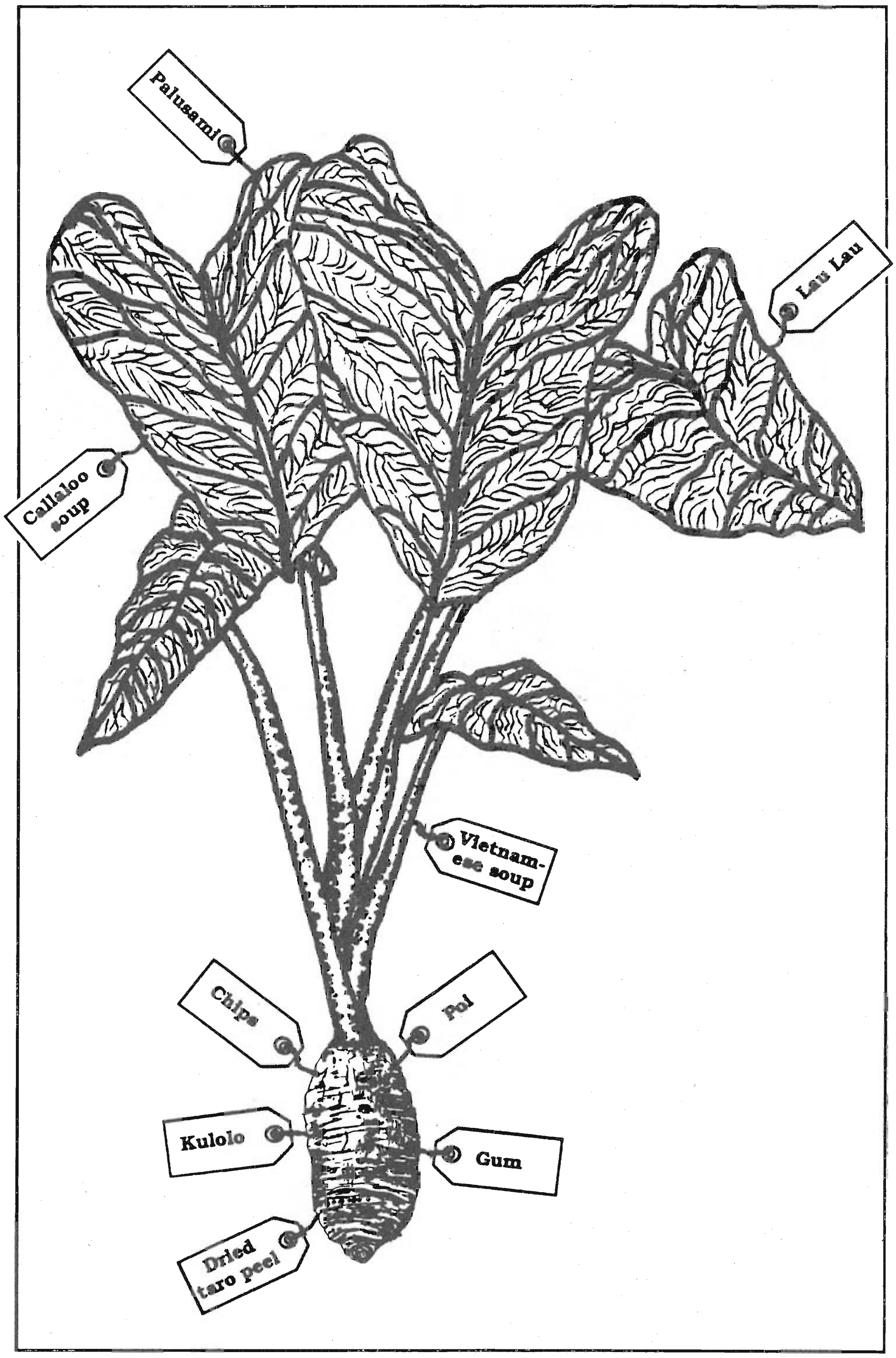
630 US ISSN 0271-9916 January 1990 RESEARCH EXTENSION SERIES 114

Proceedings of

Taking Taro into the 1990s: A Taro Conference



Edited by
JAMES R. HOLLYER
and
DWIGHT M. SATO

HITAHR
•
COLLEGE OF TROPICAL AGRICULTURE AND HUMAN RESOURCES
•
UNIVERSITY OF HAWAII

The Library of Congress has catalogued this serial publication as follows:

Research Extension series / Hawaii Institute of Tropical Agriculture and Human Resources.—001— [Honolulu, Hawaii]:
The Institute, [1980–
v. : ill. ; 22 cm
Irregular.
Title from cover.
Separately catalogued and classified in LC before and including No. 044.
ISSN 0271-9916 = Research Extension Series - Hawaii Institute of Tropical Agriculture and Human Resources.
1. Agriculture—Hawaii—Collected works. 2. Agriculture—Research—Hawaii—Collected works. I. Hawaii Institute of Tropical Agriculture and Human Resources. II. Title: Research Extension Series - Hawaii Institute of Tropical Agriculture and Human Resources.
S52.5R47 630'.5—dc19 85-645281
AACR 2 MARC-S
Library of Congress [8506]

Proceedings of

TAKING TARO INTO THE 1990s: A TARO CONFERENCE

Held at the Komohana Agricultural Complex
Hilo, Hawaii, August 17, 1989

Sponsored by:

The University of Hawaii
The Hawaii Dryland Taro Association

Edited by:

James R. Hollyer
Junior Researcher
Department of Agricultural and Resource Economics
University of Hawaii at Manoa

Dwight M. Sato
Extension Agent
Cooperative Extension Service
University of Hawaii - Hawaii County CES

PREFACE

Taro was, and continues to be, an important food for many people world-wide; at least 12.6 billion pounds of the genus *Colocasia* were consumed in 1987. In Hawaii, ancient lore states that one square mile of taro feed up to 15,000 people for a period of one year, and in 1988, at least 7.7 million pounds of all types of taros, both produced in and imported to Hawaii, were eaten whole or in some processed form. While in the past, taro was not a heavily traded commodity; primarily because it was known, desired and consumed only in the countries where it was grown, the ever changing ethnic mix and progressive culinary tastes seen today in many countries is allowing more people than ever before to try this nutritious food. Hawaii taro farmers have an opportunity to capitalize on this trend by working closely with their present customers, and by establishing new markets with currently unknown buyers. This conference is the first step in a coordinative effort by the public and private sectors to help Hawaii's taro farmers take advantage of new commercial opportunities in the food and industrial use areas. The conference proceedings contained herein provides a wealth of timely information to those taro farmers, shippers and processors who wish to provide a *quality* product to their present and potential customers.

Editors:
James R. Hollyer
Dwight M. Sato

December 1989

ACKNOWLEDGEMENTS

This conference was partially supported through USDA Cooperative State Research Service grant number 88-34172-3310, "Agricultural Diversification". This grant was secured through the efforts of U.S. Senator Daniel K. Inouye and U.S. Congressman Daniel K. Akaka. The conference was also supported by the members of the Hawaii Dryland Taro Association. Thanks go out to all those University secretaries, researchers, administration, and taro growers, shippers and processors, who gave 100% of themselves in order to make this conference a success.

Cover design by Deborah Obinger

DISCLAIMER

Reference to a company or product name does not imply approval or recommendation of the product by the College of Tropical Agriculture, University of Hawaii at Manoa, or the College of Agriculture, University of Hawaii at Hilo, or by the United States Department of Agriculture to the exclusion of others that may be suitable.

TABLE OF CONTENTS

WELCOMING ADDRESS:
TAKING TARO INTO THE 1990s: A TARO CONFERENCE

Chauncey T. K. Ching
Director of HITAHR
University of Hawaii at Manoa

Recognition of Organizers and Supporters

These kinds of workshops or conferences do not just happen. Many individuals worked very hard so that this conference is in fact occurring. In particular, I wish to recognize a number of people such as Dwight Sato who initially conceived of this gathering and Jim Hollyer who worked very closely with Dwight in creating this conference. Of course, all of this would not have occurred without the blessing and support of the county administrator--Dr. Mike Nagao. There are also many faculty from our college and the U. H. Hilo College of Agriculture who are on the program along with members from the private sector. You will hear from these individuals as the day progresses. I also acknowledge the interest and support offered by the Governor's Agriculture Coordinating Committee both Mr. Takamine and Mr. Doi. Lastly, I recognize my administrative colleague, Dr. Kenneth Rohrbach, who has been understanding and supportive of the interests in taro.

I thank the Hawaii Dryland Taro Association for co-sponsoring this conference. And, I gratefully acknowledge Congressman Akaka and Senator Inouye for their support of the Agricultural Diversification project that provides the financial resources for this conference.

College Perspective

You might be asking what is the college's role in supporting a conference of this type. I point out to you that a general goal of the College of Tropical Agriculture and Human Resources (CTAHR) is to support diversified agriculture. And, we believe we will have been successful in meeting this goal if we either create some new agricultural industries or expand some existing ones. Of course, this implies that these industries or expansions are profitable.

We pursue this goal subject to a number of constraints. The most prominent of which is that we must maintain the quality of our environment. Another important constraint is that must be consistent with the state's policies and goals--in other words, reflect the desires of our communities and the individuals who reside in them.

The mechanism that we pursue in supporting diversified agriculture in this sense is to create situations where each person/agency can do what they do best. In other words, we believe that we must have very strong linkages between the various public sector agencies, including CTAHR, and the private sector (producers, marketers, and consumers). In addition, we feel that we must be looking at concepts such as added value, linkages to tourism, and developing as many end products as possible from a particular agricultural commodity. It is within this overall context of a mechanism that we pursue our support of diversified agriculture.

Taro as a Flagship Crop/Product/Industry

While I like the products that come from taro ranging from the traditional poi to the less traditional taro chip and other manufactured products, we should not forget that taro is clearly culturally important to Hawaii. Also, I see some very clear linkages, some of which are potentially strong, to link taro production/marketing/consumption to our tourist industry.

I think, also, that taro has much potential in terms of processed and fresh products. We are limited only by our imagination and creativity. Finally, I think that taro can and is consistent with maintaining a fragile ecosystem within the state of Hawaii.

Given the above, I believe that taro is, in fact, an industry with considerable expansion potential. And, the way in which we attempt to do so could serve as a very important model to follow as we try to expand and/or create new agricultural industries in Hawaii.

Commitment

I believe that we can only be successful if we make a commitment that we are in this venture (adventure?) together. I believe that it is extremely important that we take the view it's US (all of us in Hawaii) against the world not US against each other. As conflicts arise, and I'm sure they will, I believe that it is extremely important that we keep this idea in front of us and in sharp focus.

With this focus, it is clear that we must maintain a high quality of product if we are to compete in mainland or international markets. We must work very closely with our shippers and distributors. We must establish our marketing contacts now and maintain them. We must recognize that while we do have a high quality product, we also have some very stiff competition from places like the Dominican Republic and Florida. We must realize that in order to be competitive, we must look at the most efficient ways of shipping, packaging, providing corms in sizes desired by marketers, and provide promotional materials such as brochures, labels, recipes. We must also recognize that in order to be successful as an industry, we need to promote the industry and this will likely involve an assessment of producers in order to support marketing activities.

While I believe that those of us in the college can play an important coordinative role, we must clearly make a commitment that together we are expanding the taro industry in Hawaii. We all need to take ownership of what we are doing and to support the total effort even if some of our personal short-term gains may have to be sacrificed. For example, we are producing a marketing handbook and production handbook. We need two things from the industry in order to complete these products. First, we need response from the industry to these surveys. Secondly, we need your financial support to print these handbooks. Again, it's not so much requiring your financial support to print it, but rather for you to take ownership of it. I believe that ownership is best accomplished when a commitment is made. Therefore, we will be asking you to take ownership either by helping pay the printing bill for these handbooks and/or to provide some mechanism for recapturing some of the costs of printing.

Conclusion

In conclusion, I note that you will receive a lot of information today. This information, however, will not be useful in expanding the taro industry in Hawaii unless all of us make the commitment that we are in this venture together. If we take steps to create this feeling on being on the same team, the conference will have been successful.

Thank you and best wishes for a successful conference.

TARO FOOD PRODUCTS

Wai-Kit Nip
Dept. of Food Science and Human Nutrition
University of Hawaii at Manoa

Abstract

Taro is a tropical root crop grown in Hawaii with a promising future. Now, the potential of taro has been under-estimated. This presentation reviews briefly (a) the cultural practices in Hawaii, (b) the availability of taro-based products, (c) other available technologies in processing taro, (d) problems involved in processing taro, (e) some prospective taro products, and (f) some recommendations to make taro the star of agri-business in Hawaii and the Pacific.

Introduction

Taro is a tropical root crop that can be grown easily. We can cultivate taro either under wet-land conditions or under dry-land conditions given adequate irrigation or rainfall. In the old days, Hawaiians grew taro under wet-land condition and they harvested them for the preparation of poi (taro paste). The practice is still carried on nowadays in Hawaii. Consumers with Hawaiian ancestry prefer poi and it is indispensable in occasions such as luaus (feasts). However, the gradual decrease of available wet-land in Hawaii and the hard work involved in the production of this crop has endangered the production of wet-land taro. Taro growers are currently attempting the production of poi taro under dry-land conditions with irrigation and mechanization.

