V. I. P. -

Virgin Islands Perspective - Agricultural Research Notes

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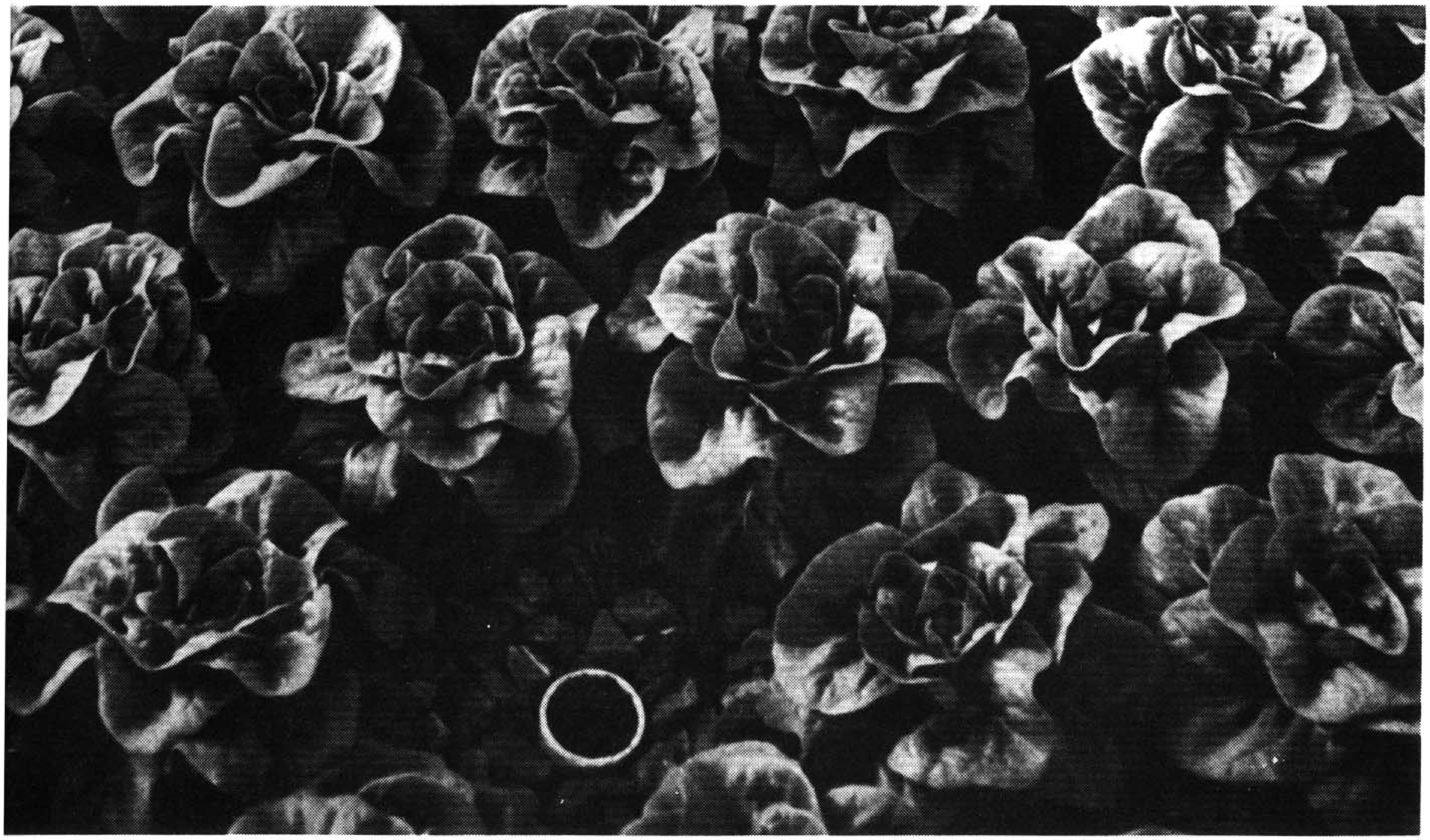

AGRICULTURAL EXPERIMENT STATION · UNIVERSITY OF THE VIRGIN ISLANDS

Arthur A. Richards
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AGRICULTURAL RESEARCH FOR A BETTER TOMORROW

Hatch Act Centennial
1887-1987

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Cover Photo: Hydroponically grown lettuce in a recirculating system integrated with fish culture.

From the Director . . .

We are pleased to share with you the second issue of the *V.I. Perspective,* the Agricultural Experiment Station's semi-annual research report to farm constituents, colleagues and the public at large.

A perusal of the topics covered in this issue attest to our dual role of serving both the producers and consumers. Research reports on white hair sheep, pasture legumes, fish culture and vegetable varietal testing offer information for the food producer, whereas the report on ciguatera poisoning addresses a public health concern of fish consumers.

The Virgin Islands are passing through challenging times. The pressure for development is so great that it threatens to damage the fragile ecosystems and encourage social inequality. Agriculture can no longer enjoy a protective shield, but, instead, must operate as a competitive economic enterprise. To pass this test today, agriculture must function as a business enterprise that is technology-based.

At the same time, the justifiably strong public sentiment in favor of the small farmer and part-time producer cannot be ignored. Many of these small farmers may not be able to participate in strictly "business-like economic development," and, yet, they represent an important way of life which needs to be preserved.

These divergent needs of our community add to the complexities of agricultural development in the U.S. Virgin Islands. They offer a special challenge to agricultural scientists and community leaders to promote, initiate and develop systems that are based on social, economic and technological considerations.

Technical information developed at the Agricultural Experiment Station and made available to the Virgin Islands public through this, as well as other publications, will hopefully contribute towards balanced territorial growth, promoting food production and, at the same time, conserving and enhancing our limited natural resources.

Darshan S. Padda
Vice President
Research and Land-Grant Programs

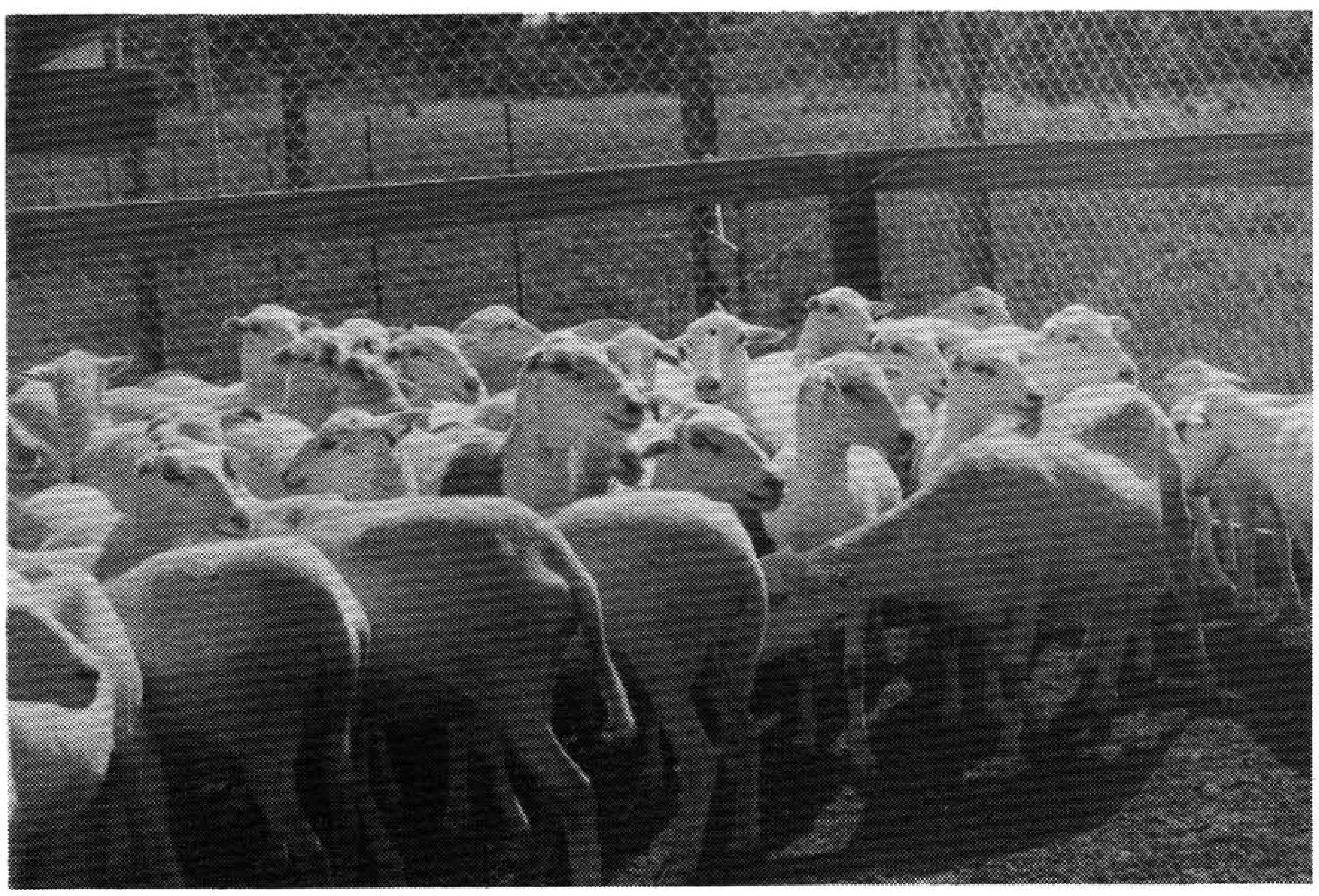
Growth and Reproductive Characteristics in a Flock of V.I. White (St. Croix) Hair Sheep

By S. Wildeus
Research Animal Scientist

The Virgin Islands White or St. Croix sheep are a breed of hair sheep that was developed on St. Croix over the past century. The animals are white in color, hornless, and show a body conformation similar to those of other hair sheep in the Caribbean. Most of these Caribbean breeds are of West African origin; however, it has been speculated that the V.I. White sheep were crossed with the British Wiltshire Horn during some developmental phase of the breed.

