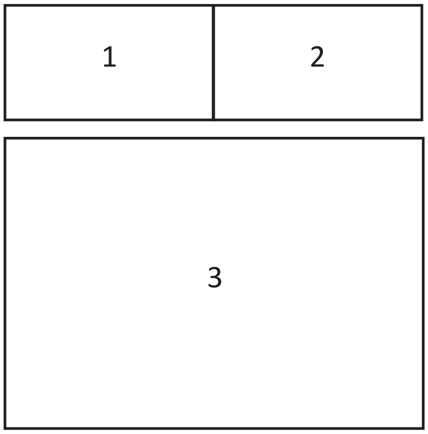
Agricultural Experiment Station

2015 ANNUAL REPORT

University of the Virgin Islands

On our cover...



1. Aquaponic cucumber harvest from the Horticulture & Aquaculture program.
2. Roller crimper being used to prepare a green manure cover crop of sunn hemp (*Crotalaria juncea*) by the Agronomy program.
3. Father (CN 615N on the right) and son (CN Rock Star 9026W on the left) Senepol herd sires in the Animal Science program cattle herd.

University of the Virgin Islands
Agricultural Experiment Station
RR 1, Box 10,000
Kingshill, VI 00850
Telephone: (340) 692-4020 Fax: (340) 692-4035
www.uvi.edu/research/agricultural-experiment-station

Dr. Robert W. Godfrey, Director
Dr. Robin Sterns, Editor & Publication Design

University of the Virgin Islands

Historically American. Uniquely Caribbean. Globally Interactive.

Agricultural Experiment Station

MESSAGE FROM THE DIRECTOR

This Annual Report is a new publication series to document the research activities of the faculty and staff of the Agricultural Experiment Station (AES) located on St. Croix on the Albert A. Sheen Campus of the University of the Virgin Islands. AES is one of the two Land Grant units that are part of the Research and Public Service component of UVI, the other being the Cooperative Extension Service.

Our scientists conduct basic and applied research to meet the needs of the local agricultural community. We have research programs in agronomy, agroforestry, animal science, aquaculture, biotechnology and horticulture. Research is conducted on a variety of agriculture commodities that include sheep, beef cattle, vegetables, root crops, fish, trees and forages.

Our research programs have gained national and international recognition for the research they conduct in tropical agriculture. The information generated by our scientists is applicable to areas outside the Caribbean in tropical regions throughout the world. Our research on a wide variety of crops and production systems have been beneficial to the farmers in the US Virgin Islands and beyond. Our Biotechnology & Agroforestry program has used cutting edge technology to evaluate plant propagation in a variety of crops including, but not limited to, papaya, cassava and pitaya. The Aquaponics Short Course developed by our Horticulture & Aquaculture program faculty and staff has provided training in plant and tilapia production to individuals from around the Caribbean, the mainland U.S. and around the world. The Agronomy program has conducted research to evaluate forages and grazing systems to enhance small ruminant livestock production under tropical conditions. The research conducted in our Animal Science program on St. Croix White hair sheep and Senepol cattle has developed management and production practices that enhance livestock production and are characterizing how these two breeds are adapted to the tropical environment.

Our scientists have develop collaborations with other scientists in the US mainland and around the world to enhance our research capabilities and our access to grant funds. For the past 10 years AES scientists have been mentoring students with support for USDA-NIFA funds for Resident Instruction in the Insular Areas. Because UVI has no academic program in agriculture AES has developed this system to provide opportunities for experiential learning and research training for UVI students. The student interns have become an integral part of the AES research activities as indicated by the number of research presentations they make at local, regional, national and international conferences.

Agricultural research generated by AES researchers continues to provide science based information to help our community move forward and make informed decisions about their food, nutrition and lifestyle in the US Virgin Islands.

Robert W Godfrey

Robert W. Godfrey, Ph.D.
Director & Professor of Animal Science

RR 1 Box 10,000, Kingshill ● St Croix ● U.S. Virgin Islands 00850-9781 ● Tel: (340) 692-4020 ● Fax: (340) 692-4035
http://www.uvi.edu/research/agricultural-experiment-station/

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Effects of Pasture Finishing Hair Sheep Lambs with Supplemental Maize on Native or Improved Pasture on Animal Performance and Carcass Characteristics in the Tropics

By Stuart A. Weiss, Robert W. Godfrey, Rachel Ben-Avraham and Rosemary C. Ketring

Figure 1. Dorper x St Croix White lambs grazing improved pasture consisting of a base of guinea grass seeded with cow pea, blue pea and lablab.

SUMMARY

In the tropics, improved cultivated pastures (IP) provide alternative management compared to native pasture (NP) for hair sheep production. Post-weaning hair sheep feeder lambs grazed on IP with energy supplementation can provide an alternate forage-based pasture finishing option compared to traditional grain-based finishing methods that rely upon a high-cost concentrate diet. The Dorper x St. Croix White hair (DSTX) lambs were managed under two types of post-weaning alternative pasture finishing systems, and live animal performance and carcass characteristics were measured during the fall of 2006 and 2007. For eight months after weaning (120 days after birth), all lambs grazed NP consisting of guinea grass (*Panicum maximum* Jacq.) and hurricane grass (*Boithrocloa pertusa* L. A. Camus), for eight months. Lambs were then stratified by weight and sex into two treatments with three replications consisting of grazing NP or IP. Improved pasture consisted of seeded tropical legumes including cow pea (*Vigna unguiculata* L. Walp., cv 'Iron and clay'), blue pea (*Clitoria ternetea* L., cv. Tehuana), lablab (*Lablab purpureus* L. Sweet, cv. Rongai), volunteer desmanthus (*Desmanthus vergatus* L. Willd.), and volunteer guinea grass in grazing paddocks where forage availability was not a limiting factor. All lambs were supplemented with maize (*Zea mays* L.) daily at a rate of one percent of their body weight for 100 days and slaughtered at approximately 365 days of age. Improved pasture lambs had greater total weight gain and average daily gain than NP lambs (11.1 vs. 7.6 kg and 114 vs. 73.3 g/day, respectively). IP lambs were heavier at slaughter (39.1 vs. 34.6 kg), had heavier chilled carcass weights

(18.9 vs. 16 kg) and greater dressing percent (50 vs. 47.8%) respectively. Results of this study indicate that the adoption of IP finishing practices utilizing mixed legume with maize supplementation can lead to improvements in animal performance, carcass muscularity, and beneficial fat accumulation of crossbred hair sheep lambs under tropical conditions.

INTRODUCTION

The U.S. Virgin Islands (USVI) imports 100% of the concentrated feed used in animal production and the added transportation increases the cost of concentrate feed by 2 to 3 times that of the cost of feed sold in the continental USA. Alternative pasture finishing systems that utilize legumes may provide viable options to livestock producers. Improved pastures that contain both grasses and a variety of legumes offer grazing livestock a choice of different forages compared to monocultures dominated by a single graminaceous species. In a review by Rutter (2006), cattle and sheep did not graze at random, but consumed mixed diets of grass and legumes with a partial preference of approximately 70% for legumes. Rutter (2006) and Dewhurst et al (2009), detail the importance of a mixed grass and legume diet for ruminant production that includes carbon/nitrogen balance, maintaining rumen function, and the basic need to maximize the nutrient benefit achieved per unit energy expended grazing.

Forage legumes, when incorporated into small ruminant diets, have been shown to increase ruminant performance due to an increased intake potential and a higher crude protein (CP) concentration compared to perennial grass-based grazing systems. Speijers et al (2004), found that lambs grazing legumes had higher daily growth rates and required fewer days to finish than lambs grazing perennial rye grass pasture. Fraser et al (2004) finished lambs on improved pasture (IP) with legumes compared to perennial ryegrass (*Lolium perenne* L.) pasture. In his study, legume forages had higher CP compared to ryegrass, and lambs grazing legumes had higher forage intake. This resulted in increased weight gain and decreased time to slaughter for lambs finished on IP compared to ryegrass pasture. Fat-tailed sheep when grazed on tropical native grass pasture improved with the leguminous shrub *Leucaena leucocephala* had nearly twice the growth rate as animals grazing native rangeland (Nguluve and Muir 1999). Goats grazing IP have also demonstrated greater average daily gain (ADG) compared to goats grazing native pasture (Muir and Weiss 2006; Goodwin et al 2004; Muir and Massaette 1996).

Ruminant pasture finishing systems rely upon an all forage diet that are often limiting in energy; therefore, energy supplementation is utilized to increase digestible energy intake to improve animal performance. The use of a high-energy, rapidly degraded starch, such as maize, fed to supplement ruminants on pasture is not a novel practice, and has been correlated to decreases in forage intake. However, increases in total dry matter intake and digestibility result (Jochims et al 2010; Islam et al 2000; Kawas et al 1999).

Attempts at the University of the Virgin Islands, Agricultural Experiment Station to produce heavier carcasses from hair sheep have primarily focused on crossbreeding. Godfrey and Collins (1999) reported that Suffolk x St. Croix White lambs had higher ADG and carcass weights than St. Croix White lambs. Lower feed efficiency and higher cost of gain of

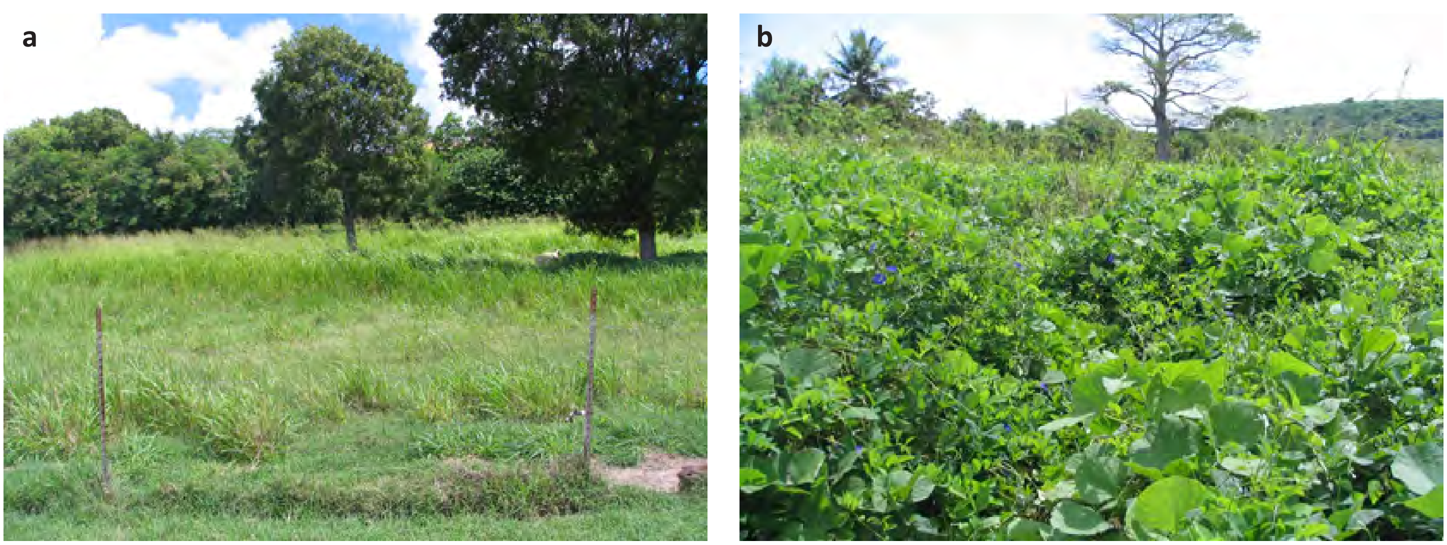

Figure 2. (a) Improved pasture consisting of a mixture of forage legumes, forbes, and grass and (b) native pasture consisting of grass alone.

the crossbred lambs, coupled with the high cost of imported concentrate feed, eliminated any economic advantage of the growth and size of the Suffolk-sired lambs. In a subsequent study, Godfrey and Weis (2005) reported that Dorper x St. Croix White lambs had a lower cost of gain and higher ADG than St. Croix White lambs fed a concentrate diet. This led to a net value for the crossbred carcasses of $12 compared to $0.67 for the St Croix White lamb carcasses. The high cost of imported concentrate feed for small ruminant production systems in the USVI has led to greater interest in utilizing native and improved pastures to provide nutrients during the finishing phase of production. The aim of this research is to evaluate lambs supplemented with maize grazing improved pasture planted with legumes or traditional native grass pasture.

MATERIALS AND METHODS

Two pasture finishing systems consisting of either a native pasture (NP) treatment or an improved pasture (IP) treatment were evaluated at the Animal Science Sheep Research Facility, Agricultural Experiment Station, at the University of the Virgin Islands in 2006 and 2007 (Figure 1). Native pasture was dominated by guinea grass (*Panicum maximum* Jacq cv. Mombasa) and hurricane grass (*Boithrocloa pertusa* L. A. Camus). The IP was plowed and lightly disked; seeds were broadcasted and pressed into the soil using a culti-packer in August of 2006 and 2007. Species included in the IP mix included: *Vigna unguculata* L. Walp. cv. 'Iron and Clay', *clitoria ternetea* L. cv. Tehuana, *Lablab purpureus* L. Sweet cv. Rongai, and *Panicum maximum* Jacq. cv. Mombasa; and planted at 50, 10, 20, and 3 kg/ha, respectively (Figure 1). Volunteer desmanthus (*Desmanthus vergatus* L. Willd.) and hurricane grass were also present (Figure 2). No irrigation, fertilizers, or pesticides were applied for the duration of the experiment.

Dorper x St. Croix White (DSTX) lambs were 9 to 10 months of age with a mean starting weight of 27 kg. Seven days prior to the start of the experiment, wether and ewe lambs were stratified by weight and gender and randomly assigned to either IP or NP in groups of six with three replications per treatment (n=36). All lambs received maize (11.5% crude protein and 88% TDN) supplement daily at one percent body weight for the duration of the 100-day pasture finishing period (Figure 3). All lambs were weighed on a weekly basis to determine average daily gain (ADG) and the amount of supplement fed was adjusted weekly. Maize supplement was fed in standard feed troughs and all

Table 1: Growth performance of Dorper x St. Croix White lambs finished on Native Pasture and Improved Pasture during the 100-day pasture finishing trial in 2006 and 2007.