Under dry-land conditions, taro growers can produce another taro crop successfully in Hawaii. This is the Chinese or Bunlong taro. It is gaining considerable interest among the farmers because of the simpler growing conditions and better profit as compared to the poi taro. In Hawaii, Chinese taro is consumed mainly in the form of deep-fried taro chips (a snack product) and deep-fried baskets (shredded taro molded into basket shape and then deep-fried) in restaurants. Other ways of consuming taro in Hawaii include steamed taro cakes, taro batter, taro bread or rolls, taro pancakes and taro chunks in casserole. However, the limited consumption and use of taro in Hawaii and the limited export marketing connections are not good enough to attract the farmers to increase their production. We have to develop other forms of consumption and uses, and a diversified marketing strategy to promote taro in the agricultural segment of the Hawaii economy. The increased export potential of fresh taro to the West Coast and Canada, and the development of taro-based food products in Hawaii are two of the more promising alternatives. In this presentation, I will discuss the taro-based products only.

Availability of Taro-Based Food Products

We process taro into various types of products and marketed them in Hawaii. Those which use taro as the main ingredient include poi in the bag, poi in the jar (baby food), dehydrated poi, deep-fried taro chips (snack) and taro baskets (found mostly in the restaurants). Other products such as taro bread or rolls, taro pancakes, and kulolo (a type of fudge-like candy) use taro as one of the main ingredients in their formulations. Improvements on existing technologies definitely can make the products more attractive to the consumers.

In other countries, other forms of taro such as taro flakes (Taiwan), frozen taro chunks (China), dried taro chips (Fiji and Western Samoa) and frozen taro cake (Taiwan) are available.

Other Available Technologies in Processing Taro

Researchers have conducted studies on the use of taro as food ingredient, in canned products and extruded pasta products. These include the manufacturing of baby food type products, taro flour, taro meal or grits, canned taro, extruded products (rice, noodles and macaroni), fermented alcoholic beverage and gum replacer. However, food processors have not considered these for commercial applications.

Problems Involved in Processing Taro

Even though taro corms have been available for years and have been processed into a few products, it is one of those crops which is not readily adapted to modern processing technologies. From the food technologist's standpoint, there are several major problems which we must overcome in order to fully utilize this particular crop (the corms) for processing in Hawaii.

(a) Shape of the corms. Taro corms do not present a uniformed shape at harvest, thus making it difficult for mechanical peeling and marketing. Currently, taro farmers are throwing away about 30% of their harvest because they are too small for the fresh market. The processors would not take them either.

(b) Internal color of the corm. Internal color of raw taro corms ranges from white, yellow, pink to a combination of colors and varies depending on cultural practices. Upon heating, the color may be creamy white, grayish purple, bright yellow or a combination of colors depending on the cultivar. This is a problem shared by both producers and processors. Poi manufacturers like their products as purple-colored as possible. Deep-fried taro chips should be light in color with or without the purple specks. Food ingredient manufacturers probably would like to have the color of taro flour or taro gums as light as possible.

(c) Texture of the corm. The texture of taro corms varies within themselves after cooking. The outer portions are not as starchy as the center portions. They also differ in specific gravity. This particular phenomenon poses a serious problem if we want to process the taro corms into chunks and patties with uniform texture.

(d) The acridity principle - or itchy reaction to consumption of taro. One of the major problems in using taro as a food crop is the presence of the acridity principle in the corms and the leaves. The degree of acridity various with cultivars. The exact nature of the acridity principle is not well understood. Proper heating can inactivate this acridity principle. However, no detailed information is available on the amount of heat required and its mechanism for this inactivation. Nor does there exist an objective method for the determination of this acridity principle. Taste is the only method by which we can determine acridity at this time. The absence of these information hinders the development of taro-based products, as the acridity principle must be inactivated before consumption or a non-acrid taro is available.

(e) Physiol-chemical properties of the major components in taro. Starch is the major component in taro corms besides water. It is known that taro starch granules are relatively small as compared to the other starches. However, no systematical studies on the physiol-chemical nature of this starch are available. In addition, taro flour contains about 10% mucilage. The physiol-chemical properties of this taro mucilage have not been systematically studied either. The lack of information in these areas hinders the prospective utilization of taro as a food ingredient and other industrial applications.

(f) Changes during post-harvest handling and storage. The shelf-life of fresh taro corms ranges from two or three weeks to several months depending on the source of information. There is no literature available on the systematical studies of the handling and storage of taro corms. Information on changes during post-harvest handling and storage of taro is crucial to the development of new markets for fresh taro corms and the processing of taro corms into other products.

Prospective Taro Food Products

There are several products which can be considered if we want to promote the increased utilization of taro in Hawaii or the Pacific Islands, provided the above-mentioned problems have been resolved.

(a) Ready-to-eat taro chunks and patties. Pacific Islanders consume considerable amount of taro in baked or boiled form with or without coconut cream. With the upgrading of living style, it is desirable to have ready-to-eat taro chunks and patties available for the residents in the Pacific Islands and those living elsewhere. This can eliminate the problem of handing a large corm at the household level. Food service establishments can also increase the use of these products in their menus if they are available.

(b) Taro flour as a food ingredient. Taro corms which are not suitable for the fresh market or for the taro chip industry can be converted to taro flour. The taro flour can then be used in other food formulations such as taro bread, taro cookies, kulolo, baby food, pasta, instant or flavored poi, or other products.

(c) Taro starch. Because of the small granular size, taro starch may lend itself to specialty markets such as the food, plastic or cosmetic industries. There should be some opportunities available if its physiol-chemical properties are known.

(d) Taro mucilage. Taro contain about 10% mucilage on a dry weight basis. This mucilage may have some potential in the gum or dietary fiber market if its physiol-chemical properties have been known.

(e) Taro peels. The peels generated from the production of taro food products must be fully utilized in order to maximize the use of the taro corm. The peels may be used as animal feed, to generate bio-energy, or dried to a mulch for the agriculture industry.

(f) Taro leaves. One of the major vegetables in the Pacific Islands is taro leaf. Currently, we use taro leaves produced in Hawaii mainly for the lau-laus (vegetable wrapping for meats during cooking). The Western Samoans produce canned 'palusami' or taro leaves in coconut cream. We must explore the production of processed taro leaves now so that the technologies and markets will be readily available when the production of taro leaves exceeds our local market demand.

Conclusion

In conclusion, I must say that we don't know much about taro and it has been under-utilized even though this crop has been available for all these years. It has the potential of becoming one of the most profitable crops in Hawaii. In order to achieve this goal, we must form a 'taro research team' to cover the different aspects of taro, from production, harvesting, handling, processing, marketing, to consumption and utilization. The industry, government and academics must work together to solicit enough funding for the different tasks involved and plan to make taro the star in Hawaii and the Pacific agribusiness.

WHAT'S THE MAINLAND MARKET FOR CHINESE TARO AND WHO'S THE COMPETITION?

James R. Hollyer
Department of Agricultural & Resource Economics
University of Hawaii at Manoa

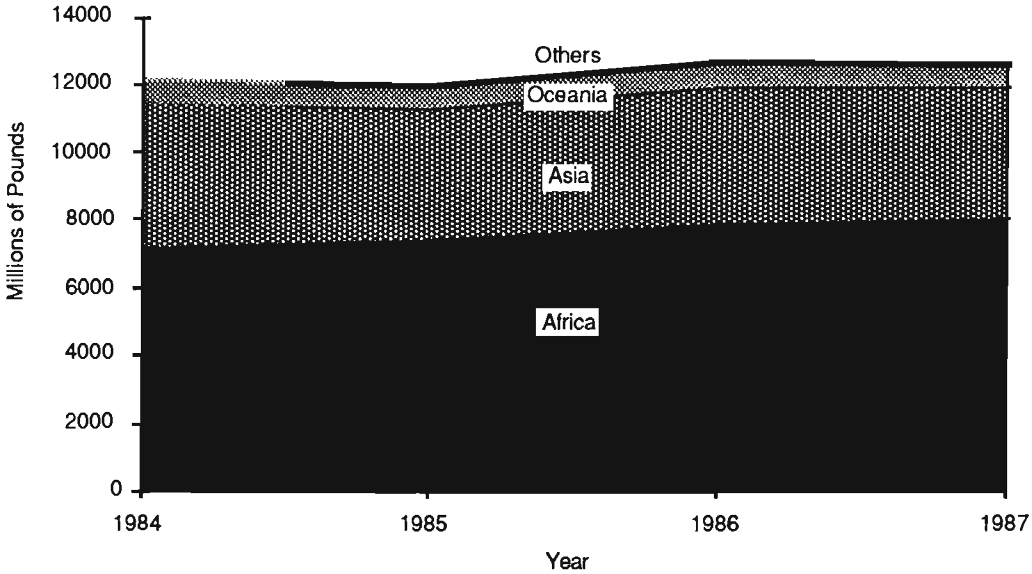
Abstract

This paper describes world production of taros, and the marketing of taro corms and leaves in Hawaii and on North America. Suggestions for the improvement of taro marketing are also provided.

Introduction

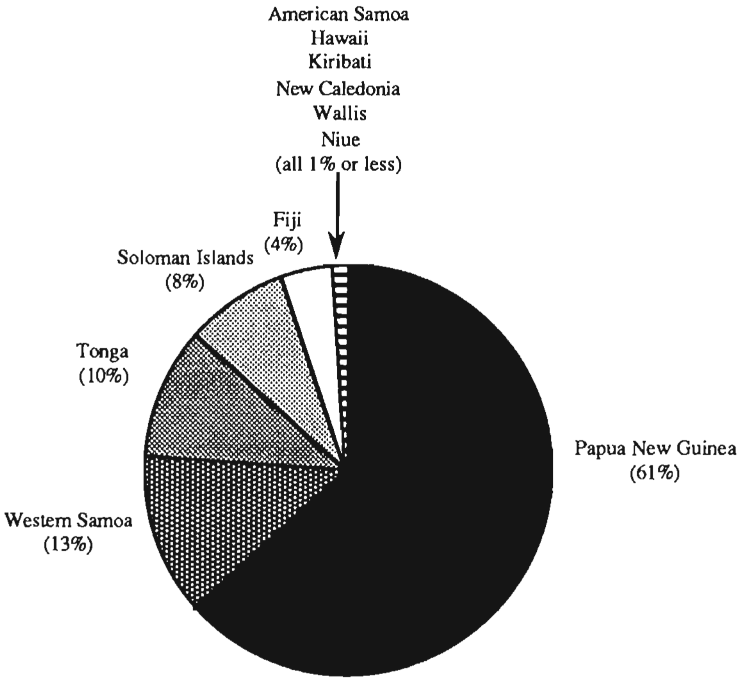
Taro forms the basis or is an intricate part of many traditional diets worldwide. In its various forms, (e.g. baked, boiled, fried, whole or mashed) taro is a nutritious food consumed by millions of people everyday. According to the FAO Production Yearbook, 12.6 billion pounds of taro (*Colocasia*) were produced worldwide from 2,440,360 acres in 1987. Major producing regions are Africa (8 billion pounds), Asia (3.9 billion pounds), and Oceania (667 million pounds) (Figure 1).

Figure 1. Major *Colocasia* Producing Regions of the World, 1987



In 1987, the countries of the Pacific region produced the following amounts of taro, in millions of pounds: Papua New Guinea (411.4), Western Samoa (85.8), Tonga (66.0), Solomon Islands (52.8), Fiji (24.2), American Samoa (8.8), Hawaii (6.8), Kiribati (6.6), New Caledonia (6.6), Wallis (4.4) and Niue (2.2). Relative shares of Pacific production are illustrated in Figure 2 (FAO Production Yearbook, 1987).

Figure 2. Taro Production in the Pacific by Percent, 1987



Until relatively recently, taro was not a big export item for most producing countries. In fact, there are no world-wide comprehensive trade figures kept for taro as are kept for its production. The main reason there was not much of a taro trade was because it was an unknown commodity outside of its traditional growing areas. Which meant then for a taro trade to become established in a new market it had to compete with other well-ingrained staples such as bread, rice, yams, and potatoes. Today the situation is changing, however, as a greater number of countries have a more diverse ethnic mix to them. And with this new mix naturally comes immigrants bringing their traditional grocery lists to their adopted homes. On the shopping lists of some Pacific Islander, Asian, Caribbean and African shoppers in Hawaii and North America are taro root, taro stalk and taro leaf.

The Taro Market in Hawaii

There are four somewhat distinct markets for taro in Hawaii: the dasheen, poi, Chinese, and Samoan markets. The dasheen, Japanese, or "sato imo" type taro (the small cormels are eaten, but the mother corm is usually not), is consumed cooked, but unprocessed, primarily by oriental consumers and is typically eaten as a side vegetable to a meal. The "poi taro" (produced under both dry and wet cultivation conditions), usually the Lehua variety for commercial usage, is more often than not processed and is the basis for two primary products: poi (the traditional Hawaiian pudding-like starch-staple) and kulolo (a equally traditional fudge-like confection). Raw corm-to-poi processing facilities presently number about 14 State-wide. The market for poi taro products is typically the "local" population and the visitor industry as an introduction to traditional Hawaiian foods at staged luaus. Chinese taro is consumed in its cooked non-processed form; as an increasingly popular snack chip (see Table 1 for more information), and in more traditional Chinese dim sum dishes. Lastly, the Samoan taros (Niue [Samoan pink], Manu'a and Palagi) are consumed almost exclusively by the Samoan population in Hawaii and very often eaten in a cooked whole form as a substantial part of a meal.

