, using a common strength (15%) urea solution, on the chemical composition and in vitro digestion of guineagrass hay in Experiment 4.

| Method | | Urea, %DM (U) 0 | 4 | 6 | SE | U Effect |
|---|---|---|---|---|---|---|
| Spray | CP** | 5.4 | 8.0 | 8.2 | 0.27 | L** |
| | NDF | 75.6 | 73.0 | 71.6 | 0.39 | L* |
| | IVOMD** | 41.6 | 48.0 | 48.0 | 0.78 | L** Q* |
| Inject | CP | 5.1 | 6.7 | 6.9 | 0.27 | L* |
| | NDF | 74.2 | 74.9 | 74.5 | 0.39 | NS |
| | IVOMD | 40.4 | 45.4 | 43.0 | 0.78 | Q* |

CP** = Significant method effect on CP (P<0.01);
L, Q, NS = linear, quadratic or non-significant urea effect.

**Table 4.** The effects of method of application, forage moisture and urea treatment level on in vitro digestion of guineagrass hay in Experiment 3.

| Application | Moisture | Urea, %DM (U) 0 | 4 | 6 | Mean | U Effect |
|---|---|---|---|---|---|---|
| | | | IVOMD | | | |
| Spray | 25 | 42.6 | 48.2 | 49.3 | | |
| | | | | | 46.1 | |
| | 40 | 42.4 | 45.9 | 48.2 | | |
| | | | | | | L** |
| Inject | 25 | 42.0 | 44.0 | 43.5 | | |
| | | | | | 44.1 | |
| | 40 | 43.8 | 44.3 | 46.7 | | |
| | | | | | NS | |

mixed with the hay by hand and the entire contents were sealed in plastic bags. we obtained improvement in forage crude protein content in the order of 400 percent and organic matter digestibility of 30 percent. A small farmer with a few square bales that can be completely soaked with urea solution inside a container could approach laboratory conditions and obtain similar high levels of quality improvement. However, laboratory treatment conditions are different from those in the field where larger amounts of round-baled forage are treated.

With large round bales (320 kg or 700 lbs) of approximately 87 percent DM, we used approximately 64 kg (140 lbs) or 164 kg (360 lbs) of water as urea solution to reconstitute bales to 25 or 40 percent forage moisture contents, respectively. The solution could not be mixed into hay by hand but rather applied by spraying or injection. Large quantities of urea solution was observed to seep out of bales at the 40 percent moisture level. This considerably reduced the overall effective urea treatment level at the 40 percent moisture content. Nevertheless, we obtained an improvement of 100 percent in crude protein (from 5 to 10% CP) and of 14 percent (from 43 to 49% IVOMD) in organic matter digestibility by spraying urea solution to the flat surfaces of round bales of hay to a final moisture content of 25 percent. The injection method was less effective probably because the urea solution became localized in the bales.

When the 15 percent strength urea solution was used to obtain urea treatment levels, final forage moisture contents of treated bales were approximately 26 and 31 percent for the 4 and 6 percent urea treatment levels, respectively. Therefore, increasing urea treatment level produced intermediate effects on hay quality as described above for 25 and 40 percent moisture contents. When dealing with dry hay (87% DM), farmers will have to select appropriate urea solution strength (15 to 22% w/v) that will allow reconstituted final forage moisture to be restricted between 25 and 30 percent in order to avoid excessive urea seepage losses.

Urea treated hay when fed to sheep improved daily gain by as much as 150 percent. Such large improvements in the feeding value of conserved forage via urea treatment will aid considerably in sustaining livestock production in the Caribbean during the dry season if the technology is adopted. The new technology is ready to be tested on selected farms on St. Croix. Several scientists from other Caribbean islands have expressed interest in the technology as well. The next phase of the project will have to focus on the need to conduct feeding trials on dairy cattle and measure residual levels of ammonia in the milk product before technology can be extended to the regional dairy industry.

We conclude that inexpensive livestock diets based on urea-treated hay could be formulated to overcome many of the perennial, dry-season feed constraints to ruminant livestock production in the Caribbean.