Factor	Level	Total weight gain (kg)	Average daily gain (g/d)
Treatment	Native Pasture	8	73
	Improved Pasture	11	114
	SEM	0.43	4
	P	< 0.0001	< 0.0001
Sex	Wethers	11	109
	Ewes	8	79
	SEM	0.4	4
	P	< 0.0001	< 0.0001
Treatment x Sex	Native Pasture Wethers	8^{ab}	80^{ab}
	Native Pasture Ewes	7^{a}	67^{a}
	Improved Pasture Wethers	13^{c}	137^{c}
	Improved Pasture Ewes	9^{b}	90^{b}
	SEM	0.6	6
	P	0.0104	0.0064
Treatment x Year	Native Pasture 2006	7^{a}	65^{a}
	Native Pasture 2007	9^{b}	81^{a}
	Improved Pasture 2006	11^{c}	119^{b}
	Improved Pasture 2007	11^{c}	109^{b}
	SEM	0.6	6
	P	0.0636	0.0304

[abc]Means in the same column group without common letters are different at $P < 0.05$

Table 2: Mean carcass characteristics of pasture finished Dorper x St. Croix White lambs grazed on improved pasture or native pasture during the 100-day pasture finishing trial in 2006 and 2007.

	Native Pasture	Improved Pasture	SEM	*P*
Slaughter weight, kg	34.6	39.1	0.73	< 0.0001
Chilled Carcass, kg	16	18.9	0.41	< 0.0001
Dressing percent, %	47.8	50	0.0056	0.0067
Back Fat Thickness, mm	2.66	3.33	0.2	0.0273
Kidney/Pelvic Fat, g	530	696	33.1	0.0007
Body Wall Thickness, µm	10.8	14.4	0.497	< 0.0001
Loin Eye Area, cm^2	10.1	12	0.28	< 0.0001
Leg Circumference, cm	41.6	43.9	0.4	0.0002

lambs had free access to salt and water. Total gain was determined as the difference between body weight at the start and end of the 100-day pasture finishing period. Average daily gain was calculated for each lamb as total weight gain divided by the number of pasture finishing days ending at the final live weight prior to slaughter. At the end of the trial, all lambs were slaughtered by treatment. At 24 hours postmortem, carcasses were evaluated for chilled weight, back fat thickness (mm) over the 12th rib, body wall thickness (mm) below the 12th rib, kidney/pelvic fat (KPF; g),

Figure 3. Dorper x St Croix White lambs being supplemented with cracked corn during the 100-day finishing period on both the native and improved pastures.

leg circumference at the base of the tail (cm), and loin eye area (cm^2) measured between the 12th and 13th rib (LEA). Dressing percent yield was calculated as hot carcass weight/live weight x 100.

Data were analyzed using General Linear Models procedures (SAS 1996). Animal performance data (dependent variables) consisting of ADG, total gain, and carcass measurements were analyzed for treatment, sex, year, replication, and all possible interactions. When no significant differences were detected between replication and year, data was pooled across years. Forage species composition, total forage yield, and plant tissue nutrient data were utilized as supportive data only, with only means and standard deviations reported. An alpha value of $P \leq 0.05$ was selected for the determination of statistical significance throughout the manuscript and least significant difference ($LSD_{0.05}$) was utilized to separate treatment means for the ADG, total gain, and carcass data.

RESULTS & DISCUSSION

In both 2006 and 2007, IP lambs out performed NP lambs. Increased lamb growth performance was observed for total weight gain and ADG (Table 1) when pasture finishing lambs on IP compared to NP. Lambs grazing IP gained 11.1 ± 0.43 kg compared to NP lambs that gained 7.6 ± 0.43 kg ($P < 0.0001$). Average daily gain followed a similar pattern with IP lambs gaining 114 ± 4.2 g/day and NP lambs gaining 73.3 ± 4.2 g/day ($P < 0.0001$). Wethers had higher total weight gain and ADG than ewe lambs (Table 1). A treatment x sex interaction was observed and when analyzed for treatment and sex, growth performance was highest for IP wethers that gained 13.4 ± 0.6 kg and exhibited 137 ± 6 g/d of ADG. The combined effect of higher nutrition and the increased physiological gain potential of castrated male lambs over female lambs influenced this result. Ewes grazing IP had greater gains than ewes grazing NP, but were not different than wethers grazing IP. Improved pasture lambs were heavier at slaughter (39 ± 0.7 kg) than

NP lambs (35 ± 0.7 kg; Table 2). Improved pasture ewe lambs had improved growth performance than ewe lambs finished on NP, but exhibited lower growth performance than either IP or NP wethers (Table 1).

Improved growth performance of the IP lambs resulted in increased carcass quality postmortem. Carcass characteristics of IP and NP lambs are shown in Table 2. Improved pasture lambs had heavier chilled carcass weights ($P < 0.0001$; 19 ± 0.4 vs. 16 ± 0.4 kg, respectively). Improved pasture lambs dressed at 50 ± 0.005 % and NP lambs dressed at 47.8 ± 0.005 % ($P = 0.0067$). Increased muscle mass was observed in the IP lambs compared to the NP lambs with IP lambs having greater leg circumference, body wall thickness, and loin eye area. Improved pasture lambs had greater back fat thickness and kidney/pelvic fat than NP lambs with 3.33 ± 0.2 and 2.66 ± 0.2 mm, respectively ($P = 0.0273$); and 696 ± 33 vs. 530 ± 33 g, respectively ($P = 0.0007$). Data suggests that the IP resulted in heavier carcasses and improved carcass quality than that of the NP. Overall, results of this study indicate that IP finishing systems led to an improved rate of gain and muscle development in lambs compared to finishing lambs on NP.

IMPLICATIONS

In conditions where native forage quality is limited and there is a high cost for concentrated feed, legume-based pasture finishing systems can provide economic incentives and increased farm sustainability. This is particularly the case in tropical climates where native pastures dominated by grasses are typically low in feed value and the cost of imported feed is prohibitive. Results of this experiment indicate that lambs finished on pastures improved with a diverse blend of forage legumes, native forbs, and grasses can increase growth performance and improve carcass quality of lambs. Legume-based pasture finishing systems could provide alternative livestock management options to small farmers with limited resources to reduce imported commercial feed dependence, lower production costs, and improve lamb performance.

ACKNOWLEDGMENTS

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Wild Frangipani (*Plumeria alba* L.): A Native Virgin Islander

By Michael Morgan and Thomas W. Zimmerman

Figure 1. Wild frangipani (P. alba) tree with leaves and flowers.

SUMMARY

Plumeria alba or wild frangipani is a native tree of the Virgin Islands and Puerto Rico that can replace the more widely planted, but introduced, pink frangipani (*Plumeria rubra*) in landscape plantings. The fragrant attractive flowers of the wild frangipani compensate for its seasonal deciduousness. It also tolerates difficult growing conditions in the driest areas where other trees have difficulty thriving. Its wood is heavy and durable, and has been used for cabinetry and fuelwood in the past, but large specimens are hard to find.

Because wild frangipani is a native tree species with beautiful and fragrant white flowers, it has been suggested as a replacement for the yellow flowers of the non-native ginger thomas (*Tecoma stans*) as official territorial flower of the U.S. Virgin Islands.

INTRODUCTION

Wild frangipani is a small tree with fragrant white flowers that is native to the Virgin Islands and Puerto Rico. It is a tree that grows up to 11 meters tall and up to 20 centimeters in diameter. The tree has an open crown formed by a few stout branches ending in spreading clusters of long, narrow and corrugated leaves (Figure 1). It is deciduous in the dry season (Figure 2). Seed pods are rare but when present, are paired, brown, cigar-like capsules with many flat-winged seeds inside (Figure 3).

Wild frangipani is the wild relative of the more frequently seen, non-native pink-flowered ornamental *Plumeria rubra* L. The ornamental frangipani is often found in churchyards and cemeteries. Both species are members of the Apocynaceae family. The Spanish name of wild frangipani is Alelí. When cut, the trees of this genus exude a thick, milky-white latex sap. This must have reminded someone of sweetened milk custard flavored with almonds made in Italy and France called "frangipani." Another story has an Italian noble family with the last name of Frangipani making a perfume from the flowers of *Plumeria* spp. Then by extension, they got to make their last name

Figure 2. Wild frangipani growing on Buck Island National Monument, St. Croix, U.S. Virgin Islands. Note that the tree is deciduous and has lost its leaves because the photo was taken in the dry season.

Figure 3. A wild frangipani seed. Note that the seed is winged for dispersal with the wind.

the common name of the tree.

MATERIALS AND METHODS

Ecology

Wild frangipani grows in coastal thickets and on rock bluffs. It tolerates salt spray, drought and the alkalinity or high pH often associated with limestone soils. It is exceptionally resistant to wind damage. The species is much more common on St. John and St. Thomas than it is on St. Croix. However, wild frangipani is common on Buck Island National Monument, which is off the north coast of St. Croix.

An interesting aspect of this plant's ecology is that it is pollinated by the sphinx moth, also called hawk moth, at night. One would think that a tree with such a fragrant white flower (Figure 4) would be pollinized by bees during the day, but it is not. White flowers tend to attract moths and bats. Because frangipani flowers have a sweet fragrance, moths are drawn to them. The moths do not find any nectar in the first flower they visit, so they move onto the next frangipani flower they see hoping to find some. By visiting different flowers in search of nectar, the moths themselves get smeared with pollen, and with each visit to a different flower, they inadvertently deposit pollen from the flower they just visited, as they look for nectar in the flower they are currently visiting. This is how frangipani flowers get pollinated. These moths also lay their eggs upon the leaves of the frangipani plant. Some months later, the eggs hatch and turn into big orange and black striped caterpillars that eat the leaves in order to change themselves into moths. Their presence may be unsightly, but they do not kill the tree since they are a natural occurrence the plant has adapted to.

Propagation

The tree is most easily propagated by cuttings, simply because it is difficult to get the seeds. The tree produces seed only every few years. Since seeds are rare, trees can be propagated by cuttings. The process is to cut branches, roughly 12 inches long, let them dry in the shade for two weeks and plant. About 30% will take. It appears that where one cuts a branch affects the growth habitat of the tree. Cuttings from the terminal of the tree will grow straight, whereas branches from the side will grow in a branchy form.

Although the tree produces flowers every year, seed pods are produced rarely, about every 10 years. Since the seeds are wind-dispersed, one must collect the seeds before the pods open and the seeds blow away. One way to do this is to put a plastic bag around the seed pod so the seeds fall in the bag. Another way is to loosely tie a paper-and-wire twist tie around the pod, so the pod can mature and start to split open, yet the seeds stay in the pod. Another way is to find a pod that is already open and collect nearby pods found on the same tree. If one pod has already ripened and opened, odds are that the other pods on the same tree or branch are about to open. Collect these pods and put them in a sunny, dry place free of wind. Wait for the seed pods to dry and split open. There are roughly 100 seeds per ounce. Germination begins within 5 days of planting and 80% of the seeds planted should germinate.

The seedlings are epigeal, or take the form of a match head. That means, first the root emerges from the seed to enter the soil. Next, the juvenile leaves still joined as one rise above the soil. Then, the two leaves separate and start making food from the sun. Adult leaves that are long and narrow appear soon

Figure 4. A flower of wild frangipani.

Figure 5. Left: recently emerged frangipani seedlings with thick stem and wide fleshy juvenile leaves. Right: three-month-old seedlings with adult narrow leaves.

afterwards. Since the seedlings are fleshy and large forming an epigeal type of seed, plants can be transplanted into a planting container at this early stage (Figure 5).

In a greenhouse study performed in the University of the Virgin Islands Agricultural Experiment Station greenhouses, trees grew best given 2 liters of water a week in a three-gallon pot and grew 6 millimeters per week. This translates to roughly 2.5 cm of rain per month. Trees also grew almost just as well with 1 L or 4 L of water a week; however, to put more than 2 L on the plants is a waste of water. Plants growing outside in a field trial that are dependent on rainwater for their growth average 8 mm in height growth per month. However, during some months there is no growth at all.

It does not take very long for plants derived from cuttings to flower in the field. Usually within a year they are flowering because the cutting comes from mature tissue. However, plants derived from both seeds and cuttings grow slowly, about 10 centimeters a year.

Landscape Use

This tree is appropriate for planting in small spaces such as patios because it does not get too big, looks attractive, smells sweet, and tolerates salt spray, drought and poor soils. The only drawback is that it periodically gets defoliated by caterpillars during the wet season. Defoliation might be less of a problem closer to the sea than inland, but since defoliation is part of the plant's life cycle, one must get used to it. The moths and the caterpillars are essential if the tree is to produce seed and survive as a rare native plant species in the Virgin Islands.

IMPLICATIONS

The key to planting trees is picking the right tree for the right space or use. By promoting native trees over exotic ornamental species for landscape plantings, we conserve the world's biodiversity and make each place biologically unique. Native tree species are adapted to the conditions they grow in. The use of attractive, drought-tolerant, native wild frangipani for landscape plantings in dry climates conserves water. Once past the initial stages of growth, all this species needs is rainwater to survive and flourish.

ACKNOWLEDGEMENTS

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Using Thermal Imaging to Measure Body Temperature in Cattle

By Robert W. Godfrey, Rosemary C. Ketring and Sanlin Robinson

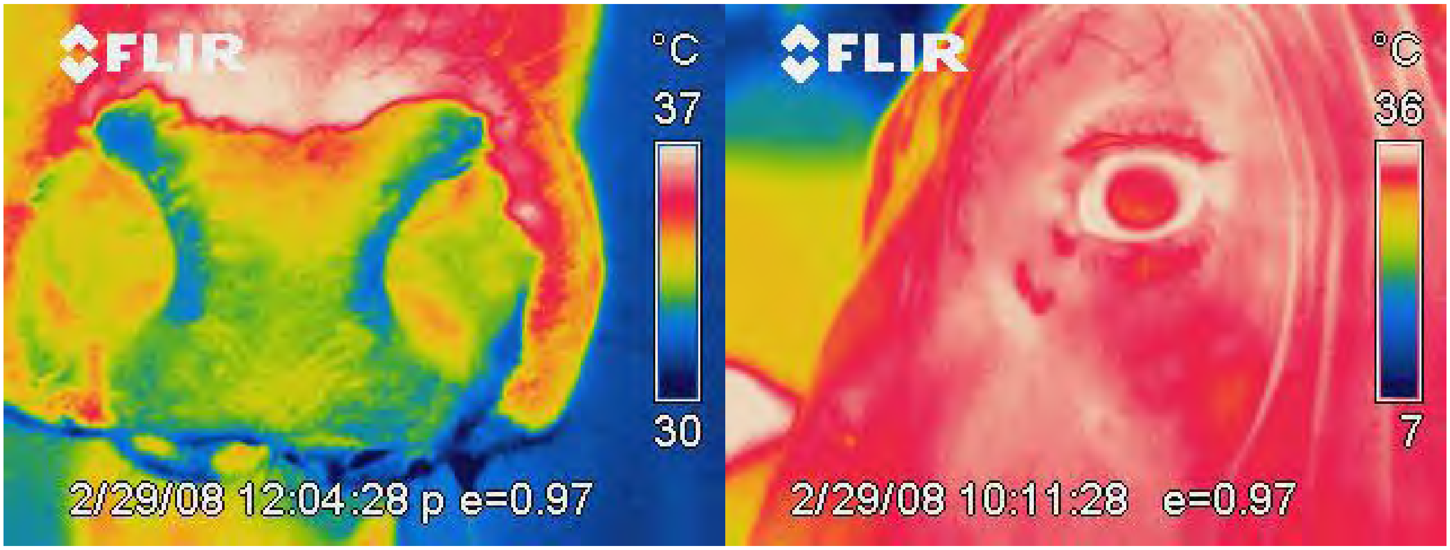

Figure 1. Thermal images produced by the camera of the muzzle (left) and eye (right) of the Senepol cows.