Table 1. Estimated "Made-in-Hawaii" Chip Market in Hawaii

Chip Variety	Number of Chippers	Amount of Raw Material Imported (million lb)	Amount of Raw Material Produced in Hawaii (million lb)	Amount of Finished Product (million lb)
Potato	5 (1989)	12.9 (1988) [1]	0 [1]	3.9 [2]
Taro	5 (1989) [3]	0	.6 - .7	.18 - .21

[1] Market News Service, Hawaii State Department of Agriculture, 1988.
[2] Calculated using a 30 percent conversion factor
[3] There is one additional chipper in Colorado

As each taro variety caters to a somewhat distinct clientele the demand for the product often varies throughout the year with the social activities of that clientele, for instance, the demand for Chinese taro may be higher around the time of the Chinese New Year as there are many Chinese rituals or celebrations observed at this time with taro being an important ingredient in many meals.

The supply of each taro variety depends on a number of conditions. For example, poi taros are very susceptible to flooding conditions in the valleys where they are usually grown. Chinese taro availability is governed by the former condition, along with its own price, and (often) the price of ginger, i.e. as the price of ginger goes up the supply of taro often goes down, as currently most Chinese taro farmers grow the often more profitable ginger as well. As there are no monthly production statistics kept for these two taro varieties, a look at the average of five years of 'arrivals' provides at least some insight into monthly availability of taro within the State. Note arrivals and production figures may not match due to on-site loss and usage or because the product does not pass through the market channels where statistics are being kept.

Table 2. Average Poi and Chinese Taro 'Arrivals' Within Hawaii by Weight, Month and Percentage

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/Average Shipped
						Thousand Pounds							
1984	35	14	26	21	19	16	20	12	8	5	4	4	184
1985	24	16	17	18	15	16	20	16	13	12	5	12	184
1986	17	13	19	30	8	12	21	17	18	19	15	15	204
1987	8	10	21	10	7	9	12	18	30	10	16	19	170
1988	23	31	16	20	13	17	41	30	21	27	20	16	275
Percent= (5-year ave.)	11	8	10	10	6	7	11	9	9	7	6	6	203

Source: Market News Service, Honolulu Arrivals, Fresh Fruit and Vegetables 1984-1988, Tables 3 & 7.

In the case of dasheen, 84 percent local demand was meet by Hawaii farmers in 1988 (Hawaii Agricultural Statistics Service). Samoan taro demand is meet almost exclusively by Western Samoa and to a lesser extent by growers in American Samoa. The demand for these varieties of taro appears to be greater than supply during most of the year, in which case both poi taros and Chinese taros are consumed by the Samoans (and other Polynesian groups) living in Hawaii. There does not appear to be a constraint on the production end in the Samoas, more that the available air-cargo space is very limited, and boat-shipped taro is often considered undesirable as the taro often arrives in less than marketable shape. The Samoan taro market in Hawaii must also compete for the limited supply with the much larger Los Angeles market. Import and production figures for Hawaii-grown taro and taro leaves, and imported taros are in Table 3.

Table 3. Hawaii Grown Taro and Imports in 1988

General Taro Variety	Amount Commercially Grown in Hawaii (lb)	Amount Imported (lb)
Dasheen	220,000	43,000
Chinese	1,100,000	0
Poi	5,700,000	0
Samoan	very little	615,000
Taro leaves	99,000[1]	0

Source: Hawaii Agricultural Statistics Service. 1989. Hawaii Vegetables Annual Summary. Honolulu, Hawaii. Data also from personal communication with agency staff.
[1] Market New Service, Hawaii State Department of Agriculture, 1988. Oahu only.

The only type of Hawaii-grown taro that is exported in any appreciable quantity to North America is the Chinese variety.

Market for Chinese-like Taros on the U.S. Mainland and Canada

The ethnic groups in the West Coast markets that eat Chinese-like taros (hereinafter just called *Chinese taro*) include the Chinese, Vietnamese, Thais, Malaysians, Filipinos, Laotians and others. These people consume taro in much the same way as do their counterparts in Hawaii. However, in the frozen section of the oriental markets in Los Angeles, nearly a dozen different processed taro-based products are available. These include taro bun, ice cream, ice bars, and tofu-like products. The major taro product that is consumed, however, is the corm itself. While it is nearly impossible to identify how much taro is going into each market, Table 4 provides a general overview of the volume supplied to the U.S. national market.

Table 4. Estimated Volume of Chinese-like Taros on the U.S. Mainland Market, Various Years

Source of Taros:	Millions of Pounds
Dominican Republic[1]	8
Florida[2]	5
Puerto Rico[3]	>1
Hawaii[4]	.5 - .7

[1] represents 20% of all taro imports from Dom. Rep. 1986 (Pers. comm. R. Brenef, Florida State-Fed. Market News Service)
[2] average yield of 10,000 lbs/acre * 500 acres in production 1987 (Pers. comm. R. Brenef, Florida State-Fed. Market News Service)
[3] Estimated, no trade statistics kept as it is considered part of U.S.
[4] 1988 estimated

Fresh taro leaves and taro stems are marketed in Hawaii and on North America. Taro leaves are a traditional part of Hawaiian luaus as Laulau, are eaten by Samoans as Palusami, and the peoples of the Caribbean region consume taro leaves in various types of soups, e.g. Callaloo. Taro stems are commercially produced in green houses in California and are eaten by the Vietnamese and other Asian groups. The Vietnamese use the stems in soups as well as in other dishes. Countries importing taro leaves to the U.S. in 1986 are listed in Table 5. It is unknown how much fresh and frozen taro leaves are shipped from Hawaii to North America.

Table 5. Imports of Dasheen (taro) Leaves to the U.S. for the Fiscal Year Ending September 30, 1986

Exporting Country	Port of Entry	Amount in Pounds
Brazil	Los Angeles	16,500
Dominican Republic	New York City	61,600
	Miami	1,100
	San Juan, PR	20,000
Jamaica	New York City	158,000
Japan	Los Angeles	4,400
Leeward/Windward Is (Caribbean)	New York City	5,600
Trinidad and Tobago (Caribbean)	New York City	25,700
TOTAL		292,900

Source: U.S. Imports of Fruits and Vegetables Under Plant Quarantine Regulations, Fiscal Year 1986. U.S. Department of Agriculture, Economic Research Division, Commodity Economics Division.

Almost all of the Hawaii-grown Chinese taro produced for export goes to West Coast Markets. Florida growers market their Chinese taros in Florida, New York and Philadelphia. As for the Dominican Republic, their taros are barged to Miami where they are sometimes repacked, and then trucked all over the U.S. and Canada. (For more information on marketing names, countries, market shares, prices, and landing destination see the tables in Appendices 1 & 2. *Note that these tables represent data for all types and qualities of taros that were imported*).

While Hawaii-grown Chinese taro has a relatively small market share in Los Angeles, there is potential for growth. According to industry sources, Chinese taros from Hawaii (the number one choice of those in the business in Los Angeles) have a better taste and a more distinct aroma than their closest competitor; the Dominican Republic. These taros also enjoy some name recognition (if packed in a green bag) and have a somewhat longer shelf-life than the others. On the down side, Hawaii's prices are higher and supply is inconsistent. Table 6 provides some insight into the problems and offers some solutions.

Table 6. The Current View of Hawaii-Grown Chinese Taro by Marketers in Los Angeles

Positive Attributes	Negative Attributes	Marketer's Suggestions for Change
♦ Unique aroma		
♦ Good flavor		
♦ Some name recognition		
♦ Slightly better shelf-life than competitors	....	See suggestion below for "Rotten corms"
	♦ Short weight bags	Pack a little extra to cover shrinkage
	♦ Rotten corms in shipment	Harvest at most 2 days before shipping, final wash corms in chlorinated water, let dry, keep corms cool (put in cooler 42-52 ^{o}F), export only quality uncut corms. Sort corms by size. Try boxes.
	♦ High price	Pool materials and manpower with other farmers to reduce costs
	♦ Inconsistent supply	Plan your production with your shipper so that you produce/sell all year
	♦ Not enough product definition ...	Develop promotional materials and advertise in ethnic media
	♦ Little nutritional data on products (especially fresh taro leaves)	Contact University nutritionists for data, look at store for examples

Source: Interviews with L.A. shippers by James Lee of May Produce and the author.

Hawaii-Grown Taro in the Canadian Market

Hawaii taros in the Canadian market (which is importing from areas such as Taiwan) may also have some growth potential. The number of Asians living in the Vancouver area and elsewhere is expected to increase dramatically in the next few years as the U.S. and Canada are allowing up to 20,000 immigrants to enter their respective countries each year. This fact is especially true as many Hong Kong residents are moving to Canada in expectation of the country reverting back to Mainland China in 1997. If Hawaii makes a concerted effort to organize its marketing in the area by working with Canadian importers now (assuming a quality standard and consistent supply can be maintained), many people feel that profitable inroads in this market can be made.

Acknowledgements

This research was supported through USDA Cooperative State Research Service grant number 88-34172-3310, "Agricultural Diversification". The author wishes to thank the taro growers, shippers and processors, both in Hawaii and elsewhere, for their input into this research. The many sections of the Hawaii Department of Agriculture who also provided input also deserve a big thank you.

References

FAO (Food and Agriculture Organization of the United Nations). 1987. FAO Production Yearbook. Rome: FAO.

Hawaii Agricultural Statistics Service. 1989. Hawaii Vegetables Annual Summary. Honolulu, Hawaii.

Market News Service, Hawaii State Department of Agriculture, 1984-1988. Honolulu Arrivals, Fresh Fruit and Vegetables 1984-1988. Honolulu, Hawaii.

U.S. Department of Agriculture, Economic Research Division, Commodity Economics Division. U.S. Imports of Fruits and Vegetables Under Plant Quarantine Regulations, Fiscal Year 1986. Washington, D.C.

Yokoyama, K., J. Hollyer, S. Nakamoto, K. Wanitprapha. 1989. Taro Economic Fact Sheet. Department of Agricultural and Resource Economics, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa.

Yokoyama, K., K. Wanitprapha, S. Nakamoto, P.S. Leung, J. Roecklein. 1988. U.S. Import Statistics for Agricultural Commodities, 1981-1986. Transaction Publishers, New Brunswick, New Jersey, 1988.

APPENDIX 1

Table 7. The Names of Taro's in Different Locals*

Scientific Name		Hawaii	Los Angeles	Florida
Colocasia esculenta var. *esculenta*	-Bun Long	Chinese taro, Dryland taro	Chinese or Hawaii taro root, Poi potato	Malanga isleña *taro, dasheen, eddo*
	-Lehua	Hawaiian taro, Poi or wetland taro	*imported here?*	*imported here?*
	-Niue	Samoan taro	Samoan pink	*imported here?*
Colocasia esculenta var. *antiquorum* or var. *globuferia*		Dasheen (Araimo)	Sato Imo, Japanese taro, eddos	Taro, eddos
Xanthosoma sp.		*imported here?*	Malanga	Malanga

* Producing areas include Hawaii, Florida, Western Samoa, Dominican Republic, Costa Rica and so forth.

APPENDIX 2

Table 8. Quantity and Value of Imports of Dasheens (various taro species) Fresh and Frozen into the U.S., by Source, Landing Coast, and Mode of Transportation

Country	Mode	Reg	Yr	Quantity (lb)	F.A.S.	C.I.F.	Charges
TOTAL			81	38,070,301	$7,059,386	$ 9,723,301	$2,663,615
			82	38,412,933	6,384,885	8,719,788	2,334,903
			83	37,498,699	6,513,157	8,809,047	2,295,890
			84	42,701,357	7,138,655	9,756,198	2,617,543
			85	55,862,428	9,057,144	12,139,522	3,082,378
			86	47,430,616	8,334,944	11,040,893	2,705,949
ARGENT	V	E	85	77,161	19,250	26,000	6,750
BELGIUM	V	E	83	8,400	10,731	12,044	1,313
BRAZIL	A	W	82	15,890	4,941	13,851	8,910
			83	33,376	6,715	24,892	18,177
			84	37,788	5,082	27,874	22,792
			85	14,943	3,370	10,519	7,149
	N	E	85	89,962	21,938	33,953	12,015
			86	230,590	40,569	61,643	21,074
	V	E	83	30,500	8,890	12,452	3,562
			85	25,556	5,796	8,947	3,151
	V	W	86	12,698	2,880	4,917	2,037
C AF RP	V	W	85	11,483	2,349	3,223	874
C RICA	N	E	83	1,025,958	216,245	285,159	68,914
	O	E	81	6,000	1,800	1,848	48
	V	E	81	195,646	30,222	40,731	10,509
			82	336,926	56,414	76,841	20,427
			83	136,266	26,928	32,568	5,640
			84	1,687,740	266,105	376,578	110,473
			85	1,277,718	194,103	274,051	79,948
			86	1,939,130	308,094	429,741	121,647
	V	W	81	82,450	10,565	21,713	11,148
			82	6,305	2,035	2,597	562
			83	11,066	5,005	6,948	1,943
			84	3,803	675	1,082	407
			85	67,111	20,950	29,653	8,703
			86	56,533	17,865	24,495	6,630
CANADA	O	E	81	3,120	688	688	
			84	1,870	561	561	
			85	18,000	2,513	2,513	
	O	W	85	1,236	2,872	2,872	
CHINA M	A	E	84	3,600	540	1,418	878
	V	W	81	36,540	4,860	6,841	1,981
			82	138,699	18,709	25,568	6,859
			83	137,329	15,876	21,864	5,988
			84	120,788	17,726	24,176	6,450
			85	90,706	16,415	23,371	6,956
			86	119,847	20,618	28,110	7,492
CHINA T	V	E	85	39,682	5,580	12,135	6,555
	V	W	84	9,710	7,904	8,517	613
			85	1,560	1,404	1,659	255
			86	99,326	35,390	38,708	3,318