Information that is available on the breed under local St. Croix conditions suggests average mature weights of rams and ewes to be 119 and 75 lbs., respectively. Lambing rate estimates range from 1.44 to 1.84 lambs per ewe, with considerable variation between flocks. In order to expand the information on the V.I. White sheep, a research flock has been established at the University of the Virgin Islands Agricultural Experiment Station. The following results represent data collected on this flock during its first year of production.

The experimental flock is being housed on approximately 25 acres, divided into 12 pastures to control grazing pressure and internal parasites. The predominant forage species is guinea grass *(Panicum maximum),* and animals are stocked at a rate of 2.5 ewes with lambs per acre. As a routine management procedure, animals are confined overnight to control predation and larceny. During the duration of the



V.I. White Hair Ewes.

Funding Source: Hatch Project #787

study, the flock was exposed to continuous mating. At lambing, birth weights and litter size are recorded. All lambs are weaned and weighed at 9 weeks of age. The entire flock is routinely weighed on a weekly basis.

The body weight of mature ewes averaged 105.5 lbs., but weights fluctuated throughout the year (Figure 1). Body weights generally increased throughout the first year of observation, but showed a slight seasonal increase in June/July and January/February. The January/February peak in body weight was associated with increased seasonal rainfall and pasture growth, while the reason for the June/July peak is not readily apparent. Only one mature ram is presently maintained with the research flock, with a body weight of 140 lbs. The average weight of three yearling rams approximates 100 lbs.

Some indicators of the reproductive performance of V.I. White ewes are summarized in Table 1. Ewes that lambed twice during the first year of production had an average lambing interval of 7.5 months. This would suggest that V.I. White ewes, with limited exposure to photoperiodic variation, are capable of producing three lamb crops in a two year period. Lambing was not distributed evenly throughout the year, but increased in frequency during June and December

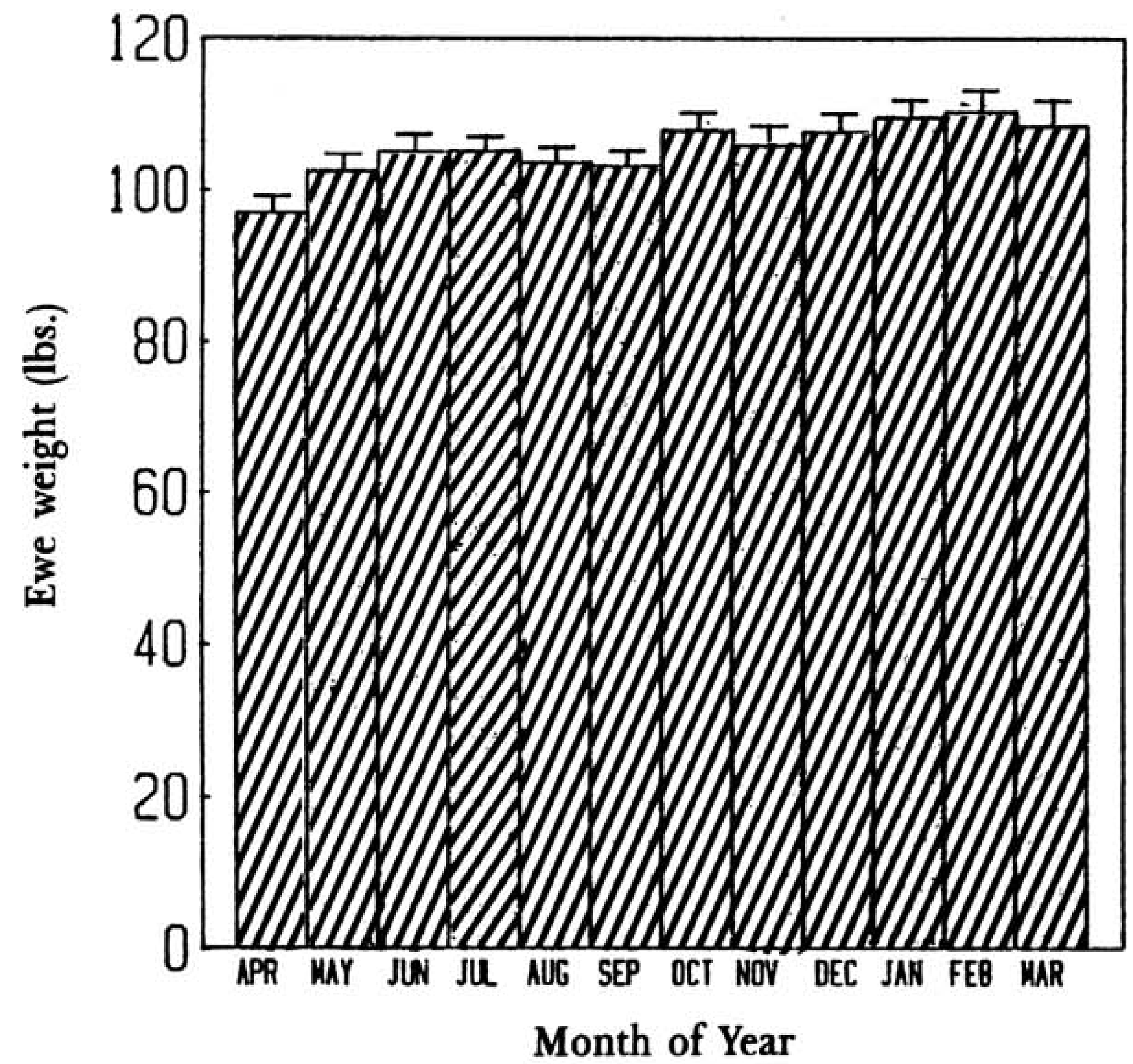


Figure 1. Fluctuations in body weight in mature V.I. White Hair ewes throughout the year.

Table 1. Lambing performance of mature V.I. White Hair ewes.

Lambing interval	7.5 months
Lambing rate	1.72 lambs/ewe
Weaning rate	1.46 lambs/ewe
Production at lambing	11.0 lbs./ewe
Production at weaning	42.9 lbs./ewe
Frequency of types of births:	
single	38%
twins	52%
triplets	10%

(Figure 2). It is not clear at this point if these lambing peaks are the result of seasonal synchronization.

At lambing, V.I. White ewes produced an average of 1.72 lambs and weaned 1.46 lambs at 9 weeks of age (Table 1). Lamb loss between lambing and weaning was associated mostly with triplet births, but also with predation and abnormal udder formation. The total amount of lamb produced per ewe lambing was 11.0 lbs. at lambing and 42.3 lbs. at weaning. The incidence of single, twin and triplet birth was distributed among the flock at 38, 52 and 10%, respectively. This frequency of multiple birth is higher than that of most breeds of wool sheep, however, not as high as that reported for the Barbados Blackbelly.

Birth and weaning weights for V.I. White lambs are summarized in Table. 2. Single lambs were significantly heavier than twin lambs at both lambing and weaning. Twins weighed 77 and 74% of single lambs at lambing and weaning, respectively. Differences were also found between male and female lambs at both lambing and weaning. Ewe lambs on average achieved weights that were approximately 86% that of ram lambs. These observations indicate that adjustment factors for type of birth (single, twin or triplet) and sex of lamb (male or female) will have to be developed for this breed in order to compare the performance of individual ewes. More lambing data will have to be collected to calculate valid adjustment factors.