SUMMARY

Digital Infrared Thermal Imaging (DITI) using a thermal camera has potential to be a useful tool for the production animal industry. Thermography has been used in both humans and a wide range of animal species to measure body temperature as a method to detect injury or inflammation. The objective of these experiments was to compare the temperature of the eye (EYE) or muzzle (MUZ) measured using DITI to vaginal (VT) and rectal temperature (RT) as measures of core body temperature in beef cattle. Thermal imaging was used to measure EYE and MUZ in multiparous, non-lactating, pregnant Senepol Cattle (n = 44) between 0900 and 1200 h on a single day. A digital veterinary thermometer was used to measure both VT and RT. There was a high correlation ($P < 0.001$) between VT and RT (r = 0.78), a moderate correlation ($P < 0.001$) between VT and EYE (r = 0.52), RT and EYE (r = 0.58) and EYE and MUZ (r = 0.48). There was no correlation ($P > 0.10$) between RT or VT and MUZ. The findings of this study indicates that temperature of the eye, measured using DITI, can be used as an indicator of core body temperature in beef cattle as an alternative to using vaginal or rectal temperature.

INTRODUCTION

There are many situations where the determination of body temperature, most often measured as rectal temperature (RT), is the initial method used to evaluate the health of an animal. The determination of body temperature using non-invasive methods decreases the need to handle or restrain animals, and can have applications in non-domestic species where handling is impractical or impossible (Speakman and Ward, 1998; Kouba and Willard, 2005). Because animals can be largely asymptomatic when unhealthy, leading to difficulty in identifying them (Schaefer et al., 2007; Poulsen and McGuirk, 2009), body temperature measurement is often used as a rapid screening test for identifying sick (febrile) animals.

Digital Infrared Thermal Imaging (DITI) has been used in the veterinary sciences as a tool to monitor lameness in horses (Purohit and McCoy, 1980; Turner, 1998; Eddy et al., 2001), testicular function in beef cattle (Lunstra and Coulter, 1993; Gabor et al., 1998), mastitis in dairy cattle (Berry et al., 2003), and scrotal temperature in rams (Coulter et al, 1988). It has also been used to evaluate animal welfare in situations such as transportation (Shaefer et al., 1988) and branding (Schwartzkopf-Genswein and Stookey, 1997).

Thermal imaging has the potential to be used as a non-invasive and rapid method of monitoring animal body temperature. This study was designed to evaluate the relationship of eye temperature (EYE) and muzzle temperature (MUZ) measured using DITI to RT and vaginal temperature (VT) in Senepol cattle in a normothermic state.

MATERIALS AND METHODS

Animals were managed in accordance with the Guide for the Care and Use of Agricultural Animals

Figure 2. Using the thermal camera to collect images of the eyes and muzzle of a Senepol cow.

in Agricultural Research and Teaching (FASS, 1999) and experimental procedures were approved by the University of the Virgin Islands Animal Care and Use Committee.

Multiparous, non-lactating, pregnant Senepol cows (n = 44) were used to evaluate the relationship of VT, RT, EYE and MUZ in cattle in February 2008. Cows were brought in to sorting pens the day prior to collecting temperature measurements. Temperature measurements were collected between 0900 and 1200 h on one day. Cows stood in a squeeze chute with no squeeze applied and in the shade for all temperature measurements. The head of each cow was restrained in the head gate to enable taking thermal images of the left and right eyes and the muzzle. A FLIR ThermaCAM P65HS infrared camera (FLIR Systems AB, Danderyd, Sweden; accuracy ± 2 %) was used to take images of the left and right eye and muzzle (Figure 2). A veterinary thermometer (GLA M700, GLA Agricultural Electronics, San Luis Obispo, CA; accuracy ± 0.1 ºC) was used to measure RT and VT while the animal was standing in the chute at the same time that thermal images of the eye and muzzle were taken. For each cow VT was measured first and then RT. The thermometer probe was washed in disinfectant and dried between cows to prevent contamination of the vagina. The camera operator took individual images of the eyes from the side of the cow's head with the camera at a distance of 30 cm. The camera operator then took an image of the muzzle from the front of the cow's head with the camera at a distance of 30 cm. Images were captured on the camera once the operator determined it to be in focus and then downloaded to a desktop computer (Figure 1). Image analysis was conducted using ThermaCAM Researcher Pro 2.7 software to determine maximum temperature (MAX) for the left and right eye. Previous work in our laboratory has shown that there is no difference in MAX eye temperature, measured using DITI, between the left and right eye (Willard et al., 2006) so EYE was determined as the average of the maximum temperature of the left and right eye. Maximum temperature for the muzzle was used to determine MUZ. Environmental conditions consisting of ambient temperature and humidity were recorded throughout the entire sampling period at 10-min intervals using HOBO data loggers (HOBO H8 Pro Series, Onset Computer Corp., Bourne, MA USA). Temperature-humidity index (THI) was calculated using the formula THI = (0.8 * T) + ((RH/100) x (T - 14.4)) + 46.4, where T = temperature, °C and RH = relative humidity (NOAA, 1976).

Data Analysis

Simple correlations were determined among RT, VT, EYE and MUZ using PROC CORR of SAS (SAS Inst. Inc., Cary, NC). Correlations with r > 0.68 were classified as high, 0.36 < r < 0.67 as moderate, and r < 0.35 as low (Taylor, 1990). Temperatures measured at the different sites (EYE, RT, VT and MUZ) were compared using GLM procedures. Mean separation was conducted using the PDIFF option. All results are presented as least square means ± SEM.

RESULTS & DISCUSSION

The mean (± SEM) of the ambient T, RH and THI during data collection were 28.9 ± 0.7 ºC, 60.0 ± 3.2

Table 1. Simple correlations (r) of rectal, vaginal, eye and muzzle temperatures in hair Senepol cows.

	Rectal temperature	Vaginal temperature	Muzzle temperature
Eye temperature	0.58*	0.52*	0.48*
Rectal temperature		0.78*	0.22
Vaginal temperature			0.029

*Correlation is significant (*P < 0.001*).

% and 78.3 ± 0.6, with ranges of 2.4 ºC, 11.4 % and 2.6, respectively. There was no difference (*P > 0.10*) between RT and VT (Figure 3), but both RT and VT were higher than EYE (*P < 0.0001*) and MUZ was lower than RT, VT or EYE (*P < 0.0001*). There was a high correlation (*P < 0.001*; Table 1) between VT and RT (r = 0.78), a moderate correlation (*P < 0.001*) between VT and EYE (r = 0.52), RT and EYE (r = 0.58) and EYE and MUZ (r = 0.48) in the cows. There was no correlation (*P > 0.10*) between RT or VT and MUZ.

Based on the results VT can be used as a measure of core body temperature, similar to RT, in cattle. Rectal and vaginal temperatures have been reported to be correlated in dairy cattle (Vickers et al., 2010), which is in agreement with the current study. In several other studies thermal imaging has been used to monitor various aspects of animal health (Purohit and McCoy, 1980; Turner, 1998; Eddy et al., 2001; Berry et al., 2003), fertility (Lunstra and Coulter, 1993; Gabor et al., 1998), and animal welfare (Shaefer et al., 1988; Schwartzkopf-Genswein and Stookey, 1997) but the relationship between eye, vaginal and rectal temperature in livestock species has not been explored to a great extent. In our laboratory thermal imaging has also been used to evaluate EYE and surface temperatures of cattle and sheep under tropical conditions (Creighton et al., 2011; Rubino et al., 2011).

Muzzle temperature was not correlated with VT or RT in cattle and this may be due to behavior. It was noted that the cattle licked their muzzle while being worked through the chute to collect the temperature measurements but nothing was done to account for the moisture on the surface of the muzzle when the thermal imaging was being conducted or the images were analyzed.

While the thermal image-based temperature measurements described in the current study were obtained via a handheld camera, a recently published study by Schaefer et al. (2012) explores the use of a thermal imaging camera attachment to a water station that is able to scan the eye of the animal, in this case a calf, as it drinks. As animals visit the water trough daily this would help producers identify sick animals more quickly and without unnecessarily stressing the animals by handling them. An animal could then be singled out and treated rather than mass treatment of the entire group. The validation of eye temperature as an acceptable and accurate measure of body temperature could lead to this type of system becoming more practical and effective.

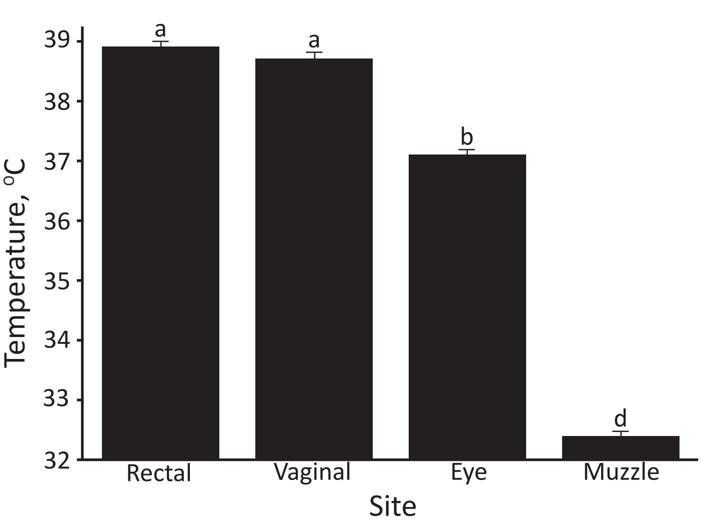

Figure 3. Mean (± SEM) rectal, vaginal, eye and muzzle temperatures of Senepol cows.
a,b,c Bars with different superscripts are different (P < 0.0001).

IMPLICATIONS

In summary, these results show that measuring the temperature of the eye in cattle using thermography can be a non-invasive method to monitor body temperature. Further research needs to be done in more animal species and under a wider variety of environmental conditions. The current price of the technology may limit its widespread use but as the technology is enhanced and prices drop it may find wider acceptance and use in animal health and well-being evaluations.

ACKNOWLEDGEMENTS

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Effect of Weaning Age on Hair Sheep Lamb Growth and Ewe Production Traits in an Accelerated Lambing System

By Robert W. Godfrey, Adam J. Weis and Kandi Facison

Figure 1. Weaned St. Croix White and Dorper x St. Croix White lambs in the pens prior to being weighed.

SUMMARY

This study was designed to evaluate the impact of weaning age on lamb and ewe productivity in an accelerated lambing system. In Experiment 1 St. Croix White and Dorper x St. Croix White lambs were weaned at 63 (Early-1; n = 106) or 90 d of age (Late-1; n = 99). In Experiment 2 STX and DRPX lambs were weaned at 63 (Early-2; n = 77) or 120 d of age (Late-2; n = 75). After weaning lambs were weighed weekly and fed a concentration ration (2 % BW•hd^{-1}•d^{-1}) while grazing guinea grass pasture. Weaning weight of late-weaned lambs was greater ($P < 0.0001$) than early-weaned lambs (14.6 ± 0.3 vs. 11.0 ± 0.3 kg and 18.7 ± 0.4 vs. 11.8 ± 0.4 kg, respectively). Litter weaning weight of late-weaned lambs was greater ($P < 0.004$) than early-weaned lambs (20.9 ± 0.8 vs. 17.4 ± 0.8 kg and 27.2 ± 1.0 vs. 17.5 ± 0.9 kg, respectively). Ewe efficiency ((ewe BW at weaning / litter weaning weight) x 100) was greater ($P < 0.004$) in late-weaned than in early-weaned ewes (50.7 ± 1.9 vs. 42.3 ± 1.8 % and 68.1 ± 2.2 vs. 41.9 ± 2.0 %, respectively). Lamb weight gain between 63 and 90 d of age was lower ($P < 0.03$) for Early-1 than for Late-1 lambs (2.7 ± 0.2 vs. 3.6 ± 0.3 kg, respectively). Lamb weight gain between 63 and 120 d of age was not different ($P < 0.10$) between Early-2 and Late-2 lambs (5.1 ± 0.2 vs. 5.6 ± 0.3 kg, respectively). Early-1 ewes exhibited estrus earlier than Late-1 ewes (10.9 ± 0.9 vs. 13.9 ± 1.0 d, respectively) but there was no difference ($P > 0.10$) between Early-2 and Late-2 ewes. Weaning hair lambs at 90 or 120 d of age can be done in an accelerated lambing system with no detrimental effect on ewe productivity. The later

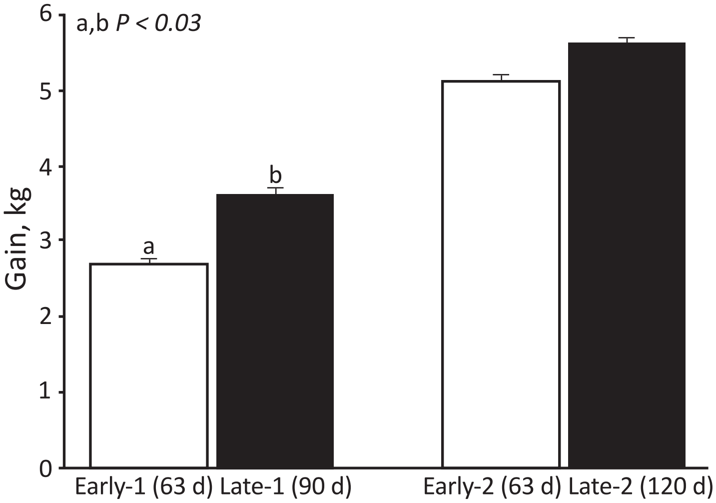

Figure 2. Weight gain of St. Croix White and Dorper x St. Croix White lambs weaned at 63 or 90 d of age in Experiment 1 or at 63 or 120 d of age in Experiment 2.

weaning resulted in a decrease in the amount of time that lambs received high cost, imported feed without a reduction in growth, resulting in savings of US$6 to US$15 per lamb.