Country	Mode	Reg	Yr	Quantity (lb)	F.A.S.	C.I.F.	Charges
COLOMB	A	E	84	3,510	674	2,814	2,140
DOM REP	A	E	81	67,775	8,037	14,067	6,030
			82	21,180	2,520	3,698	1,178
			83	10,912	1,658	2,841	1,183
			84	2,960	1,332	1,681	349
	N	E	81	33,653,210	5,848,543	7,863,540	2,014,997
			82	34,283,799	5,275,618	7,047,443	1,771,825
			83	32,842,473	5,215,023	6,825,332	1,610,309
			84	36,006,498	5,524,129	7,215,913	1,691,784
			85	43,382,881	6,176,835	8,171,062	1,994,227
			86	34,547,795	5,255,308	6,882,984	1,627,676
	N	W	84	33,350	7,827	10,850	3,023
	V	E	81	1,419,603	246,016	324,970	78,954
			82	1,312,890	254,379	322,903	68,524
			83	177,350	24,899	33,641	8,742
			84	790,402	93,268	137,761	44,493
			85	6,626,804	1,304,106	1,707,983	403,877
			86	7,219,841	1,489,545	1,944,809	455,264
	V	W	84	5,526	2,818	3,633	815
DOMINCA	V	E	81	1,995	750	903	153
			83	690	680	994	314
			86	38,601	11,594	13,254	1,660
FIJI	A	H	84	3,150	764	1,445	681
	A	W	83	96,541	32,058	58,042	25,984
			84	387,097	115,088	222,911	107,823
			85	15,650	5,634	9,763	4,129
			86	91,000	21,501	43,893	22,392
	V	H	83	1,500	1,225	1,582	357
FINLAND	A	H	86	9,306	3,165	5,695	2,530
	N	W	86	53,251	18,901	30,961	12,060
FR GERM	V	E	86	13,400	1,608	2,468	860
FR POLY	A	H	84	1,980	720	1,951	1,231
FRANCE	A	E	81	14,195	1,758	2,883	1,125
			83	5,000	500	970	470
	V	E	81	5,000	600	820	220
			84	3,000	356	656	300
GUATMAL	A	E	82	12,831	5,774	8,337	2,563
	V	E	84	18,550	1,484	3,312	1,828
HAITI	A	E	81	32,490	3,942	7,075	3,133
			82	5,400	648	1,144	496
			83	25,515	5,400	8,096	2,696
			85	25,000	6,750	9,750	3,000
	N	E	82	60,868	7,653	11,849	4,196
HG KONG	V	W	82	17,920	2,667	3,684	1,017
			83	17,500	2,871	3,963	1,092
			84	21,910	2,262	3,281	1,019
			86	31,818	8,482	10,251	1,769
HONDURA	V	E	81	79,620	8,332	12,748	4,416
			84	44,032	4,768	7,762	2,994
			85	46,800	5,940	8,464	2,524
			86	36,000	4,000	6,510	2,510
ITALY	A	E	83	3,571	640	1,240	600

Country	Mode	Reg	Yr	Quantity (lb)	F.A.S.	C.I.F.	Charges
			85	3,439	2,866	3,743	877
			86	8,089	4,400	5,734	1,334
JAMAICA	A	E	81	2,895	354	597	243
			83	3,677	968	1,565	597
			84	32,284	7,292	13,952	6,660
			85	137,033	30,613	56,772	26,159
			86	14,425	6,869	8,942	2,073
	N	E	81	324,523	110,148	155,313	45,165
			82	468,500	97,972	147,799	49,827
			83	926,547	189,999	330,294	140,295
			84	1,513,599	292,058	510,652	218,594
			85	1,205,201	368,506	562,450	193,944
			86	1,203,228	457,056	606,309	149,253
	V	E	85	29,000	3,863	5,095	1,232
			86	1,451	1,520	2,620	1,100
JAPAN	N	E	86	39,385	29,187	34,529	5,342
	N	H	84	8,352	7,969	10,105	2,136
	V	E	81	27,500	35,979	47,574	11,595
			82	37,937	52,235	64,056	11,821
			83	53,472	33,064	42,159	9,095
			84	41,138	53,952	65,534	11,582
			85	27,500	24,668	28,330	3,662
			86	2,420	2,398	2,562	164
	V	H	81	1,320	2,394	2,799	405
			83	6,934	6,148	8,205	2,057
			85	7,700	7,075	8,030	955
			86	3,080	3,897	4,720	823
	V	W	81	71,531	78,608	85,589	6,981
			82	82,962	90,124	96,725	6,601
			83	99,417	95,686	103,268	7,582
			84	134,160	155,341	166,244	10,903
			85	231,381	179,502	198,409	18,907
			86	271,198	194,786	212,560	17,774
KOR REP	A	W	81	12,500	4,086	7,375	3,289
MEXICO	O	E	81	40,500	24,300	24,300	
			83	71,232	24,085	24,085	
			84	60,342	1,916	1,916	
			85	156,700	49,673	49,673	
	O	W	82	32,400	7,560	7,560	
			83	85,153	17,071	17,071	
			84	243,080	72,856	72,856	
			85	52,134	10,835	10,835	
			86	40,686	13,008	13,008	
N ANTIL	V	E	81	3,550	305	411	106
N ZEAL	A	W	83	600	996	1,321	325
NETHLDS	V	E	85	15,000	1,750	2,438	688
NICARAG	V	E	81	41,325	8,265	12,007	3,742
PARAGUA	V	W	86	36,700	4,100	5,100	1,000
PHIL R	A	E	85	8,432	2,486	8,380	5,894
PORTUGL	A	E	81	15,872	4,680	12,482	7,802
			82	116,347	36,363	86,121	49,758
			83	169,340	59,109	124,205	65,096

Country	Mode	Reg	Yr	Quantity (lb)	F.A.S.	C.I.F.	Charges
			84	125,111	39,884	94,156	54,272
			85	23,907	7,131	18,796	11,665
			86	38,691	11,251	28,759	17,508
	N	E	81	270,411	72,620	137,567	64,947
			82	187,562	61,119	100,167	39,048
			83	141,218	53,588	75,177	21,589
			84	272,760	95,375	183,098	87,723
			85	370,148	114,060	194,714	80,654
			86	274,513	87,925	199,999	112,074
	V	E	81	37,479	11,820	17,928	6,108
			82	10,406	3,210	5,272	2,062
			83	17,800	6,944	9,003	2,059
			86	23,076	7,297	10,944	3,647
S LUCIA	A	E	84	938	825	1,188	363
S VN GR	A	E	86	1,640	1,099	1,477	378
	V	E	86	28,875	7,012	7,998	986
SPAIN	A	E	81	3,527	1,260	3,258	1,998
TONGA	V	W	82	7,630	1,526	2,682	1,156
			85	39,683	4,858	7,500	2,642
TRINID	A	E	82	663	332	847	515
			83	450	500	1,190	690
			84	3,610	3,721	4,987	1,266
			86	10,186	8,300	12,592	4,292
	N	E	81	27,885	7,025	11,375	4,350
	V	E	83	2,100	462	572	110
VENEZ	A	E	83	257,594	66,239	88,545	22,306
			84	31,856	9,641	13,383	3,742
			85	20,000	4,000	6,429	2,429
	N	E	84	121,265	23,786	34,204	10,418
	V	E	85	87,088	7,960	14,845	6,885
			86	45,635	11,700	14,717	3,017
W SAHAR	A	H	81	10,000	3,488	5,400	1,912
	A	W	81	10,000	3,000	5,631	2,631

Country	Mode	Reg	Yr	Quantity (lb)	F.A.S.	C.I.F.	Charges
W SAMOA	A	E	86	6,000	3,600	5,266	1,666
	A	H	81	292,214	99,025	188,040	89,015
			82	34,660	9,270	18,585	9,315
			83	27,000	10,322	14,249	3,927
			84	67,657	24,611	40,007	15,396
			86	80,352	15,426	34,289	18,863
	A	W	81	397,696	140,884	250,398	109,214
			82	2,500	750	1,714	964
			83	17,550	5,460	9,935	4,475
	N	H	81	866,504	280,250	447,533	167,283
			82	1,072,391	349,593	587,418	237,825
			83	823,881	289,877	510,642	220,765
			84	599,537	204,646	373,547	168,901
			85	472,290	147,209	238,801	91,592
	N	W	81	15,425	4,782	8,897	4,115
			82	146,267	43,473	82,927	39,454
			83	230,787	77,295	114,933	37,638
			84	215,660	83,870	106,030	22,160
	O	W	84	9,000	2,565	3,608	1,043
	V	W	84	33,744	4,264	6,555	2,291
			85	1,163,539	294,284	388,364	94,080
			86	801,850	224,593	300,329	75,736

Source: U.S. Import Statistics for Agricultural Commodities, 1981-1986.

Key:

Mode (of transport to the U.S.) = V= by ship; A= by airplane; O = overland transport, commodities released into U.S. consumption channels from bonded storage warehouses and/or from U.S. foreign trade zones, N= Undetermined mode of transport.

Reg(ion) of first off-load: W= Alaska, Arizona, California, Montana, Oregon and Washington; H= Hawaii, E= all other U.S. ports.

Year = Calendar year.

F.A.S. = Free Along Side: Farm gate price and in-country shipping (customs value); does not include freight, insurance, U.S. custom duties, or other transport costs in U.S.

C.I.F. = Cost Insurance and Freight: F.A.S. value plus freight and insurance; does not include U.S. custom duties or other transport costs in U.S.

Charges = Is the difference between C.I.F. and F.A.S. prices.

Table 9. Quantity, Value and Market Ranking of Imports of Dasheens (various taro species) Fresh and Frozen into the U.S., by Year

	YEAR					
	81	82	83	84	85	86
F.A.S. PRICE ($/lb):						
Highest	1.16	1.17	1.66	1.18	.83	.81
Country	JAPAN	JAPAN	N ZEAL	JAPAN	ITALY	TRINID
Lowest	.08	.12	.10	.08	.11	.11
Country	N ANTIL	HAITI	FRANCE	GUATMAL	VENEZ	HONDURA
Average F.A.S. Price	.18	.16	.17	.16	.16	.17
MAJOR SUPPLIER:						
Country	DOM REP	DOM REP	DOM REP	DOM REP	DOM REP	DOM REP
Average FA.S. Price ($/lb)	.17	.15	.15	.15	.14	.16
Market share(%)	92.30	92.72	88.08	86.27	89.52	88.06
Quantity (lb)	35,140,588	35,617,869	33,030,735	36,838,736	50,009,685	41,767,636
TOTAL:						
Quantity (lb)	38,070,301	38,412,933	37,498,699	42,701,357	55,862,428	47,430,616
F.A.S. ($)	7,059,386	6,384,885	6,513,157	7,138,655	9,057,144	8,334,944

Source: K. Wanitprapha and K. Yokoyama, personal communication
Note: Calculated prices may be off by as much as $.01 due to truncation of data.

Table 10. Market Share of Imports of Dasheens (various taro species) Fresh and Frozen into the U.S., by Source and Year

Market Share in Percent

Country	81	82	83	84	85	86
ARGENT					.13	
BELGIUM			.02			
BRAZIL		.04	.17	.08	.23	.51
C AF RP					.02	
C RICA	.74	.89	3.12	3.96	2.40	4.20
CANADA	.00			.00	.03	
CHINA M	.09	.36	.36	.29	.16	.25
CHINA T				.02	.07	.20
COLOMB				.00		
DOM REP	92.30	92.72	88.08	86.27	89.52	88.06
DOMINCA	.00		.00			.08
FIJI			.26	.91	.02	.19
FINLAND						.13
FR GERM						.02
FR POLY				.00		
FRANCE	.05		.01	.00		
GUATMAL		.03		.04		
HAITI	.08	.17	.06		.04	
HG KONG		.04	.04	.05		.06
HONDURA	.20			.10	.08	.07
ITALY			.00		.00	.01
JAMAICA	.86	1.21	2.48	3.62	2.45	2.57
JAPAN	.26	.31	.42	.43	.47	.66
KOR REP	.03					
MEXICO	.10	.08	.41	.71	.37	.08
N ANTIL	.00					
N ZEAL			.00			
NETHLDS					.02	
NICARAG	.10					
PARAGUA						.07
PHIL R					.01	
PORTUGL	.85	.81	.87	.93	.70	.70
S LUCIA				.00		
S VN GR						.06
SPAIN	.00					
TONGA		.01			.07	
TRINID	.07	.00	.00	.00		.02
VENEZ			.68	.35	.19	.09
W SAHAR	.05					
W SAMOA	4.12	3.26	2.93	2.16	2.92	1.87

Source: K. Wanitprapha and K.Yokoyama, personal communication
Note: Calculated prices may be off by as much as $.01 due to truncation of data.