This research was funded in part by the Caribbean Basin Advisory Group (CBAG) Project No. 92-34135-7300.

**Table 5.** Influence of urea treatment level on the digestibility by sheep of guineagrass hay.

| Item[1] | Urea (U) Treatment Level 0 | 4 | 6 | SE | U Effect[2] |
|---|---|---|---|---|---|
| Intake, g OM | | | | | |
| Hay | 510.9 | 614.4 | 572.6 | 20.4 | Q* |
| Pellets | 166.3 | 153.5 | 157.7 | 4.5 | NS |
| Total | 677.1 | 767.9 | 730.3 | 22.2 | Q* |
| OM digestibility, % | 62.8 | 64.9 | 65.3 | 1.2 | NS |
| Digestible OM Intake, g | 424.4 | 496.5 | 475.6 | 14.3 | Q* |
| NDF digestibility, % | 65.9 | 69.2 | 70.5 | 1.1 | L* |
| ADF digestibility, % | 62.5 | 66.7 | 67.1 | 1.3 | L* |
| HC digestibility, % | 70.9 | 73.4 | 76.3 | 1.1 | L** |

1 OM = organic matter, NDF = neutral detergent fibre, ADF = acid detergent fibre, HC = hemicellulose.
2 L, Q = Linear or quadratic urea treatment effects (* = P<0.05, ** = P<0.01).

**Table 6.** Influence of urea treatment level on the growth performance by sheep fed guineagrass hay.

| Item[1] | Urea (U) Treatment Level 0 | 4 | 6 | SE | U Effect[2] |
|---|---|---|---|---|---|
| Growth Trial | | | | | |
| Intake, g OM | | | | | |
| Hay | 1025 | 1294 | 1156 | 50.21 | L** Q** |
| Pellets | 306 | 317 | 309 | 3.6 | NS |
| Total | 1330 | 1610 | 1465 | 52.2 | L** Q** |
| Daily gain, g | 17.3 | 50.8 | 47.7 | 7.5 | L* |
| Gain/feed | 0.013 | 0.032 | 0.033 | 0.005 | L* |

1 OM = organic matter, NDF = neutral detergent fibre, ADF = acid detergent fibre, HC = hemicellulose.
2 L, Q = Linear or quadratic urea treatment effects (* = P<0.05, ** = P<0.01).

# Strategies For Increasing Yam Production In The Virgin Islands

S.M.A. Crossman, C.D. Collingwood, M.C. Palada and J.A. Kowalski

Yam, plants of the genus *Dioscorea*, is an important crop in the Caribbean, where production ranks second only to West Africa. Prices for this crop are higher than for other tropical root crops. However, production of this popular food crop declined dramatically in the Virgin Islands between 1960 and 1987 (production in 1987 was 20 percent of production in 1960). This decline was primarily due to a concurrent reduction in the available agricultural cropland during the period (acreage in 1987 was 15 percent of acreage for 1960). If this trend of reduced harvested agricultural acreage continues, it is critical that production per unit land area be increased to at least maintain the present level of local yam production. The incidence of the fungal disease anthracnose (*Colletotrichum gloeosporioides*) has also played a role in reducing the yam yield per unit area of land.

The University of the Virgin Islands Agricultural Experiment Station (UVI-AES) is conducting research investigating methods to increase the production of tropical root crops, including yam. This research has focused primarily on *D. alata* because it is the only locally grown species of economic importance.

In the Virgin Islands, yams are usually grown without pest management practices, proper fertilization or irrigation, and weeded only when infestations are severe. Yam, however, requires the most intensive management compared to other tropical root crops for a high yield of good quality tubers. This includes proper plant nutrition and optimum soil moisture levels. Most soils in the Virgin Islands pose some stress conditions for plant growth—high soil pH, deficiencies in phosphorous and micronutrients, heavy soils and low annual rainfall.

The studies summarized in this paper were conducted at UVI-AES on St. Croix. The soil is a Fredensborg loamy, fine, carbonatic, isohyperthermic, shallow, typic calciustoll.