Post-weaning growth patterns, following weaning at 9 weeks of age, were similar between male and female lambs (Figure 3a). The rate of gain for both sexes was 0.25 lbs./head/day. Post-weaning growth patterns varied in single, compared to twin lambs (Figure 3b), with twin lambs show-

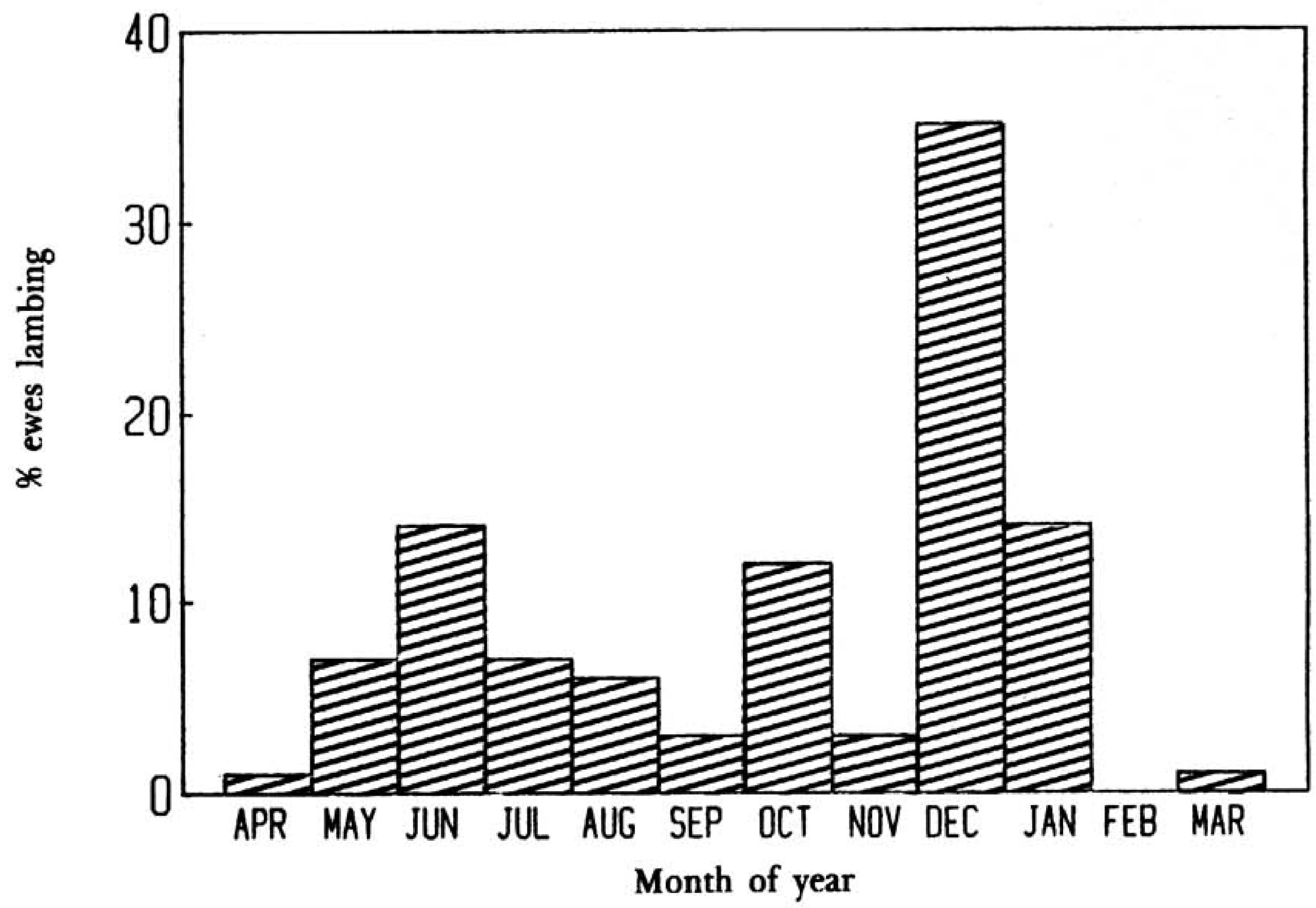
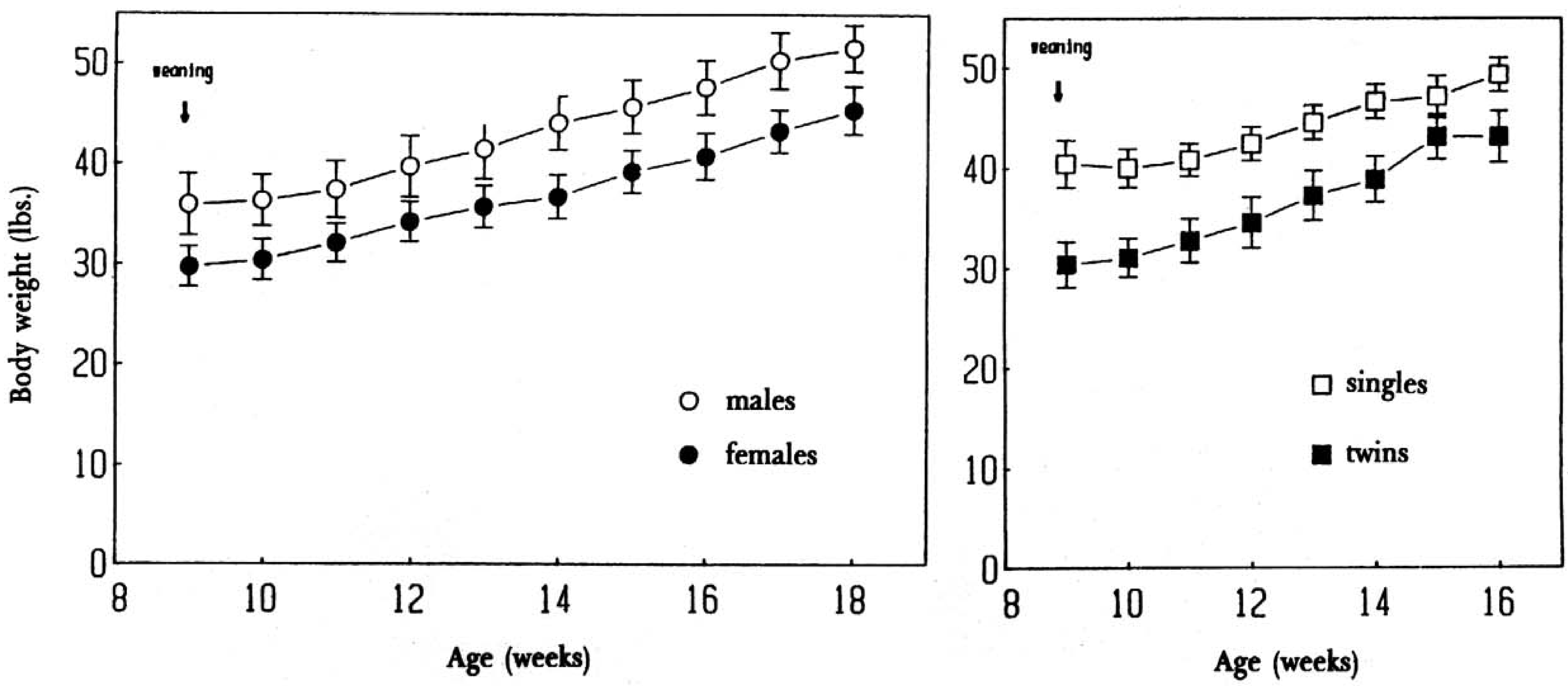


Figure 2. Annual distribution of lambing in V.I. White Hair ewes under a continuous mating regime.

Table 2. Birth and weaning (9-week) weights of V.I. White Hair lambs.

	Single birth		Twin birth	
	male	female	male	female
Birth weights (lbs.)	8.6	7.6	6.8	5.6
Weaning weights (lbs.)	44.5	37.3	31.7	28.7