Table 11. Quantity and F.A.S. Prices of Dasheens (various taro species) Fresh and Frozen into the U.S., by Year

	[------Quantity (LB)				------]	[---F.A.S. Price ($/LB)				---]	
Country	81	82	83	84	85	86	81	82	83	84	85	86
ARGENT					77,161						.24	
BELGIUM			8,400						1.27			
BRAZIL		15,890	63,876	37,788	130,461	243,288		.31	.24	.13	.23	.17
C AF RP					11,483						.20	
C RICA	284,096	343,231	1,173,290	1,691,543	1,344,829	1,995,663	.14	.17	.21	.15	.15	.16
CANADA	3,120			1,870	19,236		.22			.30	.27	
CHINA M	36,540	138,699	137,329	124,388	90,706	119,847	.13	.13	.11	.14	.18	.17
CHINA T				9,710	41,242	99,326				.81	.16	.35
COLOMB				3,510						.19		
DOM REP	35,140,588	35,617,869	33,030,735	36,838,736	50,009,685	41,767,636	.17	.15	.15	.15	.14	.16
DOMINCA	1,995		690			38,601	.37		.98			.30
FIJI			98,041	390,247	15,650	91,000			.33	.29	.36	.23
FINLAND						62,557						.35
FR GERM						13,400						.12
FR POLY				1,980						.36		
FRANCE	19,195		5,000	3,000			.12		.10	.11		
GUATMAL		12,831		18,550				.45		.08		
HAITI	32,490	66,268	25,515		25,000		.12	.12	.21		.27	
HG KONG		17,920	17,500	21,910		31,818		.14	.16	.10		.26
HONDURA	79,620			44,032	46,800	36,000	.10			.10	.12	.11
ITALY			3,571		3,439	8,089			.17		.83	.54
JAMAICA	327,418	468,500	930,224	1,545,883	1,371,234	1,219,104	.33	.20	.20	.19	.29	.38
JAPAN	100,351	120,899	159,823	183,650	266,581	316,083	1.16	1.17	.84	1.18	.79	.72
KOR REP	12,500						.32					
MEXICO	40,500	32,400	156,385	303,422	208,834	40,686	.60	.23	.26	.24	.28	.31
N ANTIL	3,550						.08					
N ZEAL			600						1.66			
NETHLDS					15,000						.11	
NICARAG	41,325						.20					
PARAGUA						36,700						.11
PHIL R					8,432						.29	
PORTUGL	323,762	314,315	328,358	397,871	394,055	336,280	.27	.32	.36	.34	.30	.31
S LUCIA				938						.87		
S VN GR						30,515						.26
SPAIN	3,527						.35					
TONGA		7,630			39,683			.20			.12	
TRINID	27,885	663	2,550	3,610		10,186	.25	.50	.37	1.03		.81
VENEZ			257,594	153,121	107,088	45,635			.25	.21	.11	.25
W SAHAR	20,000						.32					
W SAMOA	1,571,839	1,255,818	1,099,218	925,598	1,635,829	888,202	.33	.32	.34	.34	.26	.27

Source: K. Wanitprapha and K. Yokoyama, personal communication
Note: Calculated prices may be off by as much as $.01 due to truncation of data.

COST AND RETURN OF CHINESE TARO PRODUCTION IN THE HILO AREA

Ping Sun Leung
Department of Agricultural & Resource Economics
University of Hawaii at Manoa

Dwight Sato
Cooperative Extension Service
University of Hawaii - Hawaii County CES

Abstract

This study provides an update of the cost and return of Chinese taro production in the Hilo area. Return to management is estimated to be $5,575 per acre per crop. Total fixed costs and variable costs are $1,573 and $4,602 respectively. Estimated breakeven price is 20.6 cents (per lb of taro corm) to cover total costs. For a newly established operation which has to purchase hulis, return to management is reduced by the cost of hulis of $1,245 to $4,219, and breakeven price to cover total costs is estimated to be 25.1 cents. Using an optimal fertilization schedule as derived from a recent experiment, return to management can be increased by $2,500 per acre per crop and breakeven price to cover total costs is estimated to be 19.2 cents.

Introduction

This publication serves as an update to the Farm Management Report No. 17 entitled "Cost and Return of Dry Land Taro Production in Hawaii: 1984" (Marutani, 1984). In addition, the economics of applying the optimal fertilization schedule as derived from a recent experiment will be analyzed.

Because of the assumptions and sources of information used in this study, the data in this publication should be viewed as representative of what a farmer would anticipate for a well-managed Chinese taro enterprise. The data does not represent any particular grower nor does it represent the average. Therefore, many factors may alter the cost and return figures reported here when compared to a particular individual's operation. The primary purpose of this publication is to identify the type of production practices and management program considered to be typical of a well-managed Chinese taro enterprise.

Sources of Information

Data was collected from three growers in the Hilo area. These growers were considered to be representative of having well-managed Chinese taro enterprises. The data was collected with the aid of the "Vegetable-Crop Budget Template" (Cox et al., 1988). The growers were asked to fill in a blank budget template with our assistance. The data were then processed and checked by the respective growers for accuracy. We then used these data as the baseline in generating what we believe would be the typical or representative well-managed Chinese taro enterprise.

Assumptions

The following assumptions were made in developing the enterprise budget:

1. This typical farm has ten acres in production with five acres devoted to Chinese taro.
2. Growing period per crop is nine months and the land is plowed only once a year.
3. Total yield per acre per crop consists of 25,000 pounds of grade A and 5,000 pounds of off-grade taro.
4. The grower receives 40 cents per pound for grade A taro and 35 cents for off-grade taro.
5. The wage rates are $8.00 and $4.50 per hour for skilled and unskilled labor respectively.
6. Land is rented at $400.00 per acre per year.
7. Prices for gasoline and diesel fuel are $1.55 and $1.50 per gallon respectively.
8. Interest on operating loans is 12 percent.
9. This typical farm has a 2000 sq. ft. structure valued at $2000.
10. Machinery and equipment are valued at cost which would be incurred if replaced.
11. Farm overhead cost is charged at 1 cent per pound of production.

Budget Analysis (based on per acre per crop)

Case 1: Typical Operation

Table 1 shows the machinery and labor requirements by operation while Table 2 shows the material requirements by operation. Table 3 lists all the machinery and equipment necessary for a typical taro enterprise along with the derivations of their per hour fixed and variable costs. Fixed costs include depreciation, interest on investment, taxes and insurance. Variable costs include repairs, fuel and lubrication.

Table 4 shows the gross receipts. Table 5 outlines the variable expenses by operation. Table 6 summarizes the cost and return of the typical taro enterprise. Total costs is estimated to be $6,175 per acre per crop with 25 percent being fixed expenses. With a gross receipt of $11,750, net return to management is estimated to be $5,575. Table 7 shows the breakeven prices and yields necessary to cover variable costs and total costs. A grower would have to cover its total costs in the long-run in order to remain profitable. However, in the short-run, the grower would continue to operate as long as its variable costs is covered. In order to cover total costs, a production of 15,765 pounds per acre is needed at 40 cents per pound while a 20.6 cents per pound price is sufficient to cover the total costs with a production of 30,000 pounds per acre.

It should be noted that this study shows a much higher return to management as compared to the 1984 study, $5,575 vs $1,389, primarily due to the increase in both per acre yield and price per pound received by the growers.

Case 2: Newly Established Operation (with purchasing cost of hulis)

For newly established operation, the grower has to purchase hulis which are assumed to cost 10 cents per piece. Hulis were spaced one foot apart within rows and 3.5 feet apart between rows with a population of 12,446 plants per acre. In other word, an additional cost of $1,244.60 would have to be incurred per acre. This would result in a lower return to management as compared to the typical case, $4,219 vs. $5,575, and a higher breakeven price to cover total costs, 25.1 cents vs 20.6 cents. (see Table 7)

Case 3: Optimal Fertilization

Based on a recent fertilization experiment (Sato et al., 1989), the optimal fertilization schedule was estimated to be 460 lbs N (1000 lbs Urea), 600 lbs K (1185 lbs Muriate of Potash) and 3,000 lbs. TSP per acre. Using this schedule, yield was estimated to be 40,000 lbs per acre, an increase of 10,000 lbs. This yield increase generates an additional $4,000 in gross receipt along with an increase of $583 in fertilizer cost and $792 in harvesting cost. Obviously, the increase in revenue outweighs the increase in costs. This contributes to an increase in return to management of approximately $2,500 ($8,076 vs. $5,575). Also, breakeven price to cover total costs is lowered to 19.2 cents as compared to 20.6 cents for the typical case. (see Table 7)

References

Cox, L.J., Nakamoto, S.T., Marutani, H.K., and Leung, P.S. 1988. *A User's Manual for the Vegetable-Crop Budget Template,* Research Extension Series 091, Hawaii Institute of Tropical Agriculture and Human Resources.

Marutani, H.K. 1984. *Cost and Return of Dry Land Taro Production in Hawaii: 1984,* Farm Management Report No. 17, Hawaii Institute of Tropical Agriculture and Human Resources.

Sato, D., Silva, J., Leung, P.S., Santos, G., and Kuniyoshi, J. 1989. *Nitrogen and Potassium Fertilization for Dryland Taro,* A GACC Taro Fertility Progress Report No. 1, Hawaii Institute of Tropical Agriculture and Human Resources.

Table 1.--Machinery and Labor Requirements by Operation

Operation	Machinery & Equipment hours		Labor (hours) Skilled	Unskilled
1. Seedling Preparation				
Prepare Hulis				48.0
2. Land Preparation				
Rake	Rake	16.0	16.0	
Mow	Mower, 5ft.	3.0	3.0	
Plow	Plows, 18-inch	4.0	4.0	
Rotovate	Rotovator	2.0	2.0	
Cut row	Furrow Digger	2.0	2.0	
All activities	Tractor	27.0	27.0	
3. Liming				
Liming	Tractor	4.0	4.0	
	Lime Spreader	4.0		
	Tractor, front loader	4.0	4.0	
4. Planting				
Planting Hulis	Iseki	13.4	13.4	16.0
5. Maintenance of Growing Crop				
Weeding	Iseki	13.4	13.4	22.0
Fertilizing	Fertilizer applicator	4.0		4.0
6. Harvesting				
Harvest	Flatbed Truck	5.0		360.0
Wash and Trim				60.0
Bag				30.0
Hauling	Flatbed Truck	15.0		15.0

Table 2.--Material Requirement by Operation

Operation	Material	Quantity	Unit Price
1. Seedling Preparation			
	Baskets	20	$ 1.20
3. Liming			
	Lime	2 tons	20.00
5. Maintenance			
	16-16-16	10 @ 80lb bags	16.95
6. Harvesting			
	Bags	600 bags	0.25
	Water	54,000 gals	0.001
	Racks	60	2.00

Table 3.–Machinery and Equipment Cost Calculations

Name	Horse-power	Market Value	Annual Use (hours)	Use Life (years)	Salvage Value	Fuel Type*	Average Value	Depreciation (s.l.)	Interest	Taxes & Insurance	Annual Fixed Cost	Fixed Cost/hour	Repairs	Fuel	Lubrication	Annual Variable Cost	Variable Cost/hour	Total Cost/hour
TRACTORS																		
Tractor	50.00	20000	300	24	1000	Diesel	10500	791.67	1260.00	157.50	2209.17	7.36	833.33	990.00	148.50	1971.83	6.57	13.94
Tractor, front loader	30.00	12000	40	24	600	Diesel	6300	475.00	756.00	94.50	1325.50	33.14	500.00	79.20	11.88	591.08	14.78	47.91
OTHER MACHINERY W/ ENGINES																		
Truck, flatbed, 3/4 - 1 ton	200.00	16000	300	10	800	Diesel	8400	1520.00	1008.00	126.00	2654.00	8.85	1600.00	1800.00	270.00	3670.00	12.23	21.08
Iaeki (Hand-drawn Tractor)	6.50	4500	270	10	225	Gasoline	2363	427.50	283.50	35.44	746.44	2.76	450.00	54.41	8.16	512.57	1.90	4.66
ATTACHMENTS																		
Rotovator		4000	20	15	200		2100	253.33	252.00	31.50	536.83	26.84	266.67	0.00	0.00	266.67	13.33	40.18
Lime spreader		3000	40	36	150		1575	79.17	189.00	23.63	291.79	7.29	50.00	0.00	0.00	50.00	1.25	8.54
Rake		2000	160	36	100		1050	53.20	126.00	15.75	194.95	1.22	56.00	0.00	0.00	56.00	0.35	1.57
Plows, 18-inch		750	40	25	38		394	28.50	47.25	5.91	81.66	2.04	36.00	0.00	0.00	36.00	0.90	2.94
Mower, 5ft		2000	30	15	100		1050	126.67	126.00	15.75	268.42	8.95	133.33	0.00	0.00	133.33	4.44	13.39
OTHER EQUIPMENT																		
Furrow Digger		2000	20	25	100		1050	76.00	126.00	15.75	217.75	10.89	80.00	0.00	0.00	80.00	4.00	14.89
Backpack Fertilizer Applicator		225	40	5	11		118	42.75	14.18	1.77	58.70	1.47	45.00	0.00	0.00	45.00	1.13	2.59

Table 4.--Gross Receipts (based on per acre per crop)

Item	Quantity	Unit	$/unit	Value
Grade A	25,000	lb.	0.40	$10,000
Off-Grade	5,000	lb.	0.35	1,750
TOTAL	30,000	lb.	0.39	11,750

Table 5.--Variable Expenses (based on per acre per crop)