INTRODUCTION

Hair sheep in tropical areas can be managed in an accelerated lambing system that produces 3 lamb crops every 2 yr (Godfrey et al., 2004, 2010). Weaning lambs at 60 d of age allows the dam a recovery period before going back into the breeding season. After weaning lambs are fed a concentrate ration or placed on pasture. Both methods of rearing weaned lambs are suitable to local conditions but each has its own risks and limitations. Feeding lambs a concentrate ration is expensive and the return on the investment is minimal (Godfrey and Collins, 1999; Godfrey and Weis, 2005). Young lambs on pasture are more susceptible to parasite infestations and death loss (Dodson et al., 2005).

Crossbreeding local breeds with Dorper can result in increased rates of gain and size of lambs produced (Dodson et al., 2005; Godfrey and Weis, 2005). Weaning lambs at a later age may provide a way to mitigate the costs and further take advantage of the greater growth rate of crossbred lambs.
The objectives of this study were to evaluate the impact of weaning St. Croix White and Dorper x St. Croix White lambs at 63, 90 or 120 d of age on lamb growth and ewe productivity in an accelerated lambing system.

MATERIALS AND METHODS

Animals were managed in accordance with the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999) and experimental procedures were approved by the University of the Virgin Islands Animal Care and Use Committee.

Experiment 1

Multiparous St. Croix White and Dorper x St. Croix White ewes and their lambs were used (Figure 1). Lambs born in March and November 2008 and July 2009 in an accelerated lambing system were assigned at birth to treatments based on breed, sex and litter size. Treatments consisted of weaning at 63 (Early-1; n = 106 lambs and 70 ewes) or 90 (Late-1; n = 99 lambs and 64 ewes) d of age. After weaning lambs were placed in single sex groups on guinea grass (*Panicum maximum*) pastures and fed a concentrate ration (16 % CP, 68 % TDN as fed; PMI Nutrition, Mulberry, FL) at 2 % BW•hd^{-1}•d^{-1} and the amount of feed was adjusted weekly based on BW. Lamb weight gain was calculated as the difference between lamb BW at 63 and 90 d of age.

Ewes grazed guinea grass pastures as one flock in a rotational grazing system. The ewes were bred in June 2008 and February and October 2009 during a 35-d breeding period using single sires within breed with rams of the same breed as the ewes. Rams were

Table 1. Weaning weight of St. Croix White (STX) and Dorper x St. Croix White (DRPX) lambs weaned at 63 or 90 d of age in Experiment 1 or at 63 or 120 d of age in Experiment 2.

	Treatment[1]	Weaning weight, kg	Breedtype	Weaning weight, kg	Gender	Weaning weight, kg
Experiment 1						
	Early-1	11.0 ± 0.3^{a}	STX	11.5 ± 0.4^{a}	Female	12.2 ± 0.4
	Late-1	14.6 ± 0.3^{b}	DRPX	13.9 ± 0.4^{b}	Male	13.2 ± 0.4
Experiment 2						
	Early-2	11.8 ± 0.4^{a}	STX	13.3 ± 0.5^{a}	Female	14.1 ± 0.5^{c}
	Late-2	18.7 ± 0.4^{b}	DRPX	16.9 ± 0.5^{b}	Male	16.1 ± 0.5^{d}

[1] Early-1 and Early-2 = weaned at 63 d of age, Late-1 = weaned at 90 d of age, Late-2 = weaned at 120 d of age.

^{a,b} Values with different superscripts within experiment and column are different ($P < 0.0001$).

^{c,d} Values with different superscripts within experiment and column are different ($P < 0.006$).

fitted with marking harnesses to aid in the detection of estrus and day of first estrus within the breeding period was determined for each ewe (d 1 = start of breeding period). Ewe BW measured at weaning was used to determine ewe efficiency (ewe BW at weaning / litter weaning weight) x 100. Lambing rate was calculated as (number of ewes lambing / number of ewes exposed to the ram) x 100.

Experiment 2

Multiparous St. Croix White and Dorper x St. Croix White ewes and their lambs were used. Lambs were born in March and November 2010 in an accelerated lambing system. Lambs were assigned at birth to treatments based on breed, sex and litter size. Treatments consisted of weaning lambs at 63 (Early-2; n = 77 lambs and 57 ewes) or 120 (Late-2; n = 75 lambs and 56 ewes) d of age. After weaning lambs were placed in single sex groups on guinea grass (*Panicum maximum*) pastures and fed a concentrate ration (16 % CP, 68 % TDN as fed; PMI Nutrition, Mulberry, FL) at 2 % $BW•hd^{-1}•d^{-1}$ and the amount of feed was adjusted weekly based on BW. Lamb weight gain was calculated as the difference between lamb BW at 63 and 120 d of age.

Ewes grazed guinea grass pastures as one flock in a rotational grazing system. The ewes were bred in June 2010 and February 2011 during a 35-d breeding period using single sires within breed with rams of the same breed as the ewes. Day of first estrus within the breeding period, ewe efficiency and lambing rate were determined as previously described.

Feed cost

Feed costs associated with rearing Early-1 and Early-2 lambs from weaning at 63 d of age to 90 or 120 d of age, respectively, were calculated using the cost of the feed at US$900/t, which included shipping to St. Croix from Florida. The amount of feed provided per lamb (2 % $BW•hd^{-1}•d^{-1}$) was determined using individual lamb weights collected weekly during the post-weaning period. The total amount of feed provided per lamb during the post-weaning period was multiplied by the cost of the feed to determine the cost of feed for each lamb. A mean value of feed cost per lamb was then calculated for Early-1 and Early-2 lambs.

Data analysis

Lamb weight gain, individual lamb and litter weaning weight, ewe BW at lambing, weaning and breeding, ewe efficiency and day of first estrus were analyzed using GLM procedures of SAS with weaning age (63 vs. 90 d and 63 vs. 120 d), breedtype, sex of lamb and year (month and year) and the appropriate interactions in the model. Neither year nor any interactions were significant for any trait measured so only the main effects were used in

Table 2. Traits of St. Croix White (STX) and Dorper x St. Croix White (DRPX) ewes in Experiment 1 when lambs were weaned at 63 or 90 d of age.

	Treatment[1]		Breedtype	
	Early-1	Late-1	STX	DRPX
BW at lambing, kg	43.7 ± 0.9	44.9 ± 0.9	40.3 ± 0.9^{e}	48.1 ± 0.9^{f}
BW at weaning, kg	40.9 ± 0.8	41.6 ± 0.9	38.1 ± 0.8^{e}	44.2 ± 0.8^{f}
BW at breeding, kg	41.6 ± 0.8	42.3 ± 0.9	38.4 ± 0.8^{e}	45.1 ± 0.8^{f}
Litter weaning weight, kg	17.4 ± 0.8^{a}	20.9 ± 0.8^{b}	16.3 ± 0.9^{e}	21.6 ± 0.9^{f}
Ewe efficiency[2], %	42.3 ± 1.8^{a}	50.7 ± 1.9^{b}	43.2 ± 2.2^{g}	49.0 ± 2.1^{h}
Heat date[3], d	10.9 ± 0.9^{c}	13.9 ± 1.0^{d}	13.2 ± 1.0	11.5 ± 1.0
Lambing rate[4], %	91.2	88.3	90.4	89.5

[1] Early-1 = weaned at 63 d of age, Late-1 = weaned at 90 d of age.

[2] Calculated as (ewe BW at weaning / litter weaning weight) x 100.

[3] Day in breeding season when ewe was first observed in estrus (start of breeding = d 1).

[4] Calculated as (number of ewes lambing / number of ewes exposed to the ram) x 100.

[a,b] Values with different superscripts within a row are different ($P < 0.004$).

[c,d] Values with different superscripts within a row are different ($P < 0.04$).

[e,f] Values with different superscripts within a row are different ($P < 0.0001$).

[g,h] Values with different superscripts within a row are different ($P < 0.06$).

Table 3. Traits of St. Croix White (STX) and Dorper x St. Croix White (DRPX) ewes in Experiment 2 when lambs were weaned at 63 or 120 d of age.

	Treatment[1]		Breedtype	
	Early-2	Late-2	STX	DRPX
BW at lambing, kg	45.9 ± 1.1	43.9 ± 1.1	43.0 ± 1.1[c]	46.3 ± 0.9[d]
BW at weaning, kg	42.8 ± 0.9	40.4 ± 1.0	39.9 ± 1.0[c]	42.9 ± 0.9[d]
BW at breeding, kg	43.2 ± 1.0	41.4 ± 1.0	40.9 ± 1.0	43.2 ± 0.8
Litter weaning weight, kg	17.5 ± 0.9[a]	27.2 ± 1.0[b]	21.5 ± 1.1	22.8 ± 0.9
Ewe efficiency[2], %	41.9 ± 2.0[a]	68.1 ± 2.2[b]	54.2 ± 2.7	53.9 ± 2.3
Heat date[3], d	14.1 ± 1.2	13.5 ± 1.3	16.3 ± 1.3[e]	11.8 ± 1.2[f]
Lambing rate[4], %	64.7	73.4	69.9	69.1

[1] Early-1 = weaned at 63 d of age, Late-1 = weaned at 120 d of age.

[2] Calculated as (ewe BW at weaning / litter weaning weight) x 100.

[3] Day in breeding season when ewe was first observed in estrus (start of breeding = d 1).

[4] Calculated as (number of ewes lambing / number of ewes exposed to the ram) x 100.

[a,b] Values with different superscripts within a row are different (*P < 0.0001*).

[c,d] Values with different superscripts within a row are different (*P < 0.04*).

[e,f] Values with different superscripts within a row are different (*P < 0.02*).

the final analysis. Mean separation was conducted using the PDIFF option. All results are presented as least square means ± SEM. Within each experiment the proportion of ewes that were nursing lambs and lambing rate were analyzed using CATMOD procedures of SAS.

RESULTS & DISCUSSION

In Experiments 1 and 2 weaning weight of late-weaned lambs was greater (*P < 0.0001*) than that of early-weaned lambs (Table 1). In both experiments weaning weight of DRPX lambs was greater than that of STX lambs (*P < 0.0001*). In Experiment 2 male lambs were heavier than female lambs (*P < 0.006*). This is in agreement with previous reports that reported the Dorper crossbred lambs have higher weaning weights than St. Croix White lambs (Godfrey et al., 2010).

Lamb weight gain was lower (*P < 0.03*) in Early-1 than in Late-1 lambs but there was no difference in gain (*P > 0.10*) between Early-2 and Late-2 lambs (Figure 2). The weight gain for Early-1 and Early-2 lambs was achieved by using costly, imported feed. The Late-1 and Late-2 lambs gained similar, or more, during these same time periods without the use of feed. Feed cost during the post-weaning period Early-1 and Early-2 lambs was US$6.72 and US$15.86, respectively. Producers can save these amounts on a per lamb basis when weaning at the later ages, resulting in lower expenditures for feed without sacrificing lamb performance. A farmer that produces 100 lambs can save between US$672 and US$1,586 on feed costs by weaning at 90 or 120 d of age. Jenkins (1986) also reported that early-weaned lambs in an accelerated lambing system had higher feed efficiency but a longer period on feed than late-weaned lambs in an annual lambing system, resulting in higher feed costs for the early-weaned lambs.

Ewes in the late-weaning groups had higher litter weaning weight and efficiency (*P < 0.004*) than ewes in the early-weaned groups (Tables 2 and 3). Dorper crossbred ewes were heavier (*P < 0.0001*), had greater litter weaning weight (*P < 0.0001*) and greater efficiency (*P < 0.06*) than St. Croix White ewes in Experiment 1 (Table 2). In Experiment 2 Dorper crossbred ewes were heavier at lambing and weaning (*P < 0.04*) and had an earlier day of estrus (*P < 0.02*) than St. Croix White ewes (Table 3).

At the start of breeding the percentage of ewes that had lambs at side was lower (*P < 0.0001*) in Early-1 compared to Late-1 ewes (7.2 vs. 54.6 %, respectively). None of the Early-2 ewes were nursing lambs and 100 % of the Late-2 ewes were nursing lambs at the start of the breeding period (*P < 0.0001*). Day of first estrus was different between treatments (*P < 0.004*) in Experiment 1 but not in Experiment 2. Because hair sheep ewes managed in an accelerated lambing system are cycling by 45 d postpartum (Godfrey et al., 1998), which is well within the average time between lambing and the subsequent breeding (80 d) in the accelerated lambing system and prior to weaning at 63 d, there was little concern that the late weaning would impact the postpartum estrous cycles of the ewes.

Lambing rate was not different (*P > 0.10*) between treatments (Tables 2 and 3) but was lower in Experiment 2. The reason for this difference between experiments is not clear because the ewes lambed at similar times of the year in each experiment. Ewe body weights at lambing weaning and breeding were not different (*P > 0.10)* between Late-1 and Late-2 groups so nutrition is not likely a factor.

IMPLICATIONS

In summary, weaning hair sheep lambs at 90 or 120 d of age instead of 63 d of age in an accelerated lambing system can decrease the amount of expensive feed required and save producers between US$6 and US$15 per lamb without decreasing lamb growth or ewe productivity and fertility.

ACKNOWLEDGEMENTS

The authors would like to thank Willie Gonzales and Royson Joseph for assisting with animal management. This project was supported by USDA-NIFA Hatch funds (#0212727) and was a contribution to the multistate projects SCC-081 (Sustainable Small Ruminant Production in the Southeastern U.S).

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Using Sweet Potato Varieties and Harvest Date to Reduce Yield Loss from Sweet Potato Weevils

By Thomas W. Zimmerman, Carlos Montilla and Stafford M.A. Crossman[1]

SUMMARY

Sweet potato is an attractive crop for the Caribbean because of its adaptability to different growing conditions, drought tolerance, year-round production and low susceptibility to natural disasters. However, sweet potatoes are plagued by the sweet potato weevil, *Cylas formicarius*. Our objective was to evaluate the effect of harvest date on weevil damage to tuberous roots of nine sweet potato varieties. The plants were established from six-node vine cuttings grown in replicated trials at one foot in-row spacing and five feet between rows. Weevil traps with a female pheromone were distributed throughout sweet potato plantings to monitor the male weevil population. Harvest was conducted at 90, 120 and 150 days. Weevil populations were found to increase during the initial four weeks and stabilized during the rest of the growing season. These male numbers indicated that sweet potato weevils were at a high level throughout the growing period. All sweet potato varieties had weevil damage to tuberous roots at 90 days (1-7%), however by 150 days the weevil damage ranged from 10-58% unmarketable tuberous roots. Sweet potato variety 'Beauregard-14' (B-14) has tuberous roots near the soil surface and was more prone to sweet potato weevil damage than varieties with deeper tuberous roots as 'Ruddy'. Overall, marketable production can be obtained by avoiding the sweet potato weevil damage if harvested between 90-120 days after planting.