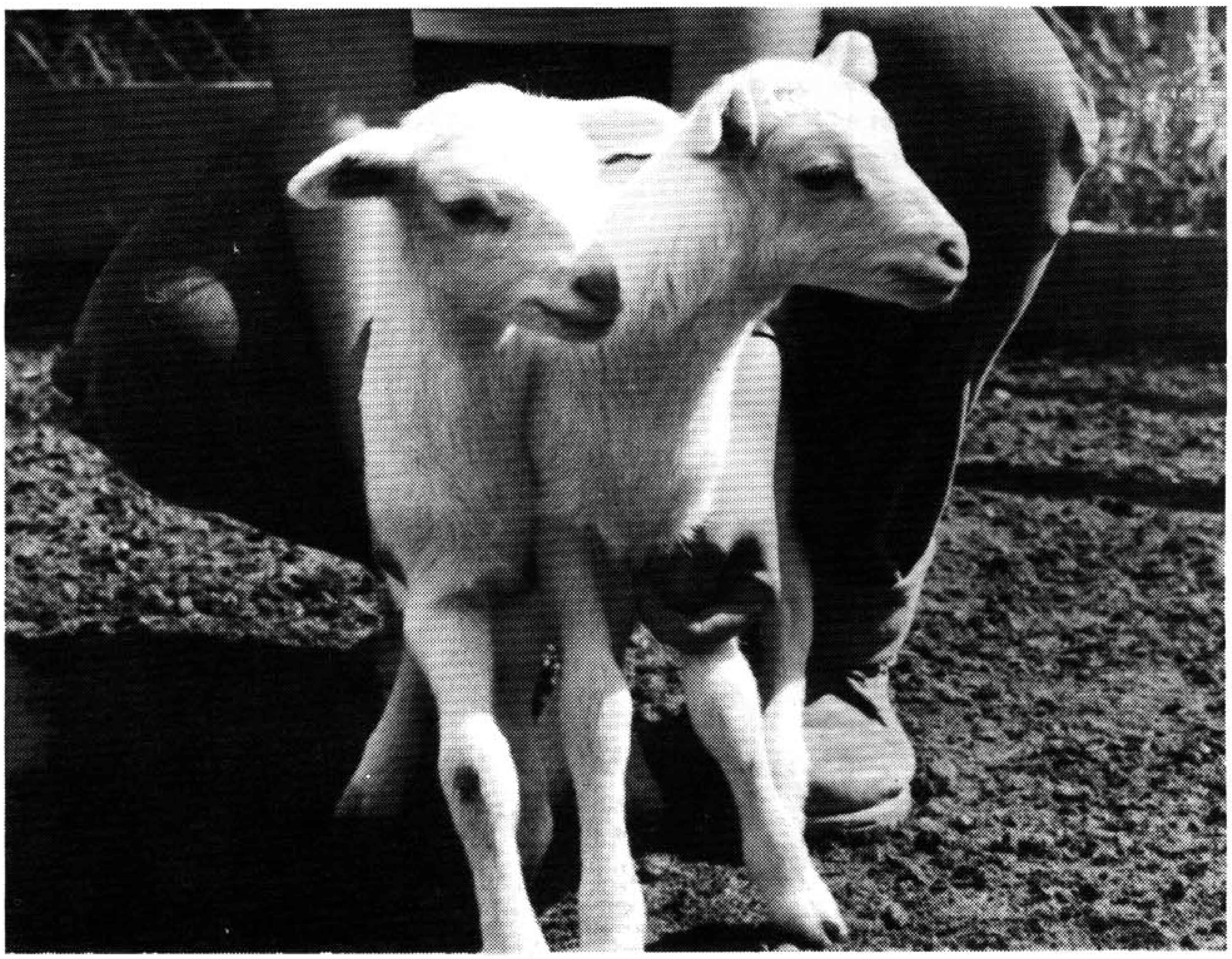


Figures 3A and B. Post-weaning growth in male vs. female and single vs. twin V.I. White Hair lambs.

ing a more rapid, compensatory post-weaning growth. Single and twin lambs achieved an average daily gain of 0.18 and 0.26 lbs./head/day, respectively, during a seven week post-weaning period. All lambs exhibited satisfactory growth after early weaning at 9 weeks of age, which would indicate that weaning at this stage may be a feasible management tool under local production conditions.

Though the results presented here reflect only data that have been collected over a period of one year, the information gives an indication of the production potential of the V.I. White sheep. The breed has a high level prolificacy and good mothering ability, with 85% of the lamb crop being weaned. The growth rate and mature size is lower than that of most wooled breeds of sheep, but similar or higher than in other breeds of hair sheep. A continued effort is being made to further characterize this breed.

The author would like to acknowledge the assistance of Ms. Kim Traugott and Mr. Allan Schuster in the collection of the data.



V.I. White Hair Twin Lambs.

Naturally-Occurring Legumes in the Pastures of St. Croix

Michael W. Michaud
Research Agronomist

P. Joy Michaud
Extension Specialist

St. Croix has large areas of both native and improved pastures that are utilized for livestock production. Naturally-occurring legumes are an important component of these pastures, affecting the quantity and quality of feed available to the animals. These indigenous legumes include herbaceous species as well as woody shrubs and trees.

Though some areas have been planted with improved forage species, unimproved pastures make the most important contribution to the livestock industry. With proper management, guinea grass *(Panicum maximum)* tends to be the most prevalent species, while hurricane grass *(Bothriochloa pertusa)* predominates on overgrazed sites. Despite the dominance of grasses in these pastures, herbaceous legumes and smaller browse species are generally present.

The extent to which these types of legumes contribute to pasture composition was quantified by surveys using a step-point method. Points were selected approximately three meters apart (five steps) along transect lines that were evenly distributed throughout each pasture being surveyed. At each point, a rod was pushed into the ground using the tip of the foot as a guide (Figure 1). Those plants that the rod touched at ground level were identified by species and recorded accordingly. If the rod touched bare ground, the closest plant within a forward 180° arc was recorded.

Results of the surveys are presented in Table 1. The two most commonly occurring legumes were *Desmanthus virgatus*, a small browse shrub, and *Teramnus labialis*, an herbaceous vine. These legumes were present in 83% and 77% of the pastures, respectively. In those pastures in which it was present, *Desmanthus* was found at 1.0% to 11.0% of the points, while *Teramnus* occurred at 0.5% to 10.9% of the points

Other herbaceous legumes found in the native pastures included *Rhyncosia minima*, *Desmodium* sp., *Stylosanthes hamata*, and *Alysicarpus vaginalis*. *Alysicarpus* and *Desmodium* were generally found in the wetter parts of the island, while *Stylosanthes* was found in areas dominated by shorter growing grasses rather than the taller guinea grass.

Figure 1. Step-point method for determining species composition in pastures.

Funding Source: Hatch Project #784

Table 1. The occurrence of indigenous legumes in the native pastures of St. Croix.

Species	Percent of pastures in which species is present
Desmanthus virgatus	83
Teramnus labialis	77
Rhyncosia minima } *Desmodium sp*	30
Stylosanthes hamata	17
Alysicarpus vaginalis	10

The extent to which legumes are found in pastures is strongly influenced by grazing management. Surveys were performed on two pastures subjected to different grazing pressures (Table 2). At the time the surveys were done, Pasture 1 had a stocking rate of 5.5 sheep and goats per hectare, reflecting the lenient grazing regime to which it had historically been subjected. While the dominant species was *Panicum maximum,* which normally occurs in well-managed pastures, legumes occurred at more than one quarter of the points. In contrast, Pasture 2 had been subjected to long-term overstocking and had 15.2 animals per hectare at the time of survey. Its dominant species was hurricane grass, while legumes occurred at only 3.5% of the points. Allowing for differences in species composition that would normally

Table 2. Species composition between two native sheep and goat pastures in St. Croix, USVI.

	Pasture 1	Pasture 2
Stocking Rate (animals/ha)	5.5	15.2
Grasses:		
Panicum maximum	67.5%	—
Bothriochloa pertusa	2.0%	87.3%
Legumes:		
Leucaena leucocephala	14.5%	1.5%
Teramnus labialis	7.5%	1.0%
Desmanthus virgatus	4.0%	1.0%
Others	0.5%	—
Weeds:	4.0%	9.2%

occur between sites with varying soils and rainfall, it can be concluded that stocking rates (animals per unit area of land) affect the legume composition in native pastures.

In addition to the herbaceous and smaller shrub legumes, larger shrubs and trees make an important contribution to pasture composition. One of the most important of these species is *Leucaena leucocephala,* known locally as tan-tan. It was found in two-thirds of the pastures surveyed. When ungrazed or uncut for long periods of time, it can grow to 9 meters in height. It is, however, particularly palatable to all classes of ruminant livestock, and its growth is limited to 2 meters or less when grazing is imposed. In addition, pastures are occasionally cut back with a shredder, which further checks the growth of *Leucaena.*

The pasture surveys quantified the presence of *Leucaena* in either one of two ways. In those pastures where it was short-statured or below the grass canopy, it was included in the step-point method used to study the other forage species. This technique was used to characterize *Leucaena* in the pastures described in Table 2. With a lenient grazing regime, it comprised 14.5% of the points. However, increasing the stocking rate decreased its presence to only 1.5%, thus demonstrating its sensitivity to management.

In the pastures where *Leucaena* growth was above the grass canopy, actual populations were determined by counting those plants whose main stalk fell within 0.5 meters of either side of the transect line used with the step-point method. This was the more frequently employed technique, and populations were found to range between 100 and 12,000 plants per hectare.

Acacia, locally known as casha, another large woody legume, was found in almost 90% of the pastures. In the dry areas, the most common species is *A. tortuosa,* while *A. macrancantha* tends to be more common in wetter areas. Populations averaged 658 plants per hectare and reached over 5,000 plants per hectare in one pasture (Table 3).

Unlike *Leucaena, Acacia* is an undesirable species. Although goats occasionally use it for browse, cattle do not consume it. Its large thorns (Figure 2) and habit of branching from the base make the pasture underneath them inaccessible to livestock (Figure 3). Diameters of the *Acacia* canopies were measured, and it was found that up to 30% of the land was covered (Table 3). Unless *Acacia* is controlled, the amount of pasture available to animals can be significantly reduced.

Table 3. The presence of *Acacia* sp. in the native pastures in St. Croix, USVI.

Frequency of Occurrence (%)		90
Number of shrubs/hectare:	Mean	658
	Range	0 to 5755
% land covered by shrubs:	Mean	5
	Range	0 to 26

Figure 2. Branch of *Acacia* showing thorns.

Figure 3. *Acacia* can make large portions of the pasture inaccessable to grazing livestock.

Though the native pastures make the largest contribution to animal production on St. Croix, small areas have been planted with improved grasses. Indigenous legumes are found in these pastures to varying degrees, sometimes making significant contributions to their composition. One such example is a buffel grass *(Cenchrus ciliaris)* pasture surveyed by the step-point method (Table 4). Legumes comprised almost 40% of the points, with *Desmanthus* and *Teramnus* the most prevalent species.

While grasses form the basis of pastures on St. Croix, legumes are an important component. Desirable herbaceous and woody species are often present in significant amounts and contribute much to animal production. Well-managed pastures require that *Acacia* species be controlled, since their presence means a reduction in feed available to the livestock utilizing them. When proper stocking rates are used, a species composition favoring the presence of legumes will be established, resulting in pastures of long-term productivity.