Operation	Machinery & Equip.	Labor	Material	Sub-Total
1. Seedling Preparation	$ 0	$ 216	$ 24	$ 240
2. Land Preparation	235	216	0	451
3. Liming	90	64	40	194
4. Planting	25	179	0	205
5. Maintenance	30	269	170	469
6. Harvesting	245	2,093	326	2,663
Total Variable Costs :	625	3,037	560	4,222

Table 6.--Summary Budget (based on per acre per crop)

Item	Value or Cost	% of Total Cost
1. Gross Receipts	$11,750	
2. Variable Costs :		
Labor	3,037	49.2
Machinery & Equipments	625	10.1
Materials	560	9.1
Interests on operating expenses	380	6.2
Total Variable Costs	4,602	74.5
3. Income Over Variable Costs	7,148	
4. Fixed Costs:		
Machinery & Equipments	777	12.6
Building	72	1.2
Land	424	6.9
Farm Overheads	300	4.9
Total Fixed Costs	1,573	25.5
5. Total Costs	6,175	100.0
6. Return to management	5,575	
7. Return to labor & management	8,612	
8. Return to machinery & management	6,352	
9. Return to land & management	5,999	

Table 7.--Breakeven Analysis

	Breakeven Yield (lbs/acre)	Breakeven Price ($/lb)
1. To cover total costs:	15,765	$0.21
2. To cover variable costs:	11,749	$0.15

Table 8.--Case Comparison

	Case 1	Case 2	Case 3
Return to Management ($/acre)	$5,575	$4,219	$8,076
To cover total costs:			
Breakeven yield (lbs/acre)	15,765	19,228	19,490
Breakeven price ($/lb)	$0.21	$0.25	$0.19
To cover variable costs:			
Breakeven yield (lbs/acre)	11,749	15,212	15,495
Breakeven price ($/lb)	$0.15	$0.20	$0.15

Note: Case 1 - Typical operation
Case 2 - Newly established operation
Case 3 - Optimal fertilization

MARKETING OF CHINESE TARO IN LOS ANGELES

James Lee
May Produce
Los Angeles, CA

Abstract

Hawaii grown Chinese taro is in high demand in West Coast markets. Disease-free and year-round taro supply in addition to product identification are pre-requisites in establishing a market and meeting foreign competition. Agricultural economists, extension specialists, growers, local handlers, and shippers must all work as closely as possible to developed a positive attitude. It is a team effort.

Quality

From my interviews with the fresh taro buyers in the West Coast, they all expressed a preference for the Hawaii grown Chinese taro (Bun Lan Woo) over the Dominican Republic imports. The Dominican Republic taro has been considered their second choice or a substitute for the Hawaii grown taro. When asked about taste, all of the buyers expressed that the Hawaii grown Chinese taro has a unique aroma, firm texture, and attractive purple colored specks within the corms. The Dominican taro has none of these attributes.

Availability

Because Chinese taro from Hawaii is not available throughout the year, the market in Los Angeles will depend on imported taro from the Dominican Republic. The amount of taro imported from the Dominican Republic is sizable but the quality is not up to par. Los Angeles buyers are forced to buy Dominican Republic taro because it's the only game in town. Consumers will gradually become accustomed to the Dominican Republic taro making the current marketing situation very critical for Hawaii growers!

Pricing

Hawaii air-flown taro has a higher price than taro shipped by boat. However, I do not advise you to ship taro by Matson containers to Los Angeles because taro doesn't have a long post-harvest shelf life. Buyers in Los Angeles look for taro quality. Years ago, nobody shipped taro by Matson containers. Now, with the two different prices for Hawaii Chinese taros (one for air-shipped and one for boat-shipped), there is confusion not only in the minds of the buyers and produce managers, but in the minds of the consumers as well.

Packing and Shipping Improvements

Hawaii grown Chinese taro are shipped in green or red vegetable bags. Los Angeles buyers always associate Hawaii grown Chinese Taro with the bag color. It would be a good idea to have product labels attached to bags identifying Hawaii grown taro. Some wholesalers even try to pack Dominican taro in green bags, giving it the grown in Hawaii appearance. Packing in boxes would also help as it reduces handing damage and is easier to market.

Conclusions and Recommendations

Quality:

With the increase in southeast Asian immigrants (the main consumers of Hawaii grown taro) to North America, Chinese taro (from anywhere) will be in high demand. In order for Hawaii to be a leader in this market, disease-free taro is a must.

Attitude and Team Effort:

Agricultural economists, extension specialists, growers, local handlers, and shippers must all work as closely as possible. A positive attitude must be developed. It must be a team effort.

Competition:

In order to meet the demand of the Los Angeles market, a year-round availability plan must be developed. This is the most effective way of meeting (and possibly beating) foreign competition.

Promotion:

In promoting Hawaii-grown Chinese taro:

a. A well designed Hawaii-grown Chinese taro label should be attached to each bag to develop a brand concept.
b. Develop a booklet of taro featuring "Why Buy Hawaii Grown Chinese Taro"; in Chinese also.
c. Run newspaper and radio campaigns in Los Angeles.
d. Free trips to Hawaii for buyers and managers of companies that sell Hawaii taros.

Improvements on Post-harvest Management:

Improvements for grading, packing, handling, and shipping are needed. Vacuum cooling may be an alternative treatment.

Development of New Markets and Specialty Crops for Hawaii Farmers

There is a Canadian market that would want fresh taro. Also in good demand are herbs, bamboo shoots, guava, leechi, lotus roots, and leaf mustards. In order to develop and be established in this market, all of the above recommendations outlined need to be accomplished.

TARO CORM QUALITY AND POSTHARVEST HANDLING FOR PROCESSING

Robert E. Paull
Department of Plant Molecular Physiology
University of Hawaii at Manoa

Robert Coltman
Department of Horticulture
University of Hawaii at Manoa

Abstract

Objectives to study the relationships between physiological age of corms, storage capabilities, and final snack food chip quality of dryland taro are outlined. Background information is to be developed that will assist in the development of the snack food chip market. The first problem is to define quality and attempt to focus on those aspects which are most important for fried chip manufacture.

Introduction

Taro corm growth and development was studied in 1969 (K.W. Ching, 1969, 1970). Four commercial cultivars were planted under dryland conditions at Waimanalo Experiment Station. Corms were sampled every 31 days after 5 months growth. Corm weight began to level out after 7 months of growth with starch content reaching its highest value at about the same time. Total soluble corm sugars began to increase at this time and continued to increase as the leaf area began to decline. These results suggest that older corms may make poorer quality chip, i.e. chips with a darker background color, because of the higher sugars. The result also suggest that corms harvested at 7 to 8 months may make better chips.

There have been many proximate analysis of taro flour and poi (Bradbury, 1988). The starch is mainly amylose with smaller amount of amylopectin (Amin, 1955). The higher amount of amylopectin leads to high oil retention during frying. The amylose is readily degradable such as during poi manufacture (Standal, 1970). The "free" or alcohol soluble sugars could be partly pentosan (Bilger and Young, 1935) and dextrins (Payne *et al.*, 1941). Payne *et al.*, (1941) also reported that dryland taro had less starch but more complex sugars and ash than wetland varieties.

Corm size is a problem in processing as well as for fresh corm consumer acceptance. Small corms are more appropriate for currently available processing equipment. Planting density is the most likely way to reduce corm size. There are a number of papers dealing with planting density and yield of both upland and dryland taro (De La Peña, 1977, 1978; Kagbo *et al.*, 1980). These papers deal with the production of corms for the fresh market and poi production. The interaction of planting density with fertilization, such as potassium with the high densities that are envisaged to reduce corm size and fried chip quality, is unknown.

Possible Measures of Corm Quality

Failure to understand the relationship between physiological age of the corm, storage capabilities and final snack food chip quality of dryland taro will hamper development of the industry. This project will concentrate on dryland Chinese taro, the object is to develop background information that will assist in the development of the snack food chip market. The first problem is to define quality and attempt to focus on those aspects which are most important for fried chip manufacture.

Possible measures of quality include:

- *i)* Size of corm, weight and length to circumference, including specific gravity.
- *ii)* Skin thickness and ease of removal.
- *iii)* Freedom from disease and injury
- *iv)* Corm storagability.
- *v)* Corm flesh color.
- *vi)* Corm flesh starch content and starch type.
- *vii)* Corm flesh free sugar, mucilage and phenol content.
- *viii)* Corm texture when boiled.
- *ix)* Chip texture, color and taste.

The measure of corm quality for fried chips is different from the quality criteria in the fresh corm market. There is, however, some overlap with a preference for smaller corms weighing from 2 to 3 lbs, freedom from disease and injury, and good color. There may, however, be a difference in textural requirements of boiled corms in the fresh market versus fried chips texture.

Large corms are a problem for both the fresh and chip processing market. Wholesalers indicate that consumers show a preference for 2 to 3 pound corms. This preference is reinforced when the cost is over $1 a pound, and a corm weighs 7 to 9 pounds. Larger corms also have to be cut before they can be mechanically processed. This requires additional handling and generates greater amounts of small chip fragments.

The published data on storage of corm after harvest is meager. The most quoted data is from a small study in 1923 that recommended storage at 55 to 60^{o}C (Browne, 1923). Maximum storage life was given as 1 to 5 months. The type of taro used was dasheen and not the Chinese Bun Long. Storage would be necessary to even out the supply for processing and in surface shipment of fresh corms. The effect of storage or holding for any period has not been studied. There is some suggestion that holding at room temperature for a week, leads to poor quality fried chips. The changes that occur in the corm during storage need to be correlated with the quality of chips produced.

The matter of corm postharvest injury and disease are interconnected. Frequently, postharvest disease starts in areas of tissue that have been damaged by mechanical injury. This relationship between injury and disease has not been determined for taro corms. The difficulty in handling 50 pound bags means they can suffer abuse engendered by frustration. Cartons (30 to 40 pounds) would be much more suitable, providing greater protection and ease of handling. The cartons are also preferable if a premium grade of corm sorted to 2 to 3 pounds is developed. For processing, handling in field bins (4 ft x 4 ft x 18 in) would be more appropriate than bagging.

Overall Objectives:

The overall objectives of this 3 year study of dryland taro for taro chips are therefore to:

(1) Determine the ability to store dryland taro corms harvested at various stage of development.
(2) Determine the snack food chip quality of corms harvest at different ages with and without storage.
(3) Determine whether simple methods can be used to evaluate corm chipping characteristics.
(4) Determine the growth, development and changes in chemical composition of dryland taro corm under irrigation.
(5) Determine the effect of planting densities and fertilization on taro corm growth and quality.

This project is part of an overall program on taro. The cooperators for this project include Ed Miranda and Alton Arakaki on Molokai; Steve Fukuda and Jim Silva on Oahu, and Dwight Sato on the Big Island. We will also be cooperating in other projects to monitor the effects of other agronomic practices on corm and chip quality.

Literature Cited

Amin, El.S. 1955. The polysaccharides of *Colocasia antiquorum* (Taro or Colocasia). J. Chem. Soc. Part III. p.2441-2445.

Bilger, L.H. and H.Y. Young. 1935. A chemical investigation of the fermentation occurring in the process of poi manufacture. J. Agric. Res. 51:45.

Bradbury, J.H. 1988. The chemical composition of tropical root crops. ASEAN Food J. 4:3-13.

Browne, M.W. 1923. Cold storage of carrots, beets and dasheens. Ice and Refrig. 64:361-362.

Ching, K.W. 1969. Some aspects of the physiological ontogeny of starch, total sugar, protein, leaf and corm of *Colocasia esculenta*. Univ. of Hawaii MSc Thesis.

Ching, K.W. 1970. Development of starch, protein, leaf and corm in *Colocasia esculenta*. Proc. 2nd Intl. Symp. Trop. Root & Tuber Crops. Honolulu, HI, Donald L. Plucknett (ed). P143-146.

Payne, J.H., G.J. Ley and G. Akau. 1941. Processing and chemical investigations of taro. Hawaii Agric. Exp. Stn. Bull. No. 86.

Standal, B.R. 1970. The nature of poi carbohydrates. Proc. 2nd Intl. Symp. Trop. Root & Tuber Crops, Honolulu, HI, Donald L. Plucknett (ed). p146-148.

DEVELOPMENT OF NEW TARO VARIETIES THROUGH BREEDING

Ramon S. dela Peña
Department of Agronomy and Soil Science
University of Hawaii-Kauai Research Branch Station

Abstract

The production of new crop varieties through hybridization is the only stable method of crop improvement. As a program, crop improvement through breeding has been a major project of most research centers and institutes. An example of the value of plant breeding was demonstrated by the release of IR-8 or "miracle rice" by the International Rice Research Institute in the mid-1960's. Other crops like corn and wheat had similar dramatic and valuable contributions. In Hawaii, new variety development has been and continues to be an important and well supported program of the Hawaiian Sugar Planters Association. Although taro is considered to be one of the oldest cultivated crops, there has virtually been no research program aimed at improving the varieties existing throughout the world. Because of the importance of taro as a commercial and staple crop in Hawaii and many countries in Asia and the Pacific area, an organized crop improvement program through breeding should be established and supported. Some of the advantages, problems, and general method of hybridizing taro are discussed.

Introduction

Production of new varieties of plants through breeding is the only stable method of improving crops. Crop yields and quality can be improved through pest and disease control, fertilizer application and cultural manipulations but all these have to be repeated each time the crop is grown (Abbott and Atkin, 1987; Hawkes, 1987; Hayes and Immer, 1942; Martin and Leonard, 1949). There are three general methods of crop improvement and these are (1) Introduction, (2) Selection, and (3) Hybridization. Introduction sometimes replaces hybridization when a superior variety is introduced from another source but often introduction provides foundation materials for hybridization. Selection follows and/or precedes either introduction and hybridization.