INTRODUCTION

Sweet potato weevil (*Cylas formicarius*) is the most serious pest of sweet potato, not only in the Virgin Islands but also throughout the Caribbean and tropical regions. The sweet potato weevils cause damage from feeding on leaves and stems during growth and burrow into the tuberous roots as they mature (Figure 1) (Martin, 1983; Nottingham, 2002). Total loss of sweet potato crop has been experienced by local farmers. Applying pesticides for control is costly and difficult since sweet potato has multiple spreading vines. Our objective was to evaluate the influence of the harvest date on sweet potato weevil damage for nine diverse sweet potato varieties.

[1]University of the Virgin Islands Cooperative Extension Service

Figure 1. The sweet potato weevil (Cylas formicarius) is 3/8" long on this infected root.

MATERIALS AND METHODS

Nine sweet potato varieties were part of a trial designed to monitor male weevil populations during sweet potato growth and their feeding on tuberous roots. Eight sweet potato varieties from tissue cultured virus-free material were obtained from the USDA germplasm repository and one was a Caribbean variety from Puerto Rico. The varieties were established in May 2013 from terminal cuttings or slips with six leaves, the basal two leaves were removed at planting. The planting was at one-foot spacing between plants within a row and five feet between rows. The cultivars tested were replicated in three blocks. There were 17 plants per variety per row with three rows per block. Preemergent herbicide was applied prior to planting for weed control. Drip irrigation was installed to establish and maintain the crop. Three female weevil pheromone bait traps were randomly set in each block (Figure 2). The pheromone traps were used to attract male weevils and monitor their population weekly over

Figure 2. Weevil trap with female sex attracting pheromone set in sweet potato plot to monitor male population.

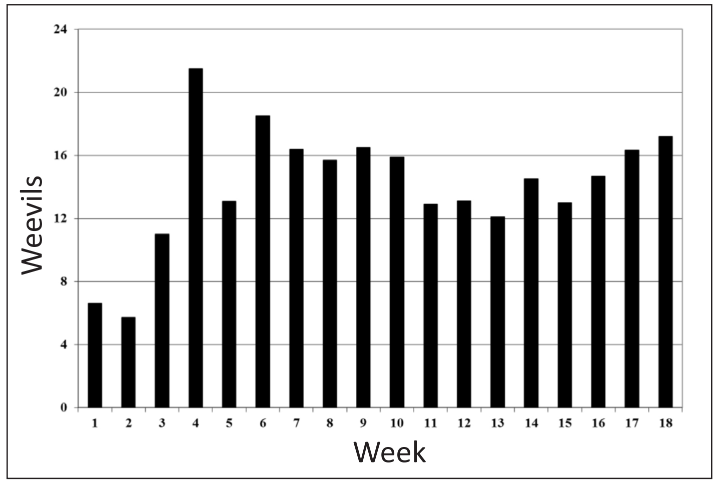

Figure 3. Average number of male sweet potato weevils captured weekly per pheromone trap.

time. Vines were cut and removed the day prior to sweet potato harvest. Harvest was conducted at 90, 120 and 150 days after planting. The harvested sweet potatoes were graded for size and level of weevil damage to determine marketability.

Figure X. Harvesting the sweet potatoes.

RESULTS AND DISCUSSION

The pheromone traps were effective in attracting and capturing the male weevils to monitor their population. Weevils were present in the plots from planting through the production cycle. Through the course of the trial, nearly 2,000 male weevils were captured and destroyed. The weevil population increased during the first four weeks and fluctuated above 12 weevils per trap throughout the rest of the growing period of eighteenth week (Figure 3). Weevil damage to the sweet potato leaves was visible by the third week. Since the pheromone traps attract only male weevils, the total population including females cannot be determined. These numbers however indicate that sweet potato weevils were at a constant high level throughout the sweet potato growing period.

Of the nine varieties evaluated, only 'Beauregard-14' had jumbo-size roots (over 3.5" diameter) present at harvest. 'Beauregard-14' had over 3.25 Lb of marketable tuberous roots at 90 days but only 1.8 Lb by 150 days (Figure 4). Marketable roots were tuberous roots over 1.5" diameter and without weevil damage. At the 120 day harvest, 'Francia', 'Mojave', 'Pujol' and 'Toquecita' produced over 2.5 Lb weevil-free marketable tuberous roots per plant. 'Beauregard-14', having tuberous roots close to the surface, had significant weevil damage by 120 days resulting in decreased marketable production per plant. After 150 days, only 'Mojave', 'Ruddy' and 'Toquecita' had over 2.0 Lb of weevil-free marketable tuberous roots per plant. 'Ruddy' was a variety developed for weevil resistance. Marketable production was reduced the longer the sweet potato remains in the field.

The percentage of unmarketable sweet potatoes, due to weevil damage at 90 days, was only 1-7%

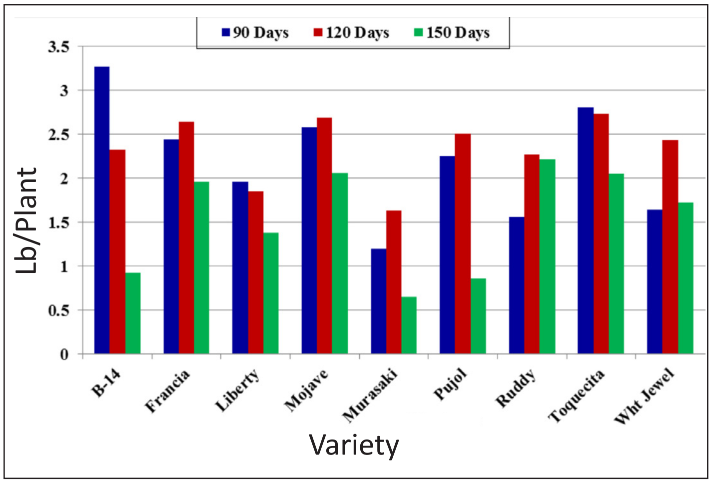

Figure 4. Average pounds per plant of marketable sweet potato tuberous roots without weevil damage harvested at 90, 120 or 150 days.

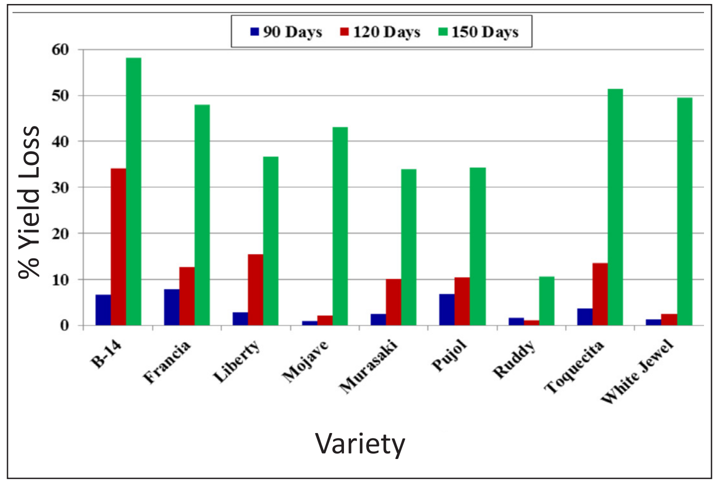

Figure 5. Percentage of marketable sweet potato yield loss due to weevil damage of tuberous roots over three harvest dates.

(Figure 5). By 120 days the yield loss due to weevils was over 10% for six of the nine varieties. However, by 150 days yield loss due to weevils was between 33 – 58% for all varieties except 'Ruddy' which has natural resistance and only had a 10% yield loss. Between 120 and 150 days the leaves were heavily damaged by the weevils and feeding moved to the tuberous roots making them unmarketable sweet potatoes (Figure 6). Harvesting sweet potato between 90 to 120 days ensures marketable production with minimal loss due to weevil damage on all varieties except 'B-14' which needs to be harvested after 90 days.

IMPLICATIONS

Sweet potatoes can be produced year round in the Virgin Islands. Marketable sweet potatoes can be produced without weevil damage by selecting early-bearing varieties or harvesting between 90 – 120 days. Growers of sweet potatoes will be able to harvest three crops a year of marketable weevil-free sweet potatoes.

ACKNOWLEDGEMENTS

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Figure 6. Weevils entered the sweet potato tuberous root from the stem (left) and lay eggs that hatch into white larvae that eat their way through the root. Center root had weevil penetration from the sides and root on the right is weevil-free.

Preliminary Evaluation of Sugar Snap and Snow Pea Varieties for Production in the U.S. Virgin Islands

By Thomas C. Geiger, Kenneth P. Beamer, Stuart A. Weiss and Rhuanito S. Ferrarezi

Figure 1. Edible-pods of pea cultivars tested at the U.S. Virgin Islands (three snow peas [Pisum sativum L. var. saccharatum] 'Little Sweetie' [LS], 'Mammoth Melting' [MM], and 'Oregon Giant' [OG], and three sugar snap peas [Pisum sativum L. var. macrocarpon] 'Super Sugar Snap' [3S], 'Cascadia' [CA], and 'Sugar Sprint' [SS]).

SUMMARY

Snow peas (*Pisum sativum* L. var. saccharatum) and snap peas (*Pisum sativum* L. var. macrocarpon) are high-value vegetables typically grown in temperate regions. The objective of this study is to evaluate if edible-pod peas can be grown in tropical climates like the U.S. Virgin Islands and to determine which variety obtains the highest yield under tropical conditions. Three cultivars of snow peas ['Oregon Giant' (OG), 'Mammoth Melting' (MM), 'Little Sweetie' (LS)], and three cultivars of snap peas ['Cascadia' (CA), 'Sugar Sprint' (SS), and 'Super Sugar Snap' (3S)] were grown at the University of the Virgin Islands, Agricultural Experiment Station, St. Croix, U.S. Virgin Islands. The experimental design was a complete randomized block consisting of six cultivar treatments with four replications. Prior to planting, trellises were constructed by stretching 1.5-m tall plastic mesh fencing between metal posts at 3 m intervals. Peas were seeded in double rows spaced at 7.6 cm in-row and 1 m between rows for a total of 263,157 plants ha^{-1}. Peas were irrigated daily and fertigated weekly using an 8 L h^{-1} drip-tape. We applied a total of 67 kg ha^{-1} nitrogen using a commercial 20-20-20 soluble fertilizer. There was no difference in germination rate observed between cultivars (89% to 93%, $P < 0.0001$). Little Sweetie produced the highest total fruit yield for the season across all cultivars at 15,442 kg ha^{-1} ($P < 0.0001$) followed by OG and 3S at 10,775 and 9,760 kg ha^{-1}, respectively. All cultivars presented similar fruit sugar content (9 to 10° Brix). Of the varieties tested, LS is recommended for our conditions. Results of this experiment indicate that edible-pod peas have potential as a specialty, short-season, high-value crop when grown in the cooler months on St. Croix, USVI.

INTRODUCTION

Snow and snap peas have probably been cultivated for centuries before any literature reference and are likely the result of spontaneous mutation of field and garden peas (Myers, 2001). Dr. Calvin Lamborn bred the snap pea that we are familiar with today in 1968 as a cross between the garden pea and snow pea (Janick, 2005). The most important difference for growers

Figure 2. Experiment overview, demonstrating the different heights among varieties, the 6-m long row, the three rows from experimental unit, the plastic mesh fixed with metal T-posts at 3 m intervals for plant support, and the layer of hay mulch applied for weed suppression.

between the two types of peas is pod shape at harvest. Snow peas have flat pods that are harvested when the pods have reached full size but before seeds have developed. Snap peas have round pods that are harvested after seed development (Gross et al., 2014). In terms of flavor, texture, growth, and yield they are very similar. For this reason, we will discuss the snow and snap pea varieties tested as simply edible-pod peas.

Peas are high-value vegetable crops, which wholesale in Miami, FL at $12-13 for a 4.5 kg carton (United States Department of Agriculture [USDA, 2015]). Data on fresh pea wholesale prices and on the quantity of fresh peas consumed in the U.S. Virgin Islands are unavailable. Local food production is encouraged to reduce reliance on food imports and keep food dollars in the local economy. One current trend in the local food movement are community-supported agriculture and farmer market stands. Fresh peas could enhance farm revenue by providing increased produce diversity and specialty crop interest to direct market consumers. Increased consumer awareness and demand could eventually lead to higher volume markets (e.g. grocery stores) and direct marketing to restaurants interested in serving high quality locally produced vegetables.

Peas are an annual crop propagated from seed. Most varieties reach maturity around 60 days after planting (DAP). They are typically grown in temperate states that include California, Kentucky, Oregon, and New York. Optimum growing temperature is between 12.8 and 18.3°C (Gaskell, 1997). The best time to grow peas in the U.S. Virgin Islands is during the cool months from November through March (Intellicast, 2015). High temperatures are tolerated during vegetative growth but will encourage rapid fruit development, which can reduce yield and fruit quality, especially if harvests are not done every two or three days.

Planting during the rainy season can reduce the need for irrigation, but high humidity and frequent rains increase disease pressure in general (Gaskell, 1997).

The objective of this study is to evaluate if edible-pod peas can be grown in tropical climates like the U.S. Virgin Islands and to determine which variety obtains the highest yield and sugar content under tropical conditions.

MATERIALS AND METHODS

Location

The trial was conducted at the University of the Virgin Islands, Agricultural Experiment Station (UVI-AES) on St. Croix (17º43'08" N, 64º47'46" W, at 33 m above sea level). The environmental data was measured through the study using a weather station from the USDA National Water & Climate Center (NWCC), Natural Resources Conservation Service (NRCS). The equipment was located 50 m from the experiment location (http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=2123). Precipitation totaled 198 mm, mean temperature = 24.8ºC, mean relative humidity = 85.6%, and mean solar radiation at noon = 1,000 W m^{-2}.

Treatments

Six different types of peas were evaluated and included three cultivars of snow peas (*Pisum sativum* L. var. saccharatum; 'Little Sweetie' [LS], 'Mammoth Melting' [MM], and 'Oregon Giant' [OG]), and three cultivars of sugar snap peas (*Pisum sativum* L. var. macrocarpon; 'Super Sugar Snap' [3S], 'Cascadia' [CA], and 'Sugar Sprint' [SS]) (Figure 1).