Thanks must be given to the many farmers who have allowed us on their land to conduct the surveys. However, special acknowledgement is given to Allan and Henry Schuster for their ideas on pasture management and permission to collect data on their farm.

Table 4. Forage species found in a pasture planted with "Common" buffel grass (*Cenchrus ciliaris),* St. Croix, USVI

Species	%
Cenchrus ciliaris	32.8
Panicum maximum (local)	9.0
Bothrichloa pertusa	3.0
Desmanthus virgatus	18.9
Teramnus labialis	12.4
Clitoria ternatea	3.0
Rhyncosia minima	2.5
Stylosanthes hamata	2.5
Other	15.9

Ciguatera Fish Poisoning in the Eastern Caribbean

By J.P. McMillan
Associate Professor of Biology

Seafood poisonings occur world-wide, but the highest incidence and greatest variety are found in tropical waters. The seriousness of this public health and economic problem is aggravated by the fact that most animals implicated in poisonings dwell in shallow water and are thus the most accessible marine food resource. Additionally, there is an environmental feature to the problem because a disturbance of the coral reef ecosystem by human activities often results in the proliferation of toxic organisms.

Among the many kinds of seafood poisonings, ciguatera is the most widespread and serious problem. It has for centuries afflicted people, particularly islanders, living by tropical seas around the world. Ciguatera poisoning results from the consumption of fish which contain ciguatoxin (CTX), a neurotoxin produced by reef-associated microorganisms called dinoflagellates. When the dinoflagellates are consumed, the CTX enters the food chain where it accumulates at each link, becoming most concentrated in predatory fish, those which commonly poison humans. Although rarely fatal, a ciguatera intoxication is usually debilitating, with gastrointestinal manifestations initially and complex neurological symptoms following for days, weeks, months, and even years.

The symptoms of ciguatera usually occur within two to twelve hours after eating ciguatoxic fish. The gastrointestinal symptoms are similar to food poisoning: abdominal pain, nausea, vomiting and diarrhea. However, because CTX is a neurotoxin, it can be distinguished from spoilage poisoning by the symptoms affecting the nervous system. These may include itching or tingling of the lips, tongue, mouth, skin, palms and soles; aching and weakness in muscles and joints; and the sensation that hot is cold and cold is hot. There is no test for ciguatera and its diagnosis is made on the history of the fish ingestion and the symptoms manifested. The symptoms may recur after the initial intoxication, becoming less frequent and less pronounced over time. The severity of the intoxication depends upon the toxicity of the fish, the amount consumed, and the body size and health of the victim. No specific, effective treatment is available.

There are probably hundreds of cases annually in the Eastern Caribbean. The varieties of fish most frequently implicated — snappers, grouper, kingfish, jacks — are those most widely esteemed, highly abundant, and, therefore, most sought. And despite local folklore, toxic fish cannot be discriminated from nontoxic ones on the basis of appearance, smell, taste or texture. No simple, reliable and inexpensive test is yet available. In the opinion of experts from local, regional and international agencies, ciguatera is the greatest single impediment to the development of the inshore fishery because of its significance as a public health problem.

From the foregoing, the urgency for research is apparent and certain objectives are imperative. A test to determine the ciguatoxicity of fish is clearly needed, as is a rational therapy for the treatment of ciguatera intoxication. For many reasons, however, progress toward these objectives has been steady but slow. The problem occurs circumtropically, affecting island populations primarily, far from the mainstream of global society and technology. Another impediment is that CTX, while an extremely potent toxin, is present even in very toxic fish, on the order of parts per billion. This causes a supply problem for research and makes CTX difficult to detect chemically in fish because there is so little there for analysis. In fact, the molecular structure of CTX has yet to be completely elucidated, although it is known to be a heat stable polar lipid with a molecular weight of about 1,112.

Our research activities are designed to take advantage of our location in the tropics where ciguatera occurs, and to extend our capabilities through collaboration with scientists

Funding Source: Hatch Project #786

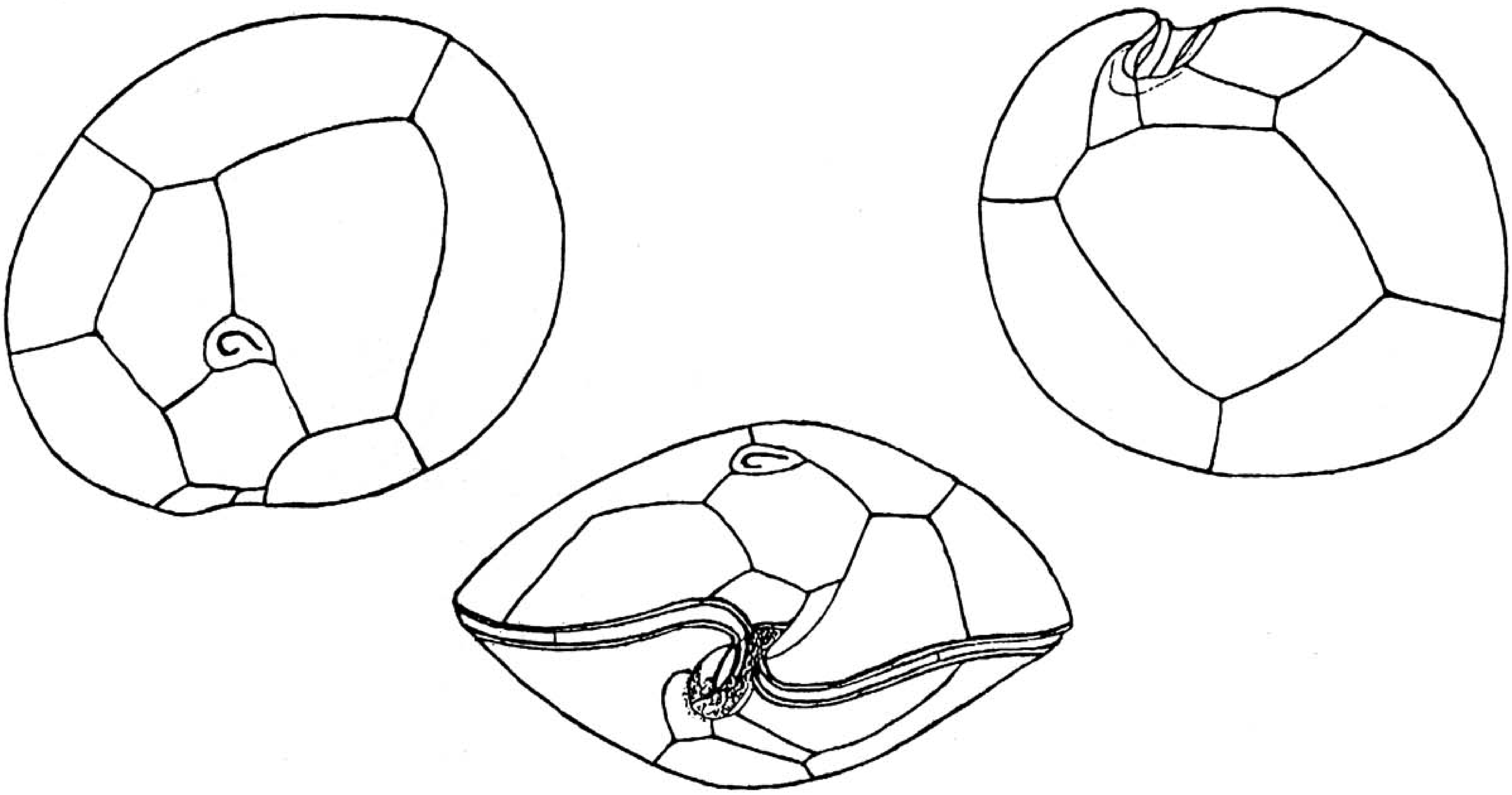


Figure 1. A line drawing taken from scanning electron micrographs of *Gambierdiscus toxicus,* the Dinoflagellate recently implicated in the biogenesis of ciguatoxin (after Dr. F.J.R. Taylor, University of British Columbia).