The process of developing new crop varieties or hybrids through breeding has been an important research program of the many international as well as national research centers and institutes. The International Rice Research Institute (IRRI) has become well known very quickly because of the success in producing the famous "miracle rice" or IR-8, a short stature, high yielding variety developed by plant breeder Henry Beachell shortly after the institute opened (IRRI, 1967). The corn and wheat programs of the U.S. as well as that of CIMMYT in Mexico produced new corn and wheat hybrids and varieties which gave similarly outstanding yield potentials and qualities.

Aside from increasing yields, plant breeding has been used to produce new plants which have resistance to some pests and diseases. The California rice breeding program has as one of its objectives the production of new varieties with resistance to low temperatures at the time of flowering. Most tropical rice varieties to not produce grains when exposed to temperatures below 60°F at flowering. Eating and processing qualities are also very important characteristics that are incorporated in new varieties or cultivars.

Taro, a crop of commercial importance in Hawaii and many Asian-Pacific countries is one of the oldest known cultivated food crops (de la Peña, 1970; Plucknett and de la Peña, 1971; Whitney, Bowers and Takahashi, 1939). In spite of its importance, there has virtually been no effort or work in improving its production potential through plant breeding. One reason for this lack of research activity is the difficulty of performing the work of cross-pollination due to the infrequent flowering habit of the taro plant. In its natural habitat, the taro plant rarely flowers and when it does, its flower anatomy discourages natural pollination (Plucknett, de la Peña and Obrero, 1970). The discovery of gibberellic acid as an aid in inducing flower formation in taro and the other edible aroids has encouraged some plant breeders to look at the possibility of producing new taro varieties or hybrids (Wilson and Cable, 1984). In a very limited breeding program at the University of the South Pacific in Apia, Western Samoa, Dr. J. Wilson was able to produce some hybrids and released a new variety which was named "Alafua Sunrise". This variety has a better yield potential than many of the commercial varieties in Western Samoa, however, its eating quality is not as good and acceptable as the popular variety, Niue. Aside from this breeding work, there has been little or no known breeding program in taro and the edible aroids elsewhere.

A Taro Breeding Program

I. Requirements

1. Foundation materials or parents for cross pollination - Without plants of known characteristics and/or quality, a breeding program can not be initiated.
2. Techniques for inducing flowering
a. Gibberellic acid spray.
b. Photoperiod manipulations (short and long days) and temperature treatments.
c. Natural flowering (not reliable, not all taro varieties flower under natural conditions).

II. Procedure

When all the necessary requirements of a breeding program are available, immediate objectives can be established to serve as a guide in the selection of parent materials. Usually, the first objective is to develop a new hybrid or variety with a potential for high yields. Once a high yielding material has been produced, other important characteristics such as resistance to pests and diseases, good eating quality, etc. are added.

The actual procedure involved in making crosses in taro is fairly simple and straight forward. Basically, pollens from one parent material is transferred or used to pollinate the flower of another plant. Figure 1 illustrates the parts of the taro flower. The inflorescence of the taro plant is called a spadix, enclosed by a part called spathe. When the flower emerges, the spadix is completely enclosed by the spathe. In approximately seven days, depending on the variety, the flower matures and reaches a stage when the pistillate part or female part becomes partly opened exposing the pistillate part. The upper tubular portion of the spathe also emits a very strong pleasant odor at this stage. When touched with the fingers, the pistillate parts or ovaries are sticky.

When pollens are shed, the upper part of the spadix or staminate part becomes covered with pollen grains which are powdery in appearance. Care should be exercised in removing this part of the flower so that the pollens will not drop or shed. Cross pollination can be accomplished by shaking the pollens over the pistillate flower, replacing the covering or spathe and bagging the whole flower to avoid further pollination by insects or other agents. Wrapping the flower with plastic flagging tape has been found to be satisfactory.

It should be noted that when the pistillate flower is receptive to pollination, pollens from the staminate part are usually not ready or available. This makes self-pollination of the flower difficult. In addition, the constriction between the male and female parts of the flower tightens preventing pollens from the same flower to reach the female part or ovaries. In cross pollination this characteristic of the taro flower is an advantage.

In approximately four weeks after pollination, the taro fruit starts to ripen and it can be harvested and the seeds extracted. Once extracted, the seeds should be stored in the refrigerator to preserve their viability. The seeds can also be planted immediately in fine peatmoss, either in a petri dish or any suitable container.

Under favorable conditions, taro seeds germinate in about five days after sowing. In another week, the seedlings can be transplanted in jiffy pots or bigger containers. When the seedlings reach a height of approximately six inches, they can be planted in the soil or field for initial evaluation.

The following slides will illustrate the various steps discussed in making crosses or producing taro hybrids. Some slides will also show the early growth of the seedlings.

Depending on the major objectives and/or priorities, evaluation of seedlings can be initiated as early or late during the first year of growth. Sometimes, evaluation for resistance to pests and diseases can be initiated as soon as the seedlings are big enough to be inoculated with the appropriate pathogen or pest.

For obvious reasons, evaluation for yield potential can not be started until at least some appreciable growth has been attained to indicate yield potentials. Usually, a fast growth or establishment accompanied by large stems and high leaf area index can be used as indicators for yield potential which means that some of these parameters have to be measured at regular intervals during the growth of the plants. The corm color which is important in the final utilization of the variety can be determined as soon as the plants are big enough to be cut into "hulis" or planting setts.

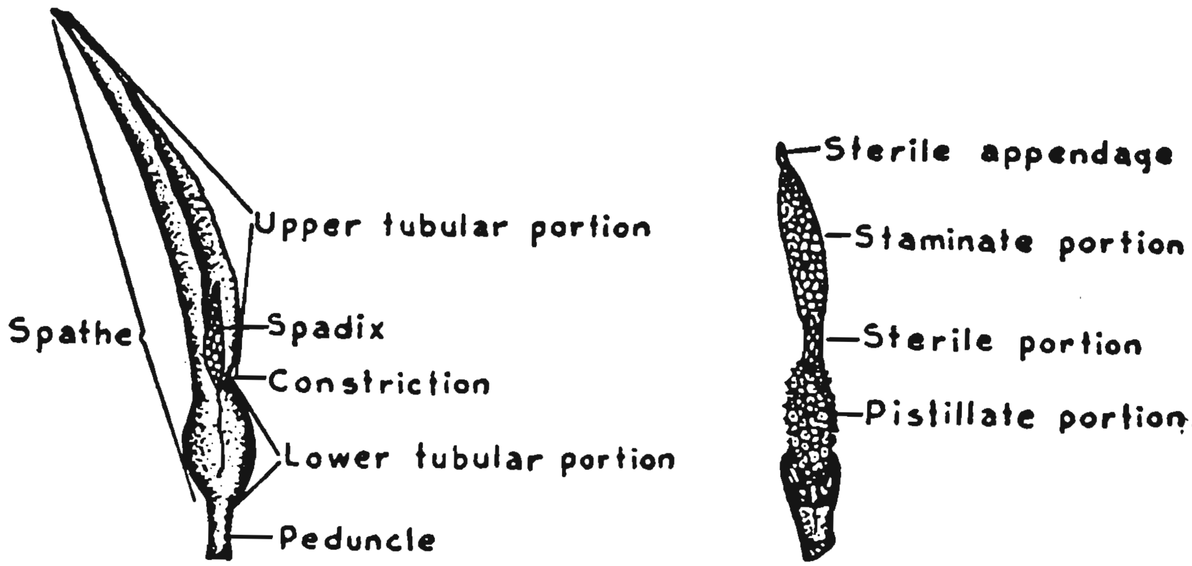


Figure 1. Anatomy of taro flowers (Adapted from Whitney, Bowers & Takahashi, 1939).

The following slides show some of the genetic variabilities than can occur when two different varieties or plants are cross-pollinated. Lehua Maoli was used as the male parent or source of pollens and Niue was the female parent of these particular hybrids.

III. Benefits

Improvement of crops through breeding offers several benefits for farmers. Production of hybrids or new plants from a breeding program increases the genetic base of any crop. The increased genetic base provides lines with different characteristics some of which could be resistance to some pests and diseases. This will prevent a catastrophic loss in crop production which might be caused by an epidemic of a plant pest or disease which in turn can cause a severe disruption of the flow of food supply to any population. The potato disaster which caused famine in Europe is a good example.

Superior agricultural productivity of the U.S. is in large part due to the high yields and quality of hybrids and varieties of crops such as corn, wheat, rice, potato, etc. grown by our farmers. Varieties and hybrids with resistance to the major plant pests and diseases account for the high production efficiency in the farms. The high yielding rice varieties patterned after IR-8 have now replaced most varieties grown in the Sacramento area accounting for the very high average production of rice in California. The flower and foliage industry of Hawaii is based on varieties produced through plant breeding.

A continuous plant breeding program such as the program of the HSPA provides new varieties with high yield potentials which are used as replacement after the yields of existing varieties have started to decline. The causes of yield decline in many existing varieties of various crops are not fully understood but one possible cause is the accumulation of non-lethal viruses in vegetatively propagated plants like sugarcane and taro.

IV. Problems

Before any plant breeding program can be initiated, germplasm nursery or foundation stocks must be available as parent materials. Initiation and maintenance of a germplasm nursery can be expensive. Collecting existing varieties can be accomplished by traveling to areas where the crop is growing. To prevent inadvertent introduction of pests and diseases, proper quarantine procedures must be followed.

In the case of taro, a known and consistent technique of inducing flowering is necessary to enable plant breeders to perform the necessary cross-pollinations. Spraying with GA or manipulation of the daylength can give satisfactory results. Researchers can not rely on natural flowering because many of the existing varieties of taro do not flower under natural conditions in Hawaii and one of these varieties is Bun-long. Bun-long and many varieties will only flower when sprayed with GA.

Plant breeding programs require manpower support for the pollination, seedling production and care, evaluation and increase of promising lines, and field plantings for advanced testing and evaluation.

The IRRI released IR-8 in a relatively short period of five years because of the tremendous support given their scientists in terms of funding and manpower but some crop improvement or breeding programs can be very time consuming depending on the objectives of the program.

Once a new material has been identified as promising and worth releasing for commercial use by farmers, planting materials can be produced and increased through conventional methods or tissue culture techniques.

References

Abbott, A. J. and R.K. Atkin (Editors). 1987. Improving Vegetatively Propagated Crops. Academic Press Ltd., London.

de la Peña, R.S. 1970. The Edible Aroids in the Asian-Pacific Area. Proceedings of the Second International Symposium on Tropical Root and Tuber Crops 1:136-140.

Hawkes, J.G. 1987. World Strategies for Collecting, Preserving and Using Genetic Resources. In: A.J. Abbott and R.K. Atkins (Eds.). Improving Vegetatively Propagated Crops. Academic Press Ltd., London pp. 285-301.

Hayes, H.K. and F.R. Immer. 1942. Methods of Plant Breeding. McGraw-Hill Book Co., New York.

IRRI. 1967. The International Rice Research Institute Annual Report, 1966. Manila Philippines.

Martin, J.H. and W.H. Leonard. 1949. Principles of Field Crop Production. The MacMillan Co., New York.

Plucknett, D.L. and R.S. de la Peña. 1971. Taro Production in Hawaii. World Crops. 23(5): 244-249.

Plucknett, D.L., R.S.de la Peña and F.P. Obrero. 1970. Taro (Colocasia esculenta), a Review. Field Crops Abstracts. 23: 413-426.

Whitney, L.D., F.A.I. Bowers and M. Takahashi. 1939. Taro Varieties in Hawaii. Hawaii Agricultural Experiment Station Bulletin No.84.

Wilson, J.E. and W.J. Cable. 1984. Promotion of Flowering, Seed Production and Seedling Screening in Minor Edible Aroids. In: Symposium of the International Society for Tropical Root Crops, 6th Proceedings. Lima. 1983. International Potato Center. pp. 151-156.

POTENTIAL FOR PRODUCTION OF *ALOCASIA*, GIANT TARO, ON THE HAMAKUA COAST OF THE ISLAND OF HAWAII

Sione Foliaki
Research Division-Vaini Experimental Farm
Ministry of Agriculture, Forestry, and Fisheries
Nuku'alofa, Kingdom of Tonga

William S. Sakai
College of Agriculture
University of Hawaii at Hilo

Sauni T. Tongatule
Agriculture Department
Alofi, Niue

Unlucky Tungata
Ministry of Agriculture
Rarotonga, Cook Islands

Ron Ka'ipo, Sheldon C. Furutani, Marcel M. C. Tsang, Gregory Nielson, and Richard Short
College of Agriculture
University of Hawaii at Hilo

Abstract

Production of six cultivars of Alocasia macrorrhiza (L.) G. Don. in the Piihonua area near Hilo on the Island of Hawaii ranged from a high of over 70,000 pounds per production acre for the cultivar Tonga to a low of 14,000 pounds for the cultivar Niu Kini. `Tonga' and `Niu Kini' are the most popular cultivars in the South Pacific. Production for other cultivars were: `Fiasega'- 19,000 pounds, `Laufola'- 22,000, `Faitama' - 18,000, and `Accession 18'- 64,000. `Niu Kini' has purple coloring and `Fiasega' has yellow coloring, the other cultivars have white fleshed stems. Production of Alocasia on the Hamakua Coast and marketing for human consumption has potential if the markets can be found on Oahu and the West Coast. Because production of stems alone in terms of starch for `Tonga' is near 13,000 pounds per acre per year, there is a definite potential for production of Alocasia for use as feed for cattle, swine, and poultry. If a method can be developed to process the leaves and stems into palatable food it would decrease the dependency of these industries on imported grains.