Initially, a series of germplasm screening and evaluation studies were conducted over a number of years. Germplasm were obtained from USDA-TARS (Mayaguez,PR), Barbados, the Dominican Republic and local farmers. Anthracnose tolerance was given high priority in these evaluations. These trials have identified cultivars which consistently produced high yields of good quality tubers, while exhibiting acceptable disease tolerance. Selected cultivars include Binugas, Seal top, Gunung, PR-PI 15580 and Forastero.

Subsequent trials were conducted to determine the optimum plant density and tuber piece size for planting. It was found that closer spacing resulted in a necessary reduction in tuber size, a larger proportion of better-shaped yams and increased yields. Closer spacing also reduced the amount of time needed for the plant foliage to cover the soil, thereby reducing weed competition and the number of times the crop needs weeding. The results of these trials indicated that combining a yam tuber piece weighing approximately 115-125 g (1/4 lb) and a planting density of 33,333 plants/ha (.3m x 1m) were optimum. This combination increased yields due to the increased number of tubers produced. The tubers were smaller and better

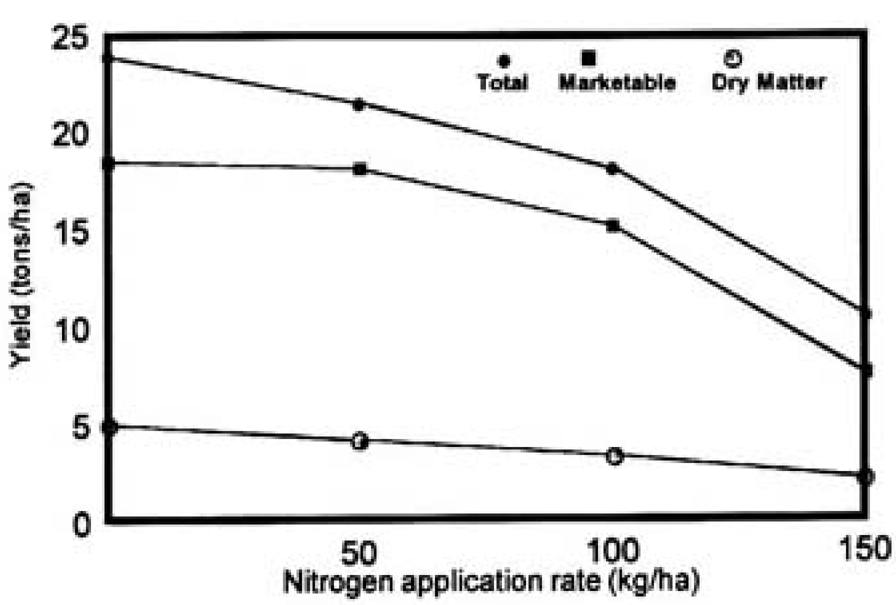



**Figure 1.** Effect of applied nitrogen on yield of 'Gunung' yam.

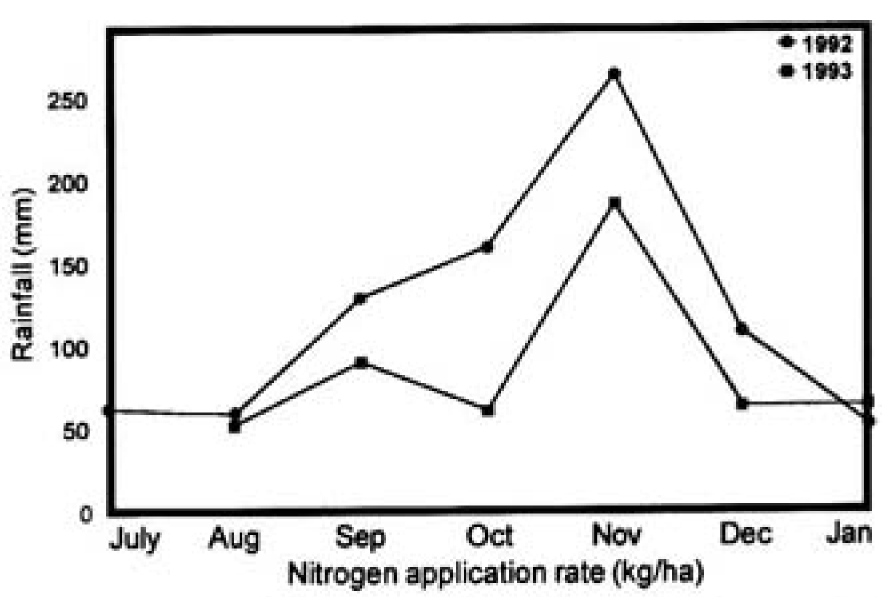
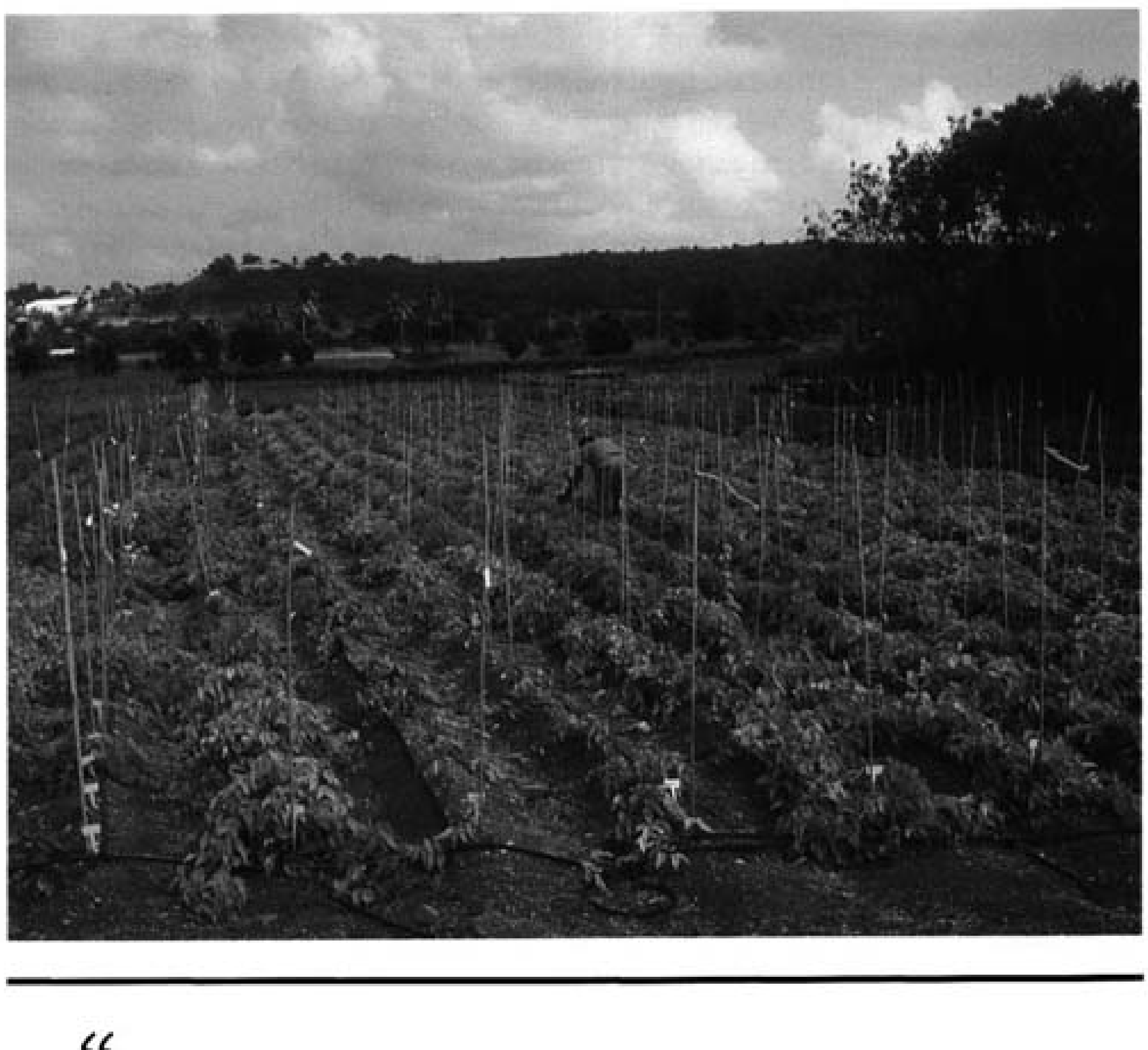