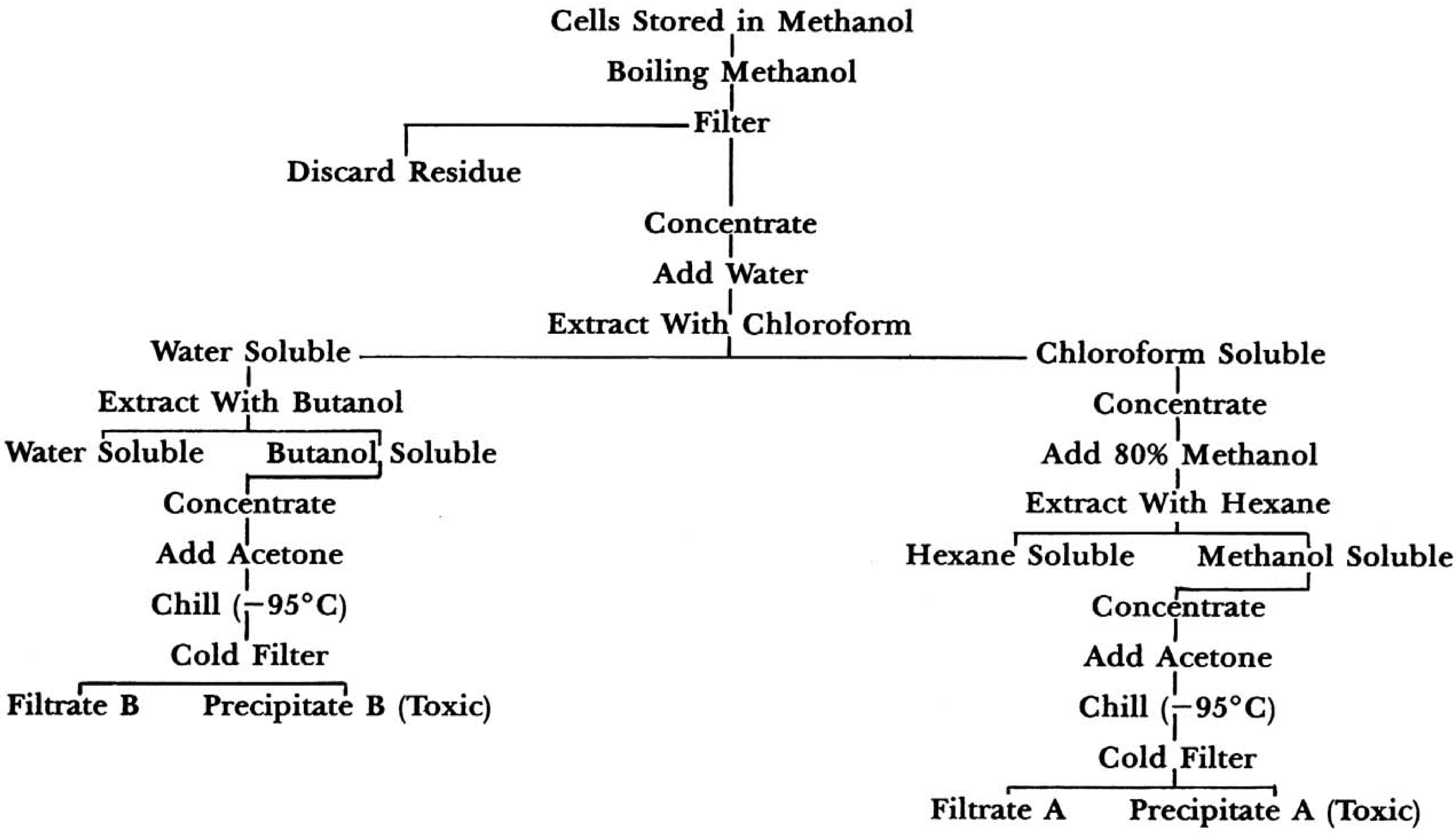


Figure 2. Extraction and preliminary purification procedure for lipid-soluble (PPT-A) and water-soluble (PPT-B) toxins from *Gambierdiscus toxicus.*

and technological resources at other institutions. Studies on the mode of action and structure of CTX require a supply of the toxin. We obtain fish samples locally that have caused ciguatera or are suspected of harboring CTX because of their species, size and catch location. From these, we extract, purify and bioassay CTX for our own and our collaborators' research activities.

Recent experimental work involved the weekly administration to mice of sublethal doses of extracts from ciguatoxic fish flesh implicated in human ciguatera cases, or doses of nontoxic, control fish extracts. The CTX-treated mice had significantly lower body weights, lower body temperatures, and higher ciguatoxicity sign ratings than controls. The effects of each weekly dose of CTX were consistent in magnitude and duration, with no progressive increase or decrease in response over the course of the eight week study. This is in contrast to reports of sensitization by human ciguatera victims who have been affected by more than one intoxication. Histopathology revealed no selective site of toxicity in the mice. At the end of the study, CTX-treated mice succumbed to a single lethal dose of CTX. No CTX antibodies were detected in the sera of the repeatedly CTX-treated mice. Collectively, the findings in these experimental animals are consistent with absence of developed immunity to ciguatera in humans.

Research on the biological source of the toxin(s) which cause ciguatera, begun a decade ago by scientists in the South Pacific, has lead to the identification of *Gambierdiscus toxicus,* a reef-associated bottom-dwelling dinoflagellate. We have collected large samples of *G. toxicus* from the Caribbean Sea. When extracted, *G. toxicus* yields two toxic components which differ in their initial solubilities, one is lipid soluble (PPT-A) and the other water soluble (PPT-B). Both are heat stable and precipitate in cold acetone. Ciguatoxic fish extract (CTX) is water insoluble but does not precipitate in cold acetone. PPT-A, PPT-B and CTX, however, produce signs in the mouse bioassay which are virtually indistinguishable, including a pronounced lowering of body temperature. In a number of chromatographic systems, PPT-A and PPT-B show strong similarities but both differ markedly in comparison to fish CTX. The toxins of *G. toxicus* thus may undergo structural transformation when passed through the food web to ultimately become the CTX in fish that causes ciguatera poisoning in humans.

Ciguatera is more than a research problem. We attempt to deal with the public health and economic aspects of ciguatera by an advisory outreach effort to the community and region. Through newspaper articles and pamphlets, radio and TV appearances, talks to civic groups, a ciguatera "hotline," and consultations with fishermen, merchants, restaurateurs, public health and government officials, we provide the facts on ciguatera. In doing so, we seek to dispel folklore, avoid sensationalism, and offer the basis for informed choices and action.

Yield Results of Vegetable Varietal Evaluation Trials in the U.S. Virgin Islands

By Arthur C. Petersen, Jr.
Vegetable Specialist

Tomatoes, peppers and eggplants are as popular in the U.S. Virgin Islands as in any other part of the world. These three Solanaceous crops are widely used in many native dishes, and the demand for them is continuously high. Currently, about 80% are imported from neighboring Eastern Caribbean Islands and the U.S. mainland. Because of transportation costs, the price of imported vegetables have been climbing steadily. The high price for imported produce has stimulated both large and small-scale vegetable production. Vegetable production in the Virgin Islands is limited by soil, water, and climatic problems, as well as by plant diseases and insect pests. Another major factor limiting local production has been the high cost of labor. Because most vegetable seeds are purchased from temperate seed suppliers, choosing the proper variety for local conditions is fundamental to success regardless of production scale.

The climatic conditions of the Virgin Islands during the winter season are favorable to the production of bumper crops. Winter vegetable production in the Virgin Islands has great potential not only for self-sufficiency but also for the export market.

To determine which tomato, pepper or eggplant varieties are best adapted to the Virgin Islands environment, different varieties were tested annually at UVIAES. In addition to testing for yield, a variety of entries were also evaluated for heat and drought tolerance for breeding purposes. This report is

Table 1. 1986 estimated yield of pepper varieties.[1]

Variety:	Marketable yield (kg/hectare)	Percent Marketable yield (%)	Fruit size (g)
Hybrid Jupiter	51,300	95.2	112
California Wonder	45,800	93.2	91
Hybrid Acx-841715	45,400	95.5	93
Yolo Wonder	41,000	94.8	111
Early California	40,600	93.2	92
Giant Resistant #4	39,700	91.7	94
Cubanelle	38,900	96.3	51
Hybrid Hy-fry	36.400	95.7	63
Hungarian Hot Wax	36,100	97.2	34
Hybrid Glory	30,900	93.3	80
Sweet Banana	27,100	95.7	41
Hungarian Sweet Wax	25,700	90.4	80
Cayenne Large Thick	24,700	87.0	23

[1]Values are means of three replications per variety.

Funding Source: Hatch Project #684

Table 2. 1986 estimated yield of eggplant varieties[1]

Variety:	Marketable yield (kg/hectare)	Percent Marketable yield (%)	Fruit size (g)
Burpee Hybrid	102,600	88.4	425
Midnite	100,200	91.3	461
Bybird Black Jack	89,700	79.6	459
Black Jet	83,000	90.3	385
Black Beauty	80,700	68.3	668
Hybrid Epic	80,000	89.1	332
Rosita	78,300	83.4	327
Florida Market #10	76,000	89.5	444
Dusky Hybrid	75,300	87.0	316
Super Hybrid	51,007	62.8	397
Hybrid Beauty	51,007	77.7	364
Long Purple	48,900	68.3	220
Hybrid Imperial	34,300	65.5	210

[1]Values are means of three replications per variety.

a summary of the results obtained from such tests in 1986.

A series of three vegetable variety trials were conducted at VIAES between August, 1983 and August, 1986 on Fredenborg clay soil with a pH of 7.5 to 8.0. The field was ploughed, disked, and banked with 30-cm high ridges 90 cm apart and partitioned into 1.8 x 6-m plots. Each plot consisted of 39 plants arranged in three rows. Plant spacing within rows was 46 cm apart for pepper and eggplant and 61 cm apart for tomatoes. Weed control was accomplished using pre-emergence application of Round-Up™ or Dacthal™ along with mechanical cultivation and hand-hoeing. A randomized complete-block design with three replications was used.