Growing conditions

SS and 3S seeds were procured from Twilley Seed (Hodeges, SC), MM from Willhite Seed Inc. (Poolville, TX), and OG, LS, and CA from Stokes Seed Company (Buffalo, NY). Peas were hand-planted directly into the ground in February 2014 (Spring) in three double-rows per plot with 7.6 cm in-row spacing, 10.2 cm in-bed spacing, and 1 m between double row centers for a total of 263,157 plants ha^{-1}. Double rows measured 6 m in length and data was collected from the center double row in each plot. Plants were trained on 0.15 m apart × 6 m long × 1.5 m tall plastic mesh (0.15 m2) trellises (Tenax Hortonova FG, Baltimore, MD) installed for the length of the row between metal T-posts at 3 m intervals for plant support (Figure 2). Plots were irrigated daily based on visual observations using a 1.27 cm diameter and 0.2032 mm thickness drip lines with 0.756 L h^{-1} emitters spaced every 10.2 cm (Aqua-Traxx, Bloomington, MN). Jack's Professional 20-20-20 fertilizer (J.R. Peters Inc., Allentown, PA) was applied at 67 kg ha^{-1} through a D45RE15 fertilizer injector (Dosatron, Clearwater, FL) during irrigation. A 10-cm thick layer of hay mulch was applied 36 DAP for weed suppression, to reduce soil surface temperature, and to minimize soil moisture loss.

The field was scouted for insect pests and plant diseases weekly until first harvest and then at every harvest. *Lepidoptera* were controlled using *Bacillus thuringiensis* (DiPel DF; Valent Biosciences, Walnut Creek, CA) and *Pentatomidae* were controlled using a pyrethrin-based spray (PyGanic Crop Protection EC 1.4II; McLaughlin Gormley King Company, Minneapolis, MN).Weeds were controlled both manually and mechanically at 15, 36, and 56 DAP.

Harvests were performed on a bi-weekly basis (on 57, 62, 65, 69, 72, 76, 79, 82, 85, and 90 DAP) and ran for a total of 6 weeks with 10 harvest events. Cultivars were evaluated on rate of germination on 3 DAP, plant height, marketable and unmarketable fruit weight and fruit sugar content. Plant heights were recorded on 57, 76, and 86 DAP. Fruit sugar content was recorded on 72 and 82 DAP using a MR32ATC brix refractometer (Milwaukee Instruments, Rocky Mount, NC). Measurements were averaged since there were no significant differences.

Experimental design and statistical analysis

The experimental design was a complete randomized block with four replications for each cultivar grown in the field. Data were analyzed using general linear model (GLM) procedures of SAS (SAS 9.4; SAS Foundation, Cary, NC) with total and marketable fruit yield, height, and fruit sugar content as the main effects in the model.

RESULTS AND DISCUSSION

Germination percentages were OG 87.5%, 3S 89.3%, MM 92.3%, CA 92.5%, LS 93.3%, and SS 93.3% (Dennery, 2014). There was no difference in percent germination by varieties ($P > 0.05$). Usual germination percentages for 3S, OG, and CA are reported as 93, 72, and 100%, respectively (Miles, 1999).

Little Sweetie produced the highest total and marketable fruit yield for the season compared to all

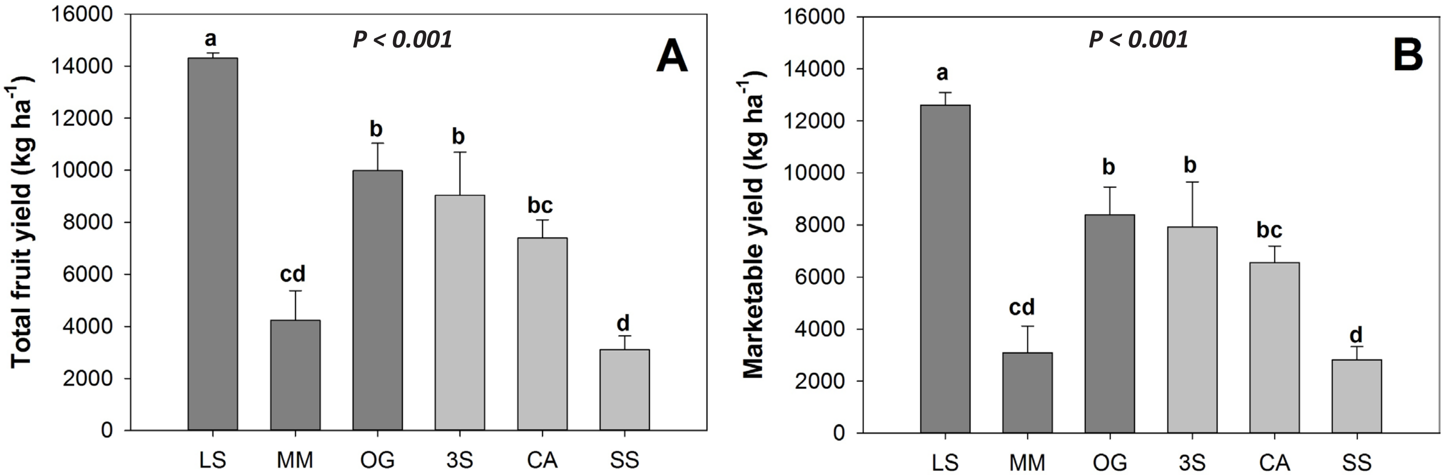

Figure 3. Total (A) and marketable (B) fruit yield of six cultivars of peas (three snow peas [Pisum sativum L. var. saccharatum] 'Little Sweetie' [LS], 'Mammoth Melting' [MM], and 'Oregon Giant' [OG], and three sugar snap peas [Pisum sativum L. var. macrocarpon] 'Super Sugar Snap' [3S], 'Cascadia' [CA], and 'Sugar Sprint' [SS]) cultivated in February 2014 (Spring). Dark grey bars indicate snow peas, while soft gray ones sugar snap peas. Different letters indicate means are statistically different (P < 0.0001).

other cultivars at 14,306 kg ha^{-1} and 13,617 kg ha^{-1} respectively (Figure 3, $P < 0.0001$). Typical yields for edible-pod peas are 4,000 to 5,000 kg ha^{-1} in Australia (Beckingham, 2001) and 5,600 to 7,800 kg ha^{-1} in California (Gaskell, 1997). To avoid over-mature fruits the crop needed to be harvested every other day during peak production. Harvesting requires about one man-hour for every 25.9 m of row. Based on our experience of this project, every 0.3 m row of peas requires about 0.25 man-hours for the entirety of the crop from initial field preparation to the end. Growers should consider their labor cost and the time commitment of this crop before deciding to grow peas.

Mammoth Melting had the tallest plant height, showing a significant difference when measurements were taken 76 and 85 DAP and reaching a final height of 63.9 cm (Table 1, $P < 0.0001$). Plant height for 3S was lower than MM but higher compared to other varieties at 76 and 85 DAP (Table 1, $P < 0.0001$). SS had the lowest height during recordings at 76 and 85 DAP, measuring 20.95 and 21.25 cm respectively. Plant height may be an important consideration for growers because taller plants are easier to harvest from. However, plant height does not positively correlate to yield since the tallest varieties resulted in the lowest yields. Mammoth Melting presented the greatest plant height (63.90

Table 1. Plant height at 56, 76, and 85 days after planting (DAP) of six cultivars of peas (three snow peas [*Pisum sativum* L. var. saccharatum] 'Little Sweetie' [LS], 'Mammoth Melting' [MM], and 'Oregon Giant' [OG], and three sugar snap peas [*Pisum sativum* L. var. macrocarpon] 'Super Sugar Snap' [3S], 'Cascadia' [CA], and 'Sugar Sprint' [SS]) cultivated in February 2014 (Spring).

	Plant height (cm)		
Variety	DAP 56	DAP 76	DAP 85
LS	67.69±0.84 b	80.39±2.87 c	86.74±5.82 b
MM	93.98±2.18 a	151.89±7.19 a	162.31±9.01 a
OG	68.45±1.81 b	92.58±2.13 c	88.52±4.40 b
3S	84.96±3.15 a	125.47±4.35 b	143.38±3.97 a
CA	84.96±3.15 a	125.47±4.35 b	143.38±3.97 a
SS	41.40±2.48 c	53.21±2.59 d	53.97±1.76 c
P-value	*< 0.0001*	*< 0.0001*	*< 0.0001*
Coefficient of variation (%)	6.83	8.36	10.29

Means followed by the same letter in the column are not significantly different level using Tukey's mean comparison test ($P < 0.0001$).

cm) but the lowest yield (4,249.27 kg ha^{-1}), while LS on the other hand is 47% shorter but is 363% higher yielding (Table 1 and Figure 2). The fact that greater plant height does not necessarily correlate to higher yield in peas is important when selecting a variety in a tropical condition, where plants grow more vigorously.

Fruit sugar content varied from 8 to 11°Brix and increased slightly from 72 to 82 DAP for all varieties ($P > 0.05$). The mean fruit sugar content of 72 and 82 DAP for the snow peas were 9.0°Brix in LS, 9.3°Brix in MM, and 9.3°Brix in OG, while for sugar snap peas were 10.2°Brix in 3S, 9.6°Brix in CA, and 9.8°Brix in SS ($P > 0.05$). Although there was no significant difference in fruit sugar content among varieties, the sugar snap varieties presented slightly higher sugar content than the snow pea varieties. It is not clear if these small differences in sugar content are useful in comparing varieties without data from sensorial analysis. Little Sweetie presented the highest yield, but lower sugar content than SS, 3S, and CA. If the variety recommendation is solely based on yield, then LS can be indicated; but LS had the lowest sugar content and may have poor consumer acceptance compared to other varieties. More studies are needed to correlate the plant yield with costumer acceptance in order to provide more information for growers selecting a variety.

CONCLUSIONS

It is possible to grow edible-pod peas in the cooler months on St. Croix, U.S. Virgin Islands. Results of this experiment indicate that both sugar snap and snow pea varieties have potential as a specialty high-value crop. Yields equal or greater than those reported in temperate regions can be achieved using the management practices described in this publication. There is high yield variability between different varieties. Of the varieties tested, our preliminary results indicate that LS was the highest yielding cultivar evaluated within the environmental and geographical conditions of this study.

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CURRENT PROJECTS

CAPACITY FUND PROJECTS

Agronomy

USDA-NIFA Hatch Project, 2009-2014, Cover crop and green manure evaluation for integrated cover-crop/livestock systems in the tropics

USDA-NIFA HATCH Project, 2014-2019, Evaluation of integrated tropical cover crop systems

Animal Science

USDA-NIFA Hatch Project, 2012-2017, Evaluation of weaning age on parasite burdens of hair sheep lambs in an accelerated lambing system in the tropics

USDA-NIFA Hatch Project, 2012-2017, Evaluation of Senepol heifer productivity in the U.S. Virgin Islands

USDA-NIFA Hatch Multistate Project (W-2173), 2011-2016, Impacts of stress factors on performance, health, and well-being of farm animals

USDA-NIFA Hatch Multistate Project (S-1064), 2014-2019, Genetic improvement of adaptation and reproduction to enhance sustainability of cow-calf production in the Southern United States

Biotechnology & Agroforestry

USDA-Hatch, 2011- 2015, Breeding and selection for early bearing large fruited papaya

USDA-Multistate Research Project (S-9), 2013-2018, Plant genetic resources conservation

USDA-McIntire-Stennis Project, 2010-2015, Growing and germinating native tree species

Horticulture & Aquaculture

USDA-NIFA Hatch Multistate Project (W-2128), 2009-2014, Microirrigation for sustainable water use

USDA-NIFA Hatch Project, 2011-2016, Variety trials and improving tropical vegetable production in the U.S. Virgin Islands

USDA-NIFA Hatch Project, 2011-2016, Development of aquaponic technology for the production of tilapia and hydroponic crops

USDA-NIFA Hatch Multistate Project (W-3128), 2015-2019, Scaling microirrigation technologies to address the global water challenge

GRANTS AND CONTRACTS

Experiment Station Grants

USDA-NIFA Resident Instruction in the Insular Areas, 2011-2012, Phase VII – Developing resident instruction in food and agricultural related sciences at Land Grant Institutions in the Pacific and Caribbean (Sub award from U of Puerto Rico)

USDA-NIFA Resident Instruction in the Insular Areas, 2012-2013, Phase VIII – Developing resident instruction in food and agricultural related sciences at Land Grant Institutions in the Pacific and Caribbean (Sub award from U of Puerto Rico)

USDA-NIFA Resident Instruction in the Insular Areas, 2013-2014, Phase IX – Developing resident instruction in food and agricultural related sciences at Land Grant Institutions in the Pacific and Caribbean (Sub award from U of Puerto Rico)

USDA-NIFA Resident Instruction in the Insular Areas, 2013-2014, Experiential learning as a form of resident instruction for students at the University of the Virgin Islands

USDA-NIFA Resident Instruction in the Insular

Areas, 2015-2017, Enhancing undergraduate students' education through experiential learning in agriculture research

Agronomy

USDA-South Eastern Region-Sun Grant, 2011-2014, Enhancing the sustainability of integrated biofuel feedstock production systems

USDA-SR-SARE, On-Farm Grant, 2011-2013, Promoting sustainable tropical cover crop organic mulch systems for minimum-till crop production in the U.S. Virgin Islands

USDA-SR-SARE, Research and Education Grant, 2012-2015, Developing sustainable tropical leguminous cover crop and green manure mulch systems for low-external-input crop production in the U.S. Virgin Islands, Puerto Rico, and Florida

USDA-NRCS, 2014-2016, Tropical cover crops and multipurpose nitrogen fixing trees to reduce soil erosion, increase soil quality and provide ecosystem services in Caribbean agroecosystems

Animal Science

USDA-CSREES-Tropical and Subtropical Agriculture Research, 2010-2013, Evaluating the influence of genotype and phenotype of Senepol cattle and hair sheep on physiological adaptations to the tropical environment

USDA-Office of Advocacy and Outreach, 2011-2012, Outreach and assistance in tropical pasture and livestock management for Pacific Islanders (Sub award from U of Hawaii)

USDA-NIFA Resident Instruction in the Insular Areas, 2015-2017, Evaluation of the relationship between body temperature and grazing behavior in livestock in the tropics

Biotechnology & Agroforestry

USDA-NIFA Beginning Farmer and Rancher Development Program, 2011-2014, Enhancing competiveness of beginning farmers in the USVI

USDA-NIFA Specialty Crop Grant, 2011-2016, Muscadine grape utilizing cisgenetic modification technology

USDA-TSTAR 2010-2013 Identification and control of a sorrel wilt disease

USDA-VI Dept. of Agriculture-Specialty Crop Block Grant, 2010-2013 On-farm evaluation and breeding sorrel to enhance marketability

USDA-VI Dept. of Agriculture-Specialty Crop Block Grant, 2010-2013 Expanding the availability of improved disease-free sweet potato to increase production and marketability

USDA-VI Dept. of Agriculture-Specialty Crop Block Grant, 2011-2014, Monitoring weevils during sweet potato production

USDA-VI Dept. of Agriculture-Specialty Crop Block Grant, 2011-2014, Production and marketing potential of Pitaya

USDA-VI Dept. of Agriculture-Specialty Crop Block Grant, 2012-2015, Evaluating ginger potential in the USVI

U.S. Fish & Wildlife Service, 2014- 2016, Federally endangered *Buxus vahlii* and *Catesbaea melanocarpa*

U.S. Geological Service-Water Resources Research Institute, 2011-2012, Evaluation of drought tolerance of native trees for landscaping

U.S. Geological Service-Water Resources Research Institute, 2012-2013, Evaluation of drought tolerance of five native trees

U.S. Geological Service-Water Resources Research Institute, 2014-2015, Active and passive irrigation

Ventria BioScience, 2011-2012, Evaluation of rice production in the Virgin Islands

Ventria BioScience, 2012-2013, Evaluation of pre- and postemergent herbicides

Ventria BioScience, 2013-2014, Evaluation of pesticide application on rice production

Ventria BioScience, 2014-2015, Covercrops after rice

PUBLICATIONS

AGRONOMY

Dissertation

Weiss S.A. 2015. Sustainability of cover crop rotations in tropical low-external-input smallholder organic cropping systems. Ph.D. Dissertation, University of Florida, Gainesville, FL.