**Figure 2.** Monthly rainfall amounts during 1992 and 1993 yam growing seasons.



"**If this trend of reduced harvested agricultural acreage continues, it is critical that production per unit land area be increased to at least maintain the present level of local yam production.**"

shaped (with fewer 'toes') than when larger-sized planting material and lower plant densities were used. The benefits of smaller tubers are that they are 1) easier to harvest, 2) less prone to damage during harvesting, 3) easier to handle (for both farmer and consumer), 4) more marketable and 5) easier for consumers to utilize.

Even though many trials have been conducted in Africa and the Caribbean to determine the response of yams to fertilizer, little research of this nature has been conducted in the Virgin Islands.

Research in other Caribbean countries has indicated that different varieties respond differently to the same fertilizer application. Fertilizer recommendations will vary based upon soil type and local climatic conditions. Varying levels of positive yield responses have been obtained when fertilizer was applied to yams. The level of response was affected by other factors including cultural practices. Nitrogen has been reported to be the most important nutrient because its application was found to significantly increase yields.

Two trials were conducted at UVI-AES to evaluate the effect of varying rates of nitrogen on the production of *D. alata* cultivars. In the first trial, varying levels of nitrogen were evaluated for their effect on the yield of two cultivars, 'Binugas' and 'Gunung'. Ammonium sulfate was split-applied to provide the plots with nitrogen at rates of 0, 100, 200 and 300 kg/ha. The first half of the nitrogen and all of the phosphorous (100 kg/ha using triple super phosphate) were applied one month after planting. The second half of the nitrogen and all of the potassium (100 kg/ha using potassium sulfate) were applied three months after planting. The initial soil pH was 7.8 for both trials and the soil nitrogen were 116 and 95 ppm for 'Binugas' and 'Gunung' trials, respectively.

Field plots were established using yam tuber pieces weighing approximately 115g as the planting material. Plots were

**Table 1.** Effect of irrigation on 'Binugas' yam production (1992).

| Irrigation Rate (kPa) | Tuber Size (g) | Total Yield (t/ha) | Marketable Yield (t/ha) | Dry Matter (%) | Total Dry Matter (t/ha) |
|---|---|---|---|---|---|
| 20 | 500 | 25.2 | 23.5 | 21 | 5.3 |
| 40 | 480 | 23.8 | 20.7 | 20.9 | 5 |
| 60 | 775 | 23.8 | 21.6 | 21.8 | 5.2 |
| Rain | 357 | 20.2 | 17.1 | 22.6 | 4.6 |
| Significance | NS | NS | NS | Q** | NS |

NS,* Nonsignificant or significant at P = 0.05.
Quadratic (Q) response.

**Table2.** Effect of irrigation on 'Binugas' yam production (1993).

| Irrigation Rate (kPa) | Tuber Size (g) | Total Yield (t/ha) | Marketable Yield (t/ha) | Dry Matter (%) | Total Dry Matter (t/ha) |
|---|---|---|---|---|---|
| 20 | 308 | 14 | 10.1 | 18.3 | 2.5 |
| 40 | 367 | 16.2 | 9.8 | 17.4 | 2.8 |
| 60 | 336 | 13.2 | 8.7 | 18.9 | 2.5 |
| Rain | 373 | 14.8 | 10.4 | 19.7 | 3.1 |
| Significance | NS | NS | NS | Q** | NS |

NS,* Nonsignificant or significant at P = 0.05.
Quadratic (Q) response.