Seeds were obtained from various sources. Transplants were started in Jiffy-Seven™ peat pellets and were maintained in a 70% shaded greenhouse for a week to provide uniform seedling establishment. Seedlings were thinned to one per peat pellet and were maintained under full sunlight until plants were six weeks old. Seedlings were watered daily and fertilized bi-weekly with 400 ppm of Peter's 20:20:20 commercial fertilizer.

The vegetable crops were irrigated using a drip irrigation system when needed to prevent moisture stress to crops. Plants received a fertilizer (amonium sulfate) application at a rate of 168 kg/hectare on the second week after transplanting and a second application at initiation of flowering. Insect pests and diseases were controlled with recommended rates of Bravo™, Lannate™, Diazion™ and Kocide™ during the course of the experiment. Marketable yields were harvested in 6 to 8 pickings for all experiments.

Yields were determined by hand harvesting mature fruits from the center row of each three-row plot at 7 to 10-day intervals, depending on the rate of fruit growth and development. Peppers were harvested when fruits were about 8 cm or greater in length. Tomatoes were harvested at the pink stage of maturity and eggplant when fully matured. All vegetables were culled and weighed in the field. Fruit harvest was discontinued when fruit quality was non-marketable.

Marketable yield and some yield attributes of pepper are summarized in Table 1. Yield in the tests ranged from 51,300 to 24,700 kg per hectare. Hybrid Jupiter, California Wonder, Hybrid Acx-841715, Yolo Wonder and Early California were the best yielders. Specialty types such as Cubanelle, Sweet Banana, Cayenne and Hungarian Yellow Wax also performed well in the trials. Blossom-end Rot and Tobacco Mosiac Virus were the major production problems of note, especially towards the end of the growing seasons; but, yields were not significantly reduced. The bell pepper varieties had a greater incidence of these diseases.

There were significant differences in yield among the eggplants (Table 2). Burpee Hybrid and Midnite, with yields of 102,600 and 100,200 kg per hectare respectively, were the most productive varieties in the trials. Hybrid Black Jack, Black Jet, Black Beauty and Hybrid Epic also performed well in the trials. The major insect pests were aphids and mites, which occurred mainly at the end of the productive period.

Yield data for tomatoes are summarized in Table 3. Hybrid Revolution, Hybrid Liberty, and Hybrid Count II were the best yielders. The major insect pests were the fruitworm *(Heliothis spp.)*, and the major disease problem was Early Blight. Some of the yield differences were probably due to differences in their tolerance to Early Blight. None of the varieties included in the trial displayed any resistance to the disease.

Results from these trials will be useful in developing the recommended list of pepper, eggplant and tomato varieties for production in the U.S. Virgin Islands.

Table 3. 1986 estimated yield of tomato varieties[1]

Variety:	Marketable yeild (kg/hectare)	Percent Marketable yield (%)	Fruit size (g)
Hybrid Revolution	57,700	91.0	179
Hybrid Liberty	52,500	89.7	166
Hybrid Count II	50,100	90.6	191
Hybrid Celebrity	48,100	93.5	194
Hybid Mountain Pride	46,600	92.6	190
Hybrid President	46,100	90.7	196
Calypso	44,600	89.2	209
Hybrid Floramerica	43,600	87.0	227
Hybrid Duke	42,800	89.1	197
Hybrid Independence	41,000	89.1	191
Hybrid Peto Pride	40,400	93.5	125
Hybrid Better Boy	29,100	86.0	180
ACE 55VF	26,100	89.0	249

[1]Values are means of three replications per variety.

Integrating Fish Culture and Vegetable Hydroponics: Problems and Prospects

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The very limited supply of fresh vegetables and fish on semiarid Caribbean islands and the heavy reliance on imported products of frequently poor quality have provided the impetus for studying the integration of fish and vegetable production in water reuse systems at UVIAES. Combining these diverse agricultural enterprises would maximize the local production of food per unit of water consumption. Additionally, fish culture wastewater would provide the majority of nutrients required by the plants while nutrient uptake by the plants would help in purifying the wastewater, which could possibly lead to higher production levels of fish.

Integrating fish culture with vegetable hydroponics creates special problems. One of these problems is the large amount of sludge that is generated from fish waste. In recirculating fish culture systems, sludge is removed by the process of sedimentation in conical or rectangular clarifiers. Although the clarifier removes most of the sludge, a certain amount of sludge remains suspended as small colloidal particles. Hydroponic systems frequently utilize fine support medium such as sand or gravel. When these media are used in integrated systems, they tend to become clogged over time with a buildup of sludge. Even the nutrient film technique faces the danger of becoming fouled with the formation of a sludge blanket. Excessive sludge buildup has a deleterious effect on plant growth because it blocks the flow of water and creates anaerobic zones.

Integrated systems require good water clarification and specially designed hydroponic tanks. Research at UVIAES has shown that reciprocating gravel biofilters with a false bottom perform well as hydroponic tanks. Reciprocating biofilters continuously flood and drain to alternately expose nitrifying bacteria to wastewater and air. This cycle is also beneficial to plant roots. The gravel will not clog with sludge if it is suspended on a sturdy wire mesh that is supported about 7.5 cm off the tank floor. It is best to use a shallow layer of gravel (20 cm) and a large grade (2.5 cm). To prevent a sludge blanket from forming on the tank floor, some fish must be placed in the hydroponic tank. Their swimming action keeps the sludge suspended and flowing through the system until it is removed by the clarifier.

There are some problems associated with the use of gravel as a hydroponic substrate. Its weight requires strong and expensive tanks. It is also very difficult to plant in coarse gravel. A better hydroponic substrate is floating sheets of styrofoam with holes for small plastic baskets to support the transplants (Figure 1). Fish are still needed to prevent sludge accumulation on the tank floor, and a screen, though less sturdy, is still needed to prevent the fish from having access to the plant roots. Some species such as tilapia will eat roots.

Another major problem with integrated systems is the buildup of dissolved nutrient salts to levels that are toxic to plants. In recirculating systems at UVIAES with a total water volume of 15 m3, an initial salt concentration of approximately 100 mg/liter reached 2,000 mg/liter after 150 kg of fish feed were consumed. These were closed systems in which daily makeup water was added at a rate of 1% of the total system volume. Tomato plants begin to exhibit signs of toxicity when the salt level exceeds 2,200 mg/liter.

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Figure 1. Hydroponically grown lettuce in a recirculating system integrated with fish culture.

Large dilutions would be required to prevent salt toxicity, but this approach could consume too much water. The rate of salt accumulation would be significantly decreased by enlarging the plant growing area so that nutrient uptake by the plants removes most of the salts. The optimum ratio between the plant growing area and the feeding rate has yet to be established.

Fish feeds do not contain adequate levels of all the nutrients required for plant growth. Iron and potassium must periodically be supplemented. During system startup, plants also benefit from the addition of phosphorous. A recent study has shown that calcium is also deficient in systems with styrofoam substrates but not in systems with gravel substrates composed of sedimentary rock (Figure 2). If plant growing areas are enlarged to decrease salt buildup, additional nutrients may have to be supplemented.

Closed fish culture systems have traditionally relied on some form of calcium carbonate such as oyster shells or