Journal Article

Ashworth, A.J., C.P West, F.L. Allen, P.D. Keyser, S. Weiss, D.D. Tyler, and A.M. Taylor, K.L. Warwick, and K.P. Beamer. 2015. Biologically fixed nitrogen in legume intercropped systems: comparison of N-difference and ^{15}N enrichment techniques. Agronomy Journal. 107:1-12. DOI:10.2134/agronj14.0639.

Conference Proceedings

Muir, J.P., T.H. Terrill, E. Valencia, S. Weiss, K. Littlefield, P.D. Jones, J. Mosjidis, and R.M.

Wolfe. 2009. A wide range in forage legume condensed tannin content in the Southeastern USA shows promise in ruminant protein and parasite management. Proc. 18th Annual Meeting of the American Forage and Grassland Council, June 21-24, Grand Rapids MI. AFGC.

Weiss, S.A., D.D. Treadwell, C.A. Chase, and R. Ben Avraham. 2009. Effect of cover crop biomass and green manure systems on vegetable yield in low-external-input (lei) organic crop production in the Caribbean. Proc. Caribbean Food Crops Society. 45:229-230.

Muir, J.R., R. Wolfe, T. Terrill, E. Valencia and S.A. Weiss. 2009. The wide range of condensed tannins in Caribbean Basin plants and their application to ruminant production systems. Proc. Caribbean Food Crops Society, 45:46-52.

Ashworth, A.J., F.L. Allen, P.D. Keyser, S. Weiss, C.P. West, D.D. Tyler, and A.M. Taylor. 2015. Enhancing the sustainability of lignocellulosic feedstock production systems in the Southeast and under intensified climatic change. Sun Grant Conference, Auburn, AL.

Abstracts

Weiss, S.A., D.D. Treadwell, C.A. Chase, and R.B. Avraham. 2009. Sustainable management of soil nitrogen and organic matter in low-external-input organic crop production in the Caribbean. In: International Annual Meetings ASA-CSSA-SSSA; AnMtgsAbsts2009.54491. Available at: https://scisoc.confex.com/scisoc/2009am/webprogram/Paper54491.html

Weiss, S.A. and R.W. Godfrey. 2010. Evaluation of sunn hemp hay for St. Croix White hair sheep production. Proc. Caribbean Food Crops Society. 46:162.

Weiss, S.A. and A. Ashworth. 2010. Nitrogen allocation in low-external-input tropical cover crop livestock forage systems. In: International Annual Meetings ASA-CSSA-SSSA; 276-4. Available at: https://scisoc.confex.com/crops/2010am/webprogram/Paper62187.html

Weiss, S.A. 2011. *Crotalaria juncea* L. cv. IAC-1 for livestock feed and seed production in low-external-input mixed crop/livestock production systems for the tropics. In: International Annual Meetings ASA-CSSA-SSSA; 188-2. Available at: https://scisoc.confex.com/crops/2011am/webprogram/Paper67119.html

Weiss, S.A., R.W. Godfrey, E. Valencia, and A. Hogg 2012. Evaluation of the condensed tannin containing tropical legume *Calliandra calothyrus* on gastrointestinal nematode control and growth performance in St. Croix White hair x Dorper lambs in the U.S. Virgin Islands. Proc. Caribbean Food Crops Society. 48:273.

Weiss, S.A. 2012. Evaluation of three cover crops and their termination with a roller-crimper to produce residual surface sheet mulch on cover crop re-growth and weed development under tropical environmental conditions. In: International Annual Meetings ASA-CSSA-SSSA; 52-6. Available at: https://scisoc.confex.com/crops/2012am/webprogram/Paper73941.html

Weiss, S.A., D.D. Treadwell, E. Valencia, and K.P. Beamer. 2013. Tropical cover crop mulch systems for low-external-input reduced tillage crop production. In: International Annual Meetings ASA-CSSA-SSSA; 317-11. Available at: https://scisoc.confex.com/scisoc/2013am/webprogram/Paper81549.html

Weiss, S.A. and K.P. Beamer. 2013. Reduced tillage termination of cover crop systems in the tropics. In: International Annual Meetings ASA-CSSA-SSSA; 187-3. Available at: https://scisoc.confex.com/scisoc/2013am/webprogram/Paper81559.html

Weiss, S.A. and K.P. Beamer. 2014. Evaluation of three cover crops terminated with a roller-crimper on cover crop re-growth and weed development under tropical conditions. Proc. Caribbean Food Crops Society. 50:41.

Weiss, S.A. T.C. Geiger, and K.P. Beamer. 2014. Evaluation of six edible-pod pea varieties as a potential high value crop for the U.S. Virgin Islands. Proc. Caribbean Food Crops Society. 50:64.

Treadwell, D.D. S.A. Weiss, E. Valencia, and K.P. Beamer. 2014. Lessons Learned in conservation tillage vegetable systems in the sub-tropics and tropics. HortScience 49(9):S329 (Supplement).

Weiss, S.A. K.P. Beamer, and R.W. Godfrey. 2014. St. Croix White hair sheep performance evaluation of lambs grazed on low quality native pasture improved with no-till sunn hemp (*Crotalaria juncea*). In: International Annual Meetings ASA-CSSA-SSSA; 290-1. Available at: https://scisoc.confex.com/scisoc/2014am/webprogram/Paper88753.html

Weiss, S.A. and K.P. Beamer. 2014. Screening of five broad leaf plants for use as tropical cover crops and their response to termination with a roller-crimper. In: International Annual Meetings ASA-CSSA-SSSA; 66-21. Available at: https://scisoc.confex.com/scisoc/2014am/webprogram/Paper89776.html

van Santen, E. and S.A. 2015. Weiss. Expired equines and other challenges in on-farm systems research in the tropics. Conference on Applied Statistics in Agriculture. Manhattan, KS.

Treadwell, D.D., S.A. Weiss, and J. Perez. 2015. Cover crops and conservation tillage in organic jalapeno pepper (*Capsicum annum* L. 'Tormenta'). HortScience 50(9) (Supplement).

Weiss, S.A., D.D. Treadwell, R.S. Ferrarezi, and K.P. Beamer. 2015. Tropical cover crop mulch systems for low-external-input reduced-tillage vegetable production. HortScience 50(9) (Supplement).

Geiger, T.C., K.P. Beamer, S.A. Weiss, and R.S. Ferrarezi. 2015. Performance of nine butternut squash varieties in summer in the U.S. Virgin Islands. HortScience 50(9) (Supplement).

Invited Presentations

Soil health in the subtropics and tropics. Florida Small Farms and Alternative Enterprises Conference, University of Florida, Kissimmee, FL. August 1-2, 2014.

Expired equines and other challenges in on-farm systems research in the tropics. Conference on Applied Statistics in Agriculture. Kansas State University, Manhattan, KS, April 26-28, 2015

ANIMAL SCIENCE

Journal Articles

Godfrey, R.W., M.C. Vinson and R.C. Ketring. 2012. Evaluation of split feeding regimens on growth and productivity of hair sheep ewes and lambs in the tropics. J. Anim. Vet. Adv. 11:2747-2752.

Godfrey, R.W., M.C. Vinson and R.C. Ketring. 2013. The effect of a split feeding regimen and breed on body temperature of hair sheep ewes in the tropics. J. Anim. Sci., 91:5205-5207.

Huson, H.J., E.S. Kim, R.W. Godfrey, T.A. Olson, M. McClure, C.C. Chase, R. Rizzi, A.M. O'Brien-Perez, C. Van Tassell, J.F. Garcia, T.S. Sonstegard. 2014. Genome-wide association study and ancestral origins of the slick-hair coat in tropically adapted cattle. Frontiers in Genetics, 5:101. doi: 10.3389/fgene.2014.00101

George, W.D., R.W. Godfrey, R.W., C. Ketring, M.C. Vinson and S.T. Willard. 2014. Relationship among eye and muzzle temperatures measured using digital infrared thermal imaging and vaginal and rectal temperatures in hair sheep and cattle. J. Anim. Sci. 92:4949-4955.

Abstracts

Creighton, T., A.M. Hogg and R.W. Godfrey. 2011. Evaluating the influence of breed on hair coat characteristics and body temperature of hair sheep in the tropics. J. Anim. Sci. 89(E-Suppl. 2): 33.

Rubino, D.L., A.J. Weis, A.M. Hogg and R.W. Godfrey. 2011. Body temperature measurements of Senepol and crossbred calves in the tropics. J. Anim. Sci. 89(E-Suppl. 2): 29.

Godfrey, R.W. and A.M. Hogg. 2011. Evaluation of weaning hair sheep lambs at 63 or 120 d of age in an accelerated lambing system in the tropics. J Anim. Sci. Vol. 89(E-Suppl. 1):513.

Thorne, M.S., J. Deenik, R.W. Godfrey, G. Fukumoto, J. Powley, M. Stevenson, L. Duponcheel, A. Badilles 2011. Extension outreach in tropical range and livestock management for Pacific Islanders. 64th Annual Meeting of the Society for Range Management, Billings, Montana, February

6-10, 2011.

Godfrey, R.W., A.J. Weis, P.E. Hillman, K.G. Gebremedhin, C.N. Lee, and R.J. Collier. 2012. Evaluation of body temperature and sweating rate of Senepol and crossbred heifers in the tropics. J. Anim. Sci. Vol. 90(Suppl. 3):240.

Godfrey, R.W., A.J. Weis, P.E. Hillman, K.G. Gebremedhin, C.N. Lee, and R.J. Collier. 2012. Evaluation of body temperature and sweating rate of Senepol cows in the tropics. J. Anim. Sci. Vol. 90(Suppl. 3):241.

Godfrey, R.W. and A.J. Weis. 2013. Production traits of spring- and fall-calving Senepol cows in the tropics. J. Anim. Sci. Vol. 91(E-Suppl. 2):417.

Godfrey, R.W. and A.J. Weis. 2013. Evaluation of hair coat, tick burden and production traits of Senepol cows in the tropics. J. Anim. Sci. Vol. 91(E-Suppl. 2):417.

Godfrey, R.W., W.D. Preston, A.M. Jung, S. Joseph, L. LaPlace, P.E. Hillman, K.G. Gebremedhim, C.N. Lee and R.J. Collier. 2014. Evaluating the impact of breed and pregnancy on body temperature of hair sheep ewes in the tropics. J. Anim. Sci. Vol. 92 (E-Suppl 1): 36.

Godfrey, R.W., W.D. Preston, A.M. Jung, S. Joseph, L. LaPlace, P.E. Hillman, K.G. Gebremedhim, C.N. Lee and R.J. Collier. 2014. Evaluating the impact of breed, hair coat and pregnancy on sweating rate of hair sheep ewes in the tropics. J. Anim. Sci. Vol. 92 (E-Suppl 1): 37.

Godfrey, R.W., S. Joseph, L. LaPlace, and W. George. 2015. Effect of weaning age on parasite burdens of hair sheep lambs and ewes in an accelerated lambing system in the tropics. J. Anim. Sci. Vol. 93 (E-Suppl 1):46.

Godfrey, R.W. and H.C. Nelthropp. 2015. Characterization of growth traits of Senepol heifers and bulls from birth through a year of age in the tropics. J. Anim. Sci. Vol. 93 (Suppl. s3):636.

Godfrey, R.W., A.J. Weis and H.C. Nelthropp. 2015. The influence of tick loads of Senepol cows on calf tick loads and production traits in the tropics. J. Anim. Sci. Vol. 93 (Suppl. s3):837.

Experiment Station Bulletins

Thorne, M.S., J. Deenik, R.W. Godfrey, G. Fukumoto, J. Powley, M. Stevenson, L. Duponcheel. 2011. Mariana Grazing Management Academy: Range and pasture management Vol. 11. University of Hawaii at Manoa Cooperative Extension Service.

UVI Symposia

Joseph, S., W. Preston, A. Jung and R.W. Godfrey. 2014. Evaluating physiology and behavior of hair sheep ewes at weaning. UVI Research Day 2014 Proceedings. p. 24.

Joseph, S., W. George, L. LaPlace and R.W. Godfrey. 2014. Evaluation of weaning age on parasite burdens of hair sheep lambs in an accelerated lambing. UVI Fall 2014 Student Research Symposium. 16:34.

Elicker, A., S. Lakos and R.W. Godfrey. 2015. A comparison of gastrointestinal parasites during the postpartum period in two breeds of hair sheep. UVI Research Day 2014 Proceedings. p. 8.

Invited Presentations

Physiology of adapted livestock in a tropical environment at Kansas State University as a part of the ADVANCE Distinguished Lecture Series, sponsored by the K-State Office for the Advancement of Women in Science and Engineering, March 25-26, 2014.

The impact of weaning age on productivity of hair sheep ewes and lambs in an accelerated lambing system in the tropics. 8th Small Ruminant Conference, Alabama A&M University, Eufaula, AL, July 23-24, 2015.

Physiology of adapted hair sheep in a tropical environment. 8th Small Ruminant Conference, Alabama A&M University, Eufaula, AL, July 23-24, 2015.

BIOTECHNOLOGY & AGROFORESTRY

Journal Articles

Morgan, M., and T.W. Zimmerman. 2014. Evaluation of drought tolerance in five native Caribbean tree species with landscape potential. Tree Planter's Notes 57(1):49-60.

Book Chapters

Morgan, M., and T.W. Zimmerman. 2014. Agroforestry in the Caribbean, traditional systems, both sustainable and biodiverse. In: Sustainable Horticultural Systems: Issues, Technology and Innovation. Springer International Publishing, Switzerland. p. 129-141.