3 m x 3.7 m and consisted of 3 rows (ridges), spaced 1 m apart. Plants were spaced 0.3 m within rows. The experimental design was a randomized complete block with four replications. A drip irrigation system was installed consisting of 1.27 cm poly-hose as the sub-mains and Drip Strip Plus (Hardie Irrigation) tubing with laser-drilled orifices 0.3 m apart (Hardie Irrigation) as the laterals. Each plot was harvested at six months after planting. Tubers from 10 plants in the center row of each plot were harvested. The weight of marketable tubers was recorded.

In a second trial, cultivar 'Gunung' was evaluated for the effect of nitrogen applied at varying rates. Ammonium sulfate was applied to provide nitrogen at rates of 0, 50, 100 and 150 kg/ha. Phosphorous and potassium were both applied at rates of 75 kg/ha using triple super phosphate and potassium sulfate, respectively. The initial soil pH was 7.9 with a nitrogen content of 90 ppm. The experimental design, plot size, layout, establishment and harvesting method were similar to those described. All of the fertilizer was applied two months after planting. At harvest (seven months after planting), the total and marketable weight of tubers were recorded. Tuber sub-samples from each replication were peeled, sliced, then dried at 70°C to obtain the dry matter content.

The application of nitrogen in the first trial up to 300 kg/ha did not affect production of the two cultivars ('Binugas' or 'Gunung') utilized in the study. Yields were very similar for both cultivars at all application rates, and there was a trend that higher yields were obtained from the 0 nitrogen plots.

Production of 'Gunung' yams was influenced by the nitrogen fertilization treatments in the second trial. Tuber size was largest from the 0 and 100 kg N/ha treatments. There was a negative linear response of both total and marketable yields to the rates of applied nitrogen (Figure 1). Yields decreased as the nitrogen application rate increased. The percent dry matter of the tubers was not affected by the treatments but total dry matter production had a linear response (Figure 1). Tuber size was not significantly affected by the application of nitrogen.

Yams do not tolerate prolonged periods of drought without a yield reduction, especially during the critical two to three month period when all of the food reserves of the seed piece have been depleted. Moisture stress also delays tuber initiation. Tubers develop best when rainfall is frequent and the soil is well-drained.

Two trials were conducted in 1992 and 1993 to evaluate the effect of varying irrigation rates on the production of *D.alata* yam. Cultivar 'Binugas' was grown in field plots and irrigated to maintain soil moisture levels of 20, 40 and 60 cb. A rain-fed treatment was also included. Nitrogen was applied at 100 kg/ha using ammonium sulfate, and P and K were both applied at 75 kg/ha (using triple super phosphate and potassium sulfate, respectively).

A drip irrigation system was installed as previously described. Tensiometers (Irrometer Co.) were placed in the root zone in the center row of plots, to monitor the soil moisture content. When the tensiometer readings exceeded the level for a specific treatment, the irrigation system was turned on until the soil moisture content was increased to the desired level. Semi-automatic timers were used to turn the irrigation system on and off. Water meters were used to measure the amounts of water applied to each treatment.

The experimental design, plot sizes, layout, establishment and harvesting method were similar to the nitrogen rate trials. Rainfall during the 1992 and 1993 growing seasons were 830 and 511 mm, respectively (Figure 2). Yams were harvested at seven and six months after planting in 1992 and 1993, respectively.

The response to the irrigation rates was similar for both years. Yields were higher in the first year, probably due to the longer growing season (Tables 1 and 2). During both growing seasons the only parameter to be influenced by the application of irrigation was the dry matter content of the tubers. There was a quadratic decrease in dry matter content as the irrigation rate, hence the soil moisture increased (Tables 1 and 2).

These trials indicated that cultivars 'Binugas,' Gunung,' 'Seal top,' Forastero' and 'PR-PI 15580' exhibited tolerance to anthracnose and produced high yields of good quality tubers. The optimum combination of planting density (.3m x 1m) and size of planting material (115-125g) have been identified. Under local environmental conditions, supplemental nitrogen applications to soils testing at levels of 95 to 116 ppm nitrogen will suppress yam yields. Rainfall amounts of 511 to 830 mm during a six to seven growing season appears to be adequate for yam production.

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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.
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.

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