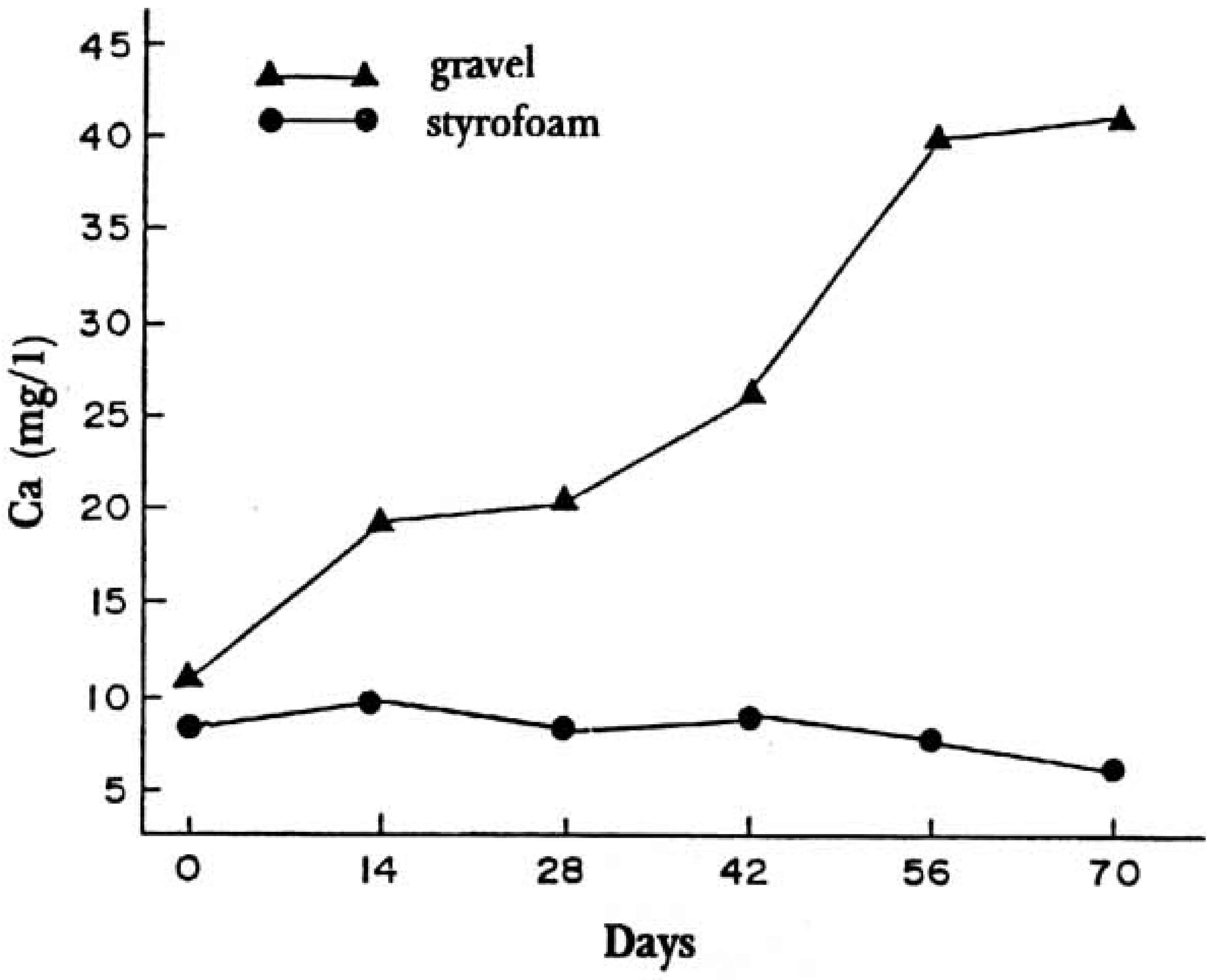

Figure 2. Calcium concentrations (mg/liter) in recirculating fish culture systems containing gravel or styrofoam substrates for vegetable hydroponics.

limestone to neutralize acid formed by ammonia removal during the process of nitrification. As carbonate ions neutralize the acid, high concentrations of calcium develop. Calcium carbonate substrates are not recommended for hydroponic systems because high calcium levels will precipitate phosphorus and make it unavailable for plant nutrition. Therefore, closed integrated systems require some other form of base to neutralize acid. Research at UVIAES has shown that potassium hydroxide is an ideal base for integrated systems because it not only neutralizes acid but also supplements potassium, which is required by plants in very high concentrations. Potassium hydroxide pellets are added once every two days as the pH approaches 6. Hydroxides of calcium and magnesium may be needed if potassium levels become too high because plants require a certain balance between potassium, calcium and magnesium ions for maximum growth.

Another problem with integrated systems is the use of pesticides to control insect and disease outbreaks on the

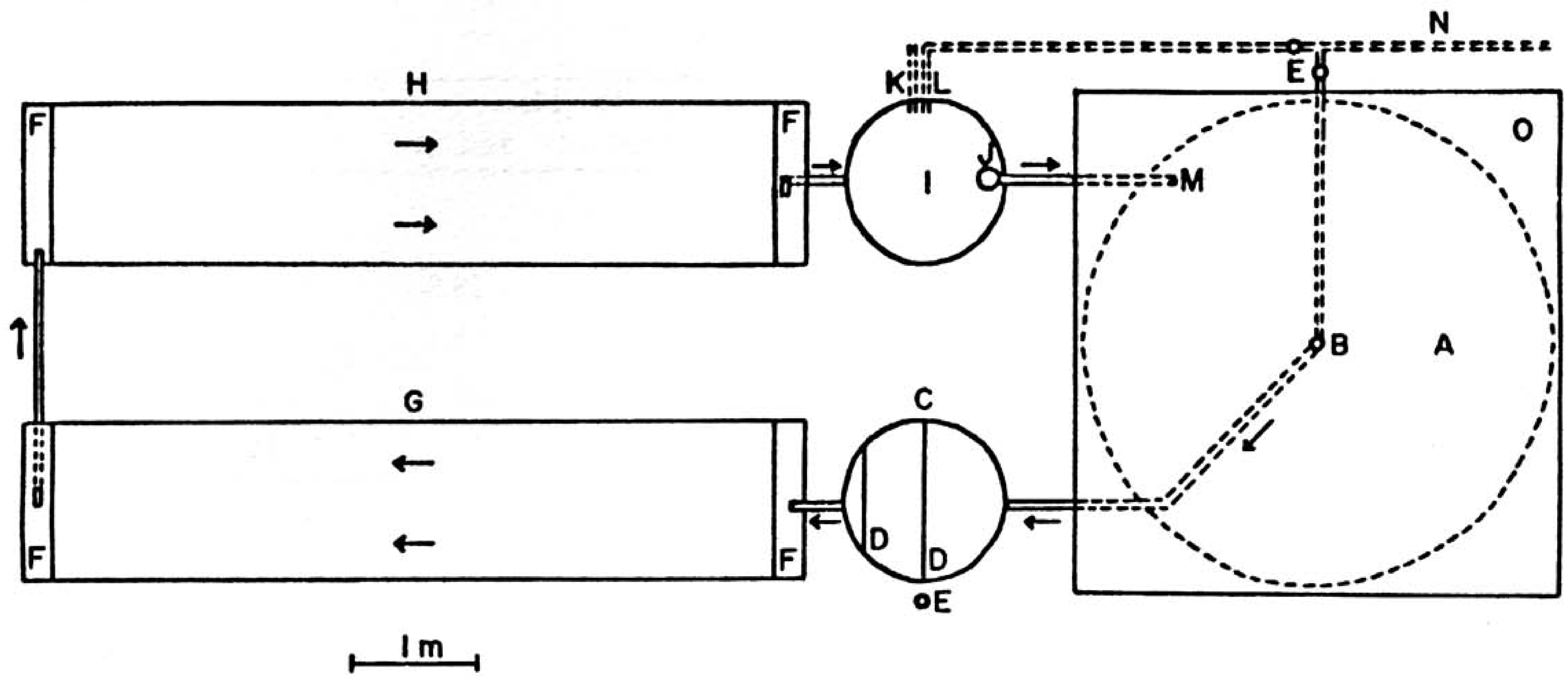

Figure 3. Plan view of a recirculating system for tilapia culture and vegetable hydroponics: A, rearing tank; B, outlet; C, clarifier; D, baffle; E, valve; F, sump; G, upper hydroponic biofilter; H, lower hydroponic biofilter; I, reservoir; J, pump; K, water inlet; L, overflow outlet; M, return inlet; N, drain line; O, canopy.

Table 1. Hydroponic production of four varieties of tomatoes in a recirculating fish culture system during a 16-week experiment.

	Cherry Challenger	Vendor	Floradade	Sunny
Fruit production*				
no/plant	163	31	79	83
kg/plant	2.9	3.7	9.	10.1
kg/m2	15.8	18	16.3	18.4
Marketable tomatoes (%)*	97	88	96	97
Survival (%)	100	81	100	100

*Does not include unripened tomatoes.

Table 2. Hydroponic production of varieties of lettuce, pac choi and Chinese cabbage in a recirculating fish culture system during a 16-week experiment.*

	Lettuce		Pac Choi		Chinese Cabbage	
	Buttercrunch	Summer Bibb	Pac Choi	Le Choi	50-Day Hybrid	Tropical Delight
Production						
no/m2/crop	24.7	24.4	18.3	18.0	18.4	18.2
kg/m2/crop	4.7	4.3	7.6	8.7	11.3	10.6
Mean size (g)+	193	180	442	508	638	589
Mean survival (%)	99	99	97	94	96	97

*Based on four crops except pac choi (3 crops).

+ Includes only edible portion of plant.

vegetables. Most pesticides are very toxic to fish. If pesticides are used, a small portion will invariably reach the culture water either through drift or leaf drip onto the hydroponic media. Integrated systems need pesticides that are relatively non-toxic to fish and break down quickly in water. One such pesticide is acephate, a systemic organophosphate. Effective biological pest management is needed for integrated systems.

In spite of the problems, integrated systems have potential for commercial production of fish and vegetables in regions where agriculture is severely limited by a shortage of freshwater. Very good results have been obtained with an experimental unit at UVIAES (Figure 3). The system is simple to operate, reliable and productive. It consists of a 12.8-m3 rearing tank, a 1.9-m3 clarifier, a 1.4-m3 reservoir and two reciprocating gravel biofilters (2.1 m3 each) that also serve as hydroponic beds. The total plant growing area is 13.8 m3. Water for the system is obtained by harvesting rainwater with a vinyl catchment.

The system has been used for the production of tilapia, tomatoes and several types of leafy green vegetables. The system is capable of producing 50,000 sex-reversed fry monthly, 8,000 fingerlings (20 g) in 3 months or 400 kg of marketable tilapia in 6 months. Water consumption per kg of tilapia production is approximately 87 liters, which is less than 1% of the water required for raceway production and only 10 to 20% of the water required for pond production. Good yields of tomatoes, lettuce, pac choi, and Chinese cabbage have been obtained in variety trials (Tables 1 and 2).

The problems that arise from integrating fish culture with vegetable hydroponics have proven to be challenging but not insurmountable. Through water reuse and resource recovery, integrated systems have demonstrated potential for expanding food production in areas with scarce water resources and a need for food self-sufficiency.

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