Conference Proceedings

Burnett, N.T., and T.W. Zimmerman. 2011. Revitalizing sweet potato cultures following one year on low sucrose medium. Proc. Caribbean Food Crops Society. 47:84-85.

Crossman, S., D. Browne, T.W. Zimmerman, E. Chichester, J. Kowalski, Y. Browne, K. Boateng and S. Lakos. 2011. Operation Breadbasket: A USVI community outreach and assistance partnership. Proc. Caribbean Food Crops Society. 47:1-7.

Emanuel, K.M., and T.W. Zimmerman. 2011. Extraction and chromatographic separation of anthocyanin in sorrel. Proc. Caribbean Food Crops Society. 47:89-93.

Matthew, K.D., C. Philemon, and T.W. Zimmerman. 2011. Plant spacing influences production on late season planted sorrel (*Hibiscus sabdariffa*). Proc. Caribbean Food Crops Society. 47:107-110.

Burnett, N.T., T.W. Zimmerman, S.M.A. Crossman and C. Montilla. 2012. Evaluation of sweet potato in the U.S. Virgin Islands for production under weevil pressure. Proc. Caribbean Food Crops Society. 48:162-167.

Zimmerman, T.W, C. Montilla and S.M.A. Crossman. 2013. Production potential of Pitaya in the Virgin Islands. Proc. Caribbean Food Crops Society. 49:120-124.

Bernier, J., C. Montilla, and T.W. Zimmerman. 2013. Influence of papaya seed age on viability. 49th Proc. Caribbean Food Crops Society. 49:129-133.

Emanuel, K.M., K. Matthew and T.W. Zimmerman. 2013. Evaluation of first and third generation sorrel for plant vigor. Proc. Caribbean Food Crops Society. 49:109-112.

Crossman, S.M.A., T.W. Zimmerman, E. Chichester, C. Robles, K. Boateng and M. Wilson. 2013. The Virgin Islands beginning farmer training program - enhancing the competitiveness and sustainability of beginning Virgin Islands farmers. Proc. Caribbean Food Crops Society. 49:187-194.

Abstracts

Cuffy, K., C. Montilla, S.M.A. Crossman and T.W. Zimmerman. 2014. Ginger production and storage in the Virgin Islands. Proc. Caribbean Food Crops Society. Abstracts 50:24-25.

Zimmerman, T.W., K. Cuffy, C. Montilla and S.M.A. Crossman. 2014. Sorrel hybrids: Fruit size evaluation. Proc. Caribbean Food Crops Society. Abstracts 50:32.

Zimmerman, T.W., S.M.A. Crossman and C. Montilla. 2014. Influence of harvest date on sweet potato weevil damage. HortSci 49(9):S45.

Zimmerman, T.W., and K.M. Emanuel. 2015. Reducing sucrose concentration extends time between in vitro sweet potato transfers. National Sweetpotato Collaborators Group Progress Report. Nashville, TN. p.32.

Zimmerman, T.W., and K.M. Emanuel. 2015. Using low sucrose concentration to extend time between sweet potato transfers. In Vitro Cell. Dev. Biol. 51:S48-S49.

UVI Symposia

Burnett, N.T., and T.W. Zimmerman. 2011. Influence of sucrose concentration on long-term sweet potato cultures. UVI Spring 2011 Student Research Symposium. 9:11.

Emanuel, K.M., and T.W. Zimmerman. 2011. Influence of extraction solvent on anthocyanin concentration in sorrel. UVI Spring 2011 Student Research Symposium. 9:17.

Matthew, K., C. Philemon and T.W. Zimmerman. 2011. Influence of spacing on production for two sorrel (*Hibiscus sabdariffa*) varieties. UVI Spring 2011 Student Research Symposium. 9:24.

Bastien-Gilbert, A., and T.W. Zimmerman. 2012. Characteristics of sorrel parents, F1 and F2 generations. UVI Spring 2012 Student Research Symposium. 10:18.

Emanuel, K., and T.W. Zimmerman. 2012. Comparison of parents with F1 and F2 generations of sorrel (*Hibuscus sabdariffa*). UVI Spring 2012 Student Research Symposium. 10:15.

Matthew, K.D., T.W. Zimmerman. 2012. Calcareous soil and photoperiod influence on Caribbean and African sorrel. UVI Spring 2012 Student Research Symposium. 10:26.

Ible, J.C., and T.W. Zimmerman. 2012. Determination of desirable traits in F1 generation of sorrel. UVI Spring 2012 Student Research Symposium. 10:23.

Montilla, C., and T.W. Zimmerman. 2012. Floral induction of greenhouse grown pineapple (*Ananas comosus*). UVI Research Day 2012 Proceedings. 1:51.

Morgan, M., T. Pascal and T.W. Zimmerman. 2012. Drought tolerance in 3 native tree species. UVI Research Day 2012 Proceedings. 1:42-43.

Zimmerman, T.W., C. Montilla and M. Morgan. 2012. Hurricane wind tolerant papaya lines. UVI

Research Day 2012 Proceedings. 1:51-52.
Cuffy, K., M. Morgan and T.W. Zimmerman. 2013. Evaluation of drought tolerance in 3 native tree species. UVI Research Day 2013 Proceedings. 2:4.
Cuffy, K., T.W. Zimmerman and M. Morgan. 2013. Evaluation of drought tolerance in three native tree species with landscape potential, a biometric approach. UVI Spring 2013 Student Research Symposium. 11:9.
Crossman, S.M.A., T.W. Zimmerman, E. Chichester, K. Boateng, C. Robles and M. Wilson. 2013. Enhancement of competitiveness and sustainability of beginning VI farmers using a value-chain agribusiness delivery system. UVI Research Day 2013 Proceedings. 2:3.
Emanuel, K., K. Matthew and T.W. Zimmerman. 2013. Evaluation of first and third generation sorrel for plant vigor. UVI Spring 2013 Student Research Symposium. 11:11.
Montilla, C., S.M.A. Crossman and T.W. Zimmerman. 2013. Production potential of Pitaya in the Virgin Islands. UVI Research Day 2013 Proceedings. 2:6.
Morgan, M., K. Cuffy and T.W. Zimmerman. 2013. Evaluation of drought tolerance via soil-water relations and biometrics. UVI Research Day 2013 Proceedings. 2:7.
Pascal, T, C Montilla and T.W. Zimmerman. 2013. Influence of sex on plant height and production. 2013. UVI Research Day 2013 Proceedings. 2:8.
Pascal, T., T.W. Zimmerman and C. Montilla. 2013. Papaya: The influence of sex on plant height and production. UVI Spring 2013 Student Research Symposium. 11:30.
Zimmerman, T.W., S.M.A. Crossman and C. Montilla. Influence of harvest date on sweet potato weevil damage. UVI Research Day 2013 Proceedings. 2:8.
Bernier, J., C. Montilla and T.W. Zimmerman. 2014. Influence of papaya seed age on viability. UVI Spring 2014 Student Research Symposium. 12:15.
Cuffy, K., and T.W. Zimmerman. 2014. Sorrel hybrids: Fruit size evaluation. UVI Spring 2014 Student Research Symposium. 12:16.
Dennery, S.A., and T.W. Zimmerman. 2014. Influence of extended refrigeration on pea seed viability. UVI Spring 2014 Student Research Symposium. 12:30.
Emanuel, K., and T.W. Zimmerman. 2014. Initiation of somatic embryoids in five varieties of sorrel (*Hibiscus sabdariffa*). UVI Spring 2014 Student Research Symposium. 12:17.
Pascal, T., and T.W. Zimmerman. 2014. Evaluating papaya fruit quality. UVI Spring 2014 Student Research Symposium. 12:36.
Dennery, S.A., and T.W. Zimmerman. 2015. Using sorrel floral bud and calyx development to predict harvest date. UVI Research Day Proceedings. 4:7.
Emanuel, K., and T.W. Zimmerman. 2015. Inducing Irish potato microtubers in tissue culture. UVI Research Day Proceedings. 4:8.
Montilla, C., H. Harris, R. Smart, J. Gordon and T.W. Zimmerman. 2015. Influence of postharvest storage on sweet potato sugar content. UVI Research Day Proceedings. 4:11.
Morgan, M., and T.W. Zimmerman. 2015. Dog almond (*Adira inermis*,(W. Wright) D.C.) a native Caribbean tree species with landscape potential. UVI Research Day Proceedings. 4:11.
Pascal, T., C. Montilla and T.W. Zimmerman. 2015. Influence of seed pre-treatments on *Bursera simaruba* germination. UVI Research Day. 4:12.

HORTICULTURE & AQUACULTURE

Journal Articles

Nandwani, D. 2012. Growth and yield response of hot pepper cultivars in the U.S. Virgin Islands. Agricultural Science Research Journal 2 (12): 653-657.
Nandwani, D. 2013. Growth and yield response of four tomato cultivars in the U.S. Virgin Islands. J. of Agriculture of the University of Puerto Rico 97 (3-4):181-184
Nandwani, D. 2013. Influence of herbicides on yield of okra (*Abelmoschus esculentus* (L). Moench) in the U.S. Virgin Islands. BRJASR. 2(10): 191-194.
Nandwani, D., S. Dennery and S. Balkaran. 2014. Effect of 4-CPA on fruit set and yield of beefsteak tomato (*Solanum lycopersicum* L.) on the island of St. Croix. Acta Hort. (ISHS) 1042: 255-259.
Ferrarezi, R.S., G.M. Weaver, M.W. Van Iersel and R. Testezlaf. 2015. Subirrigation: Historical overview, challenges, and future prospects. HortTechnology 25(3):262-276.

Book Chapter

Napoleon-Fanis, V. and D. Nandwani. 2014. Sustainable vegetable production: Caribbean perspective. In: Sustainable Horticultural Systems: Issues Technology and Innovation, D. Nandwani (Ed.) Springer, Switzerland 2: 3-17.

Conference Proceedings

Nandwani, D. 2012. Field trials of peppers (*Capsicum* spp.) on the island of St. Croix. Proc. 21st Int. Pepper Conference, Naples, FL. p. 39.

Nandwani, D., T.W. Zimmerman, V. Forbes and S.M.A. Crossman. 2012. Growth and yield response of four tomato cultivars in the U.S. Virgin Islands. HortSci 47(9) S60.

Nandwani, D., and V. Forbes. 2012. Growth and yield response of eight hot pepper varieties in the U.S. Virgin Islands. HortSci 47(9) S303.

Nandwani, D. 2013. Growth and yield response of sweet pepper cultivars in the U.S. Virgin Islands. Proc. Caribbean Food Crops Society. 49: 231-236.

Bailey, D., and D. Nandwani. 2013. Production of cucumber (*Cucumis sativus*) in the UVI aquaponic system. Proc. Caribbean Food Crops Society 50: 134-137.

Nandwani, D., S. Dennery, V. Forbes, and T. Geiger. 2014. Evaluation of four tomato varieties for commercial organic production in the U.S. Virgin Islands. Proc. Caribbean Food Crops Society 50:16.

Napoleon-Fanis, V., and D. Nandwani. 2014. The effects of preemergence herbicides on the growth, yield and quality of transplanted watermelon. Proc. Caribbean Food Crops Society 50: 467-475.

Abstracts

Nandwani, D. 2012. Field trials of peppers (*Capsicum* spp.) on the island of St. Croix. Proc. 21st Int. Pepper Conference, Naples, FL. p. 39.

Nandwani, D., and S. Dennery. 2013. Effect of 4-CPA on fruit set and yield of heat tolerant tomato cultivars. HortSci 48 (9): S16-17.

Nandwani, D. 2013. Weed control in okra (*Abelmoschus esculentus* (L). Moench) in the U.S. Virgin Islands. HortSci 49(9): S272-273.

Nandwani, D. 2013. Effect of preemergence herbicide on weed control in eggplant (*Solanum melongena* L.). HortSci 48(9): S65.

Nandwani, D., S. Dennery, V. Forbes and T. Geiger. 2014. Yield of tomato cultivars grown in the organic management in the U.S. Virgin Islands. HortSci 49 (9): S279-280.

Ferrarezi, R.S., S.K. Dove, M.W. Van Iersel and R.M.L Silva. 2015. Low-cost open-source microcontrollers to build automated irrigation and fertigation systems using soil moisture and electrical conductivity sensors. American Society of Horticultural Sciences Annual Conference, New Orleans, LA.

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FACULTY AND STAFF

Administration

Robert W. Godfrey, Director
Thomas W. Zimmerman, Assistant Director
Fiola Alexander, Administrative Specialist I
Jacqueline Romer, Administrative Specialist I
Angel Gonzalez, Trades Leader

Faculty

Robert W. Godfrey, Professor - Animal Science
Thomas W. Zimmerman, Associate Professor - Biotechnology & Agroforestry
Rhuanito Ferrarezi, Assistant Professor - Horticulture & Aquaculture
Stuart A. Weiss, Assistant Professor - Agronomy

Professional Staff

Michael J. Morgan, Research Specialist - Agroforestry
Donald Bailey, Research Specialist - Aquaculture
Kenneth Beamer, Research Analyst - Agronomy
Sue A. Lakos, Research Analyst - Animal Science
Henry C. Nelthropp, Research Analyst - Animal Science
Carlos Mantilla, Research Analyst - Biotechnology
Thomas Geiger, Research Analyst - Horticulture

Field Staff

William Gonzales, Research Assistant - Animal Science
Donna Gonzales, Research Assistant - Aquaculture
Henry Harris, Research Assistant - Biotechnology
Paulino Perez, Research Assistant - Horticulture
Nelson Benitez, Agriculture Aide - Agronomy
Jose Herrera, Agriculture Aide - Agronomy
Royson Joseph, Agriculture Aide - Animal Science
Jose Torres, Agriculture Aide - Animal Science
Ismael Montes, Agriculture Aide - Animal Science
Luis Carina, Agriculture Aide - Aquaculture
Raheem Smart, Agriculture Aide - Biotechnology
James Gordon, Agriculture Aide - Biotechnology
Victor Almodovar, Agriculture Aide – Horticulture

Current Student Interns

Seti Balkaran, Horticulture & Aquaculture
Jomanni Bernier, Horticulture & Aquaculture
Kalunda Cuffy, Horticulture & Aquaculture
Imani Dailey, Biotechnology &Agroforestry
Shamali Dennery, Biotechnology &Agroforestry
Kenya Emanuel, Biotechnology &Agroforestry
Shamal James, Biotechnology &Agroforestry
Shawn Olson, Horticulture & Aquaculture
Tyrone Pascal, Biotechnology &Agroforestry
Amran Nero, Animal Science
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Argicultural Experiment Station
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