Introduction

The giant taro, Alocasia macrorrhiza (L.) G. Don., is a member of the family Araceae and is closely related to taro (Colocasia). However, unlike taro, most of the edible part of the stem is produced above ground which allows for easier harvesting. The edible stem grows up from the planting material so is never deeper in the ground than about 6 to 8 inches. Alocasia is commonly grown in upland areas, high islands, or drier areas of atolls. Like the dryland taro it does not require flooding. Alocasia grows year around and can be harvested at any time when it is needed. However, larger plants do flower in the summer and this tends to slow growth.

Alocasia is thought to have originated in Sri Lanka or India (Plucknett, 1976). It is presently cultivated in Asia in the countries of India, Sri Lanka, and Bangladesh where crop time is from 6 to 11 months. The variety grown in Sri Lanka (Desai ala) appears to be a small variety with stems averaging 4 to 6 pounds when spaced 2 X 4 feet (Soyza, 1938). In Bangladesh and many parts of India, Alocasia is grown for the leaves as well as the stems (Rashid and Daunicht, 1979; Kundu, 1967). The stems are cut into cubes and used in curry and the young leaves are used in soups or fritters (Rashid, 1980).

In the Pacific region, Alocasia is grown in mixed plantings with taro, yams, and banana principally in Wallis, Futuna, Tonga, and Niue. In these areas the flavor is considered superior to taro. Crop time is 18 to 24 months and corms are reported to be 3 to 4 feet long, 6 to 8 inches in diameter and weigh about 40 pounds (Coursey, 1968; Plucknett, 1970; Watson, 1979). The stems are boiled in water or with added coconut milk, lightly salted and served. An alternate method is to bake the tubers whole alone or with ti tubers. The fructose sugar from the ti tubers during baking runs down over the Alocasia making them very sweet.

In Hawaii, Alocasia was planted in upland valleys and one cultivar apparently grows rapidly and produces large edible stems. However, the Hawaiian preference is for taro and because of this Alocasia has not been grown commercially in Hawaii to any great extent.

Materials and Methods

Interest in growing Alocasia on the Hamakua Coast first developed while gathering research publications for a review of the literature (Sakai, 1983) on the aroid root crops: Alocasia, Cyrtosperma (giant swamp taro), and Amorphophallus (konjac, konnyaku, or elephant foot yam). Arrangements were made for Jill Wilson, of The University of the South Pacific, Alafua Campus, to ship us plantlets of 6 cultivars of Alocasia. These arrived in Hilo with help from Ramon dela Peña of the Kauai Experiment Station and the staff at the Lyon Arboretum. The plantlets included the two major cultivars `Tonga' and `Niu Kini' and four others: `Fiasega', `Laufola', `Faitama' and `Accession 18'. The project was initiated when Mr. Sione Foliaki arrived at UH-Hilo to study for his B.S. in Agriculture. Mr. Foliaki had assisted Jill Wilson at Alafua and was familiar with the culture of Alocasia.

The experimental design was a randomized complete block with 6 cultivars, 4 replications, and 4 plants per replication. The spacing was 4 X 6 feet with a border row completely surrounding the planting.

The Alocasia were planted at the UHH-Agricultural Farm Laboratory on Waianuenue Avenue in soil of the Hilo Series. Huli were collected from plants maintained in pots at the Panaewa Farm. Initial planting was in February, 1988. However, the quality of the planting material was not good and roots were not established until March. Because of the weakened condition of the plants they were also infested with spider mites. These were controlled by spraying with wettable sulfur in late April. Because there was no appreciable growth of the plants until after the mites were controlled in May, the crop time should be estimated at one year with harvesting in May of 1989.

Fertilization was 250 lbs/acre/crop each of nitrogen, phosphate and potash. N as a preplant and at 3, 5, and 7 months; phosphate as a banded preplant; and potash as a preplant and at 5 months. Dolomite limestone was added as an amendment at 1000 lbs/acre.

Results and Discussion

In terms of growth and production the cultivars separated into two groups. In the first group were two cultivars: `Tonga' with an average stem weight of 38.9 pounds and `Accession 18' with an average weight of 35.6 pounds (Table 1). In the second group were `Laufola' (12.3 lbs.), `Fiasega' (10.5 lbs.), `Faitama' (10.0 lbs.), and `Niu Kini' (7.8 lbs.).

The cultivar with the greatest production was `Tonga'. At the spacing of 4 feet X 6 feet (24 square feet per plant) the production was 1.62 pounds per square foot. Multiplied by 43,560, this equals over 70,000 pounds per planted acre. `Tonga' develops into a huge plant (Fig. 1A, B). At harvest the larger plants were over 10 feet tall and had lateral spreads of over 15 feet. The largest stem was 41 inches long, 8 inches in diameter and weighed over 70 pounds. `Tonga' is thought to have originated in the Tonga, Wallis, and Futuna area and is among the most widely grown cultivars. The leaves are green, the stem flesh is white, and the plant is almost free of irritation (Barrau, 1961; Migvar, 1968).

The cultivar `Accession 18' had production almost equal to `Tonga' (Table 1). Production was 1.48 lbs. per square foot or over 64,000 lbs per planted acre. The largest stem was about 40 inches long, 9 inches in diameter and weighed over 70 pounds. `Accession 18' is thought to be a hybrid between `Laufola' and `Tonga'. It has the tremendous growth rate of `Tonga' with the upright growth form and leaf shape of `Laufola'. At harvest the largest plants were over 15 feet tall with a lateral spread of about 10 feet (Fig. 1C, D). The lower surface of the petioles of `Accession 18' are also slightly purple like `Laufola'. The stem flesh is white.

`Laufola', `Fiasega', `Faitama', and `Niu Kini' all had production levels that were less than a third of those of `Tonga' and `Accession 18'.

Production of `Laufola' was 0.51 pounds per square foot, which is about 22,000 pounds per planted acre (Table 1). The largest stem was 24 inches long, 7 inches in diameter, and weighed 32 pounds. At harvest the larger plants were about 8 feet tall and 6 to 8 feet in diameter (Fig 2A, B).

The cultivar `Fiasega' is variegated green and yellow. It is very striking and could probably be sold for landscape purposes. These variegated types of Alocasia are reported to be more irritating, but are grown for their flavor and the color of the stem flesh (Betham 1982). Production of `Fiasega' was 0.44 pounds per square foot, which is about 19,000 pounds per planted acre (Table 1). The largest stem was 18 inches long, 7 inches in diameter and weighed 20 pounds. The larger plants were about 6 feet tall and about 6 feet in diameter (Fig. 2C, D).

`Faitama' differs from the other cultivars in that it produces many offshoots from the base of the plant (Fig. 3A, B). It also appears to be better adapted to wetter conditions than the other varieties (Table II). On the wetter side of the plot this cultivar produced about 20,000 pounds per acre and on the drier side 14,000 pounds. This is exactly opposite of the other cultivars (Table II). Average production for `Faitama' was 0.42 pounds per square foot or 18,000 pounds per planted acre. The largest stem was 18 inches long, 6 inches in diameter and weighed 20 pounds. The larger plants were about 5 feet tall and about 4 feet in diameter (Fig. 3A, B).

`Niu Kini' is the dark purple cultivar that along with `Tonga' form the principle cultivars of the South Pacific. The midrib and the petiole is dark purple and the coloration continues into the veins of the stem. The stem flesh of `Niu Kini' resembles that of the taro cultivar `Bunlong'. Growth of this cultivar in the present trial was variable and not what was expected of a major cultivar. Average production for `Niu Kini' was 0.33 pounds per square foot or 14,000 pounds per planted acre. The largest stem was 20 inches long, 7 inches in diameter and weighed 23 pounds. The larger plants were about 5 feet tall and about 6 feet in diameter (Fig. 3C, D). `Niu Kini' differed from the other cultivars in that the orientation of the leaves was more horizontal, unlike the vertical orientation of the other cultivars.

Conclusions

I. Marketing for human consumption

Marketing of Alocasia would be primarily to the peoples of the South Pacific now living on this Island, on Oahu, and on the West Coast. Alocasia stems are presently being shipped from Tonga and arrive in New Zealand in excellent condition. Thus, storage and transport would probably not be a problem in marketing. Alocasia stems from Tonga are also being sold in California and apparently arrive there in good condition. Alocasia is also being grown and sold on Oahu at Laie.

In terms of production and flavor preferences, the grower would need to investigate the ethnic background of the consumers in each of the market areas. The cultivar `Tonga' is preferred by Tongans and the production levels in our trial would seem to be high. `Tonga' could also be sold to most of the peoples of the South Pacific. `Accession 18' has good production, but is not a recognized cultivar and may be difficult to market. `Niu Kini' is preferred by many of the peoples of the South Pacific, but the low production would require a higher selling price. We would suggest a planting space of 4 feet X 4 feet to increase production per square foot without affecting growth. We plan to replant `Niu Kini' in a drier area to determine if the production can be improved.

`Fiasega' could probably be sold at a premium price because of the yellow stems, if a market could be found. Production of `Laufola' would probably not be profitable because it has a white stem and production is much lower than `Tonga'. `Faitama' appears to be a cultivar that is ideal for the home garden where stems are small and can be harvested on a continual basis without replanting.

II. Marketing as a carbohydrate source for swine, cattle, and poultry production on the Hamakua Coast

There appears to be a tremendous potential for large scale production of Alocasia on the Hamakua Coast for use in swine, cattle, and poultry feed. Production of stems alone for the `Tonga' cultivar is over 70,000 pounds per production acre per year. Development of a silage using the leaf blades and petioles as well as the stem would increase this poundage and also increase the protein content. Stems of Alocasia from other areas of the world average from 16% to 21% starch (Sakai, 1983). Using these percentages, this calculates at about 11,000 to 15,000 pounds of starch per acre per year. The average yield of wheat world wide is 1.6 metric tons per hectare or 8,700 pounds per acre (Martin, Leonard, and Stamp, 1976). The stems of Alocasia are low in protein, but leaves are reported to contain 4.3% protein. Thus, it appears that development of methods for processing the stems and leaves of Alocasia into palatable food for the cattle, swine, and poultry industries on this Island may help to relieve the dependency on imported grains. Indeed, there is a definite need for further research on Alocasia.

Literature cited

Barrau, J. 1961. Subsistence agriculture in Polynesia and Micronesia. B. P. Bishop Museum Bulletin 223: 43-67.

Betham, R. (1982). Personal communication. Western Samoa, Samoan-German Crop Protection Center-Nuu.

Coursey, D. G. 1968. The edible aroids. World Crops 20(4):25-30.

Kundu, B. C. 1967. Some edible rhizomatous and tuberous crops of India. Proceedings of the International Symposium on Tropical Root Crops 1: 124-130.

Martin, J. H., W. H. Leonard, and D. L. Stamp. 1976. Principles of Field Crop Production, Third Edition. Macmillan Publishing Co., New York. p. 430.

Migvar, L. 1968. How to grow taros, yams, cassava, and sweet potatoes. Mariana Islands, Division of Agriculture, Department of Research and Development, Trust Territories of the Pacific Islands, Agriculture Extension Bulletin, Number 7, pp. 7-8.

Plucknett, D. L. 1970. Colocasia, Xanthosoma, Alocasia, Cyrtosperma, and Amorphophallus. Proceedings of the Second International Symposium on tropical Root and Tuber Crops 2: 127-135.

Plucknett, D. L. 1976. Edible aroids. In Evolution of Crop Plants (N. W. Simmonds, ed.). Longman, London and New York, pp. 10-12.

Rashid, M. M. 1980. Personal communication. Bangladesh Agricultural Research Institute, Dacca, Bangladesh.

Rashid, M. M., and H. J. Daunicht. 1979. Chemical composition of nine edible aroid cultivars of Bangladesh. Scientia Horticulturae 10: 127-134.

Sakai, W. S. 1983. Aroid Root Crops: Alocasia, Cyrtosperma, and Amorphophallus, In Handbook of Tropical Foods (H. T. Chan, Jr., ed.). Marcel Dekker, New York. pp. 29-83.

Soyza, D. J. de. 1938. Yam cultivation in the Kegalla district. Tropical Agriculture Magazine of the Ceylon Agricultural Society 90(2): 73-75.

Watson, J. 1979. Importing root crops from the South Pacific Islands for New Zealand markets. In Small-Scale Processing and Storage of Tropical Root Crops (D. L. Plucknett, ed.). Westview Press, Boulder, Colorado.

Table 1. Alocasia Production Cultivar Trial

Block No.	Plant No.	Tonga	Niu Kini	Fiasega	Laugola	Fiatama	Acc 18
I	1	33.5	0.5	4.5	5.0	6.5	53.0
I	2	37.0	23.0	13.0	12.0	9.5	22.5
I	3	44.5	6.5	4.5	14.0	14.0	25.5
I	4	11.0	2.0	15.0	7.0	7.5	58.0
I Avg Wt		31.5	8.0	9.3	9.5	9.4	39.8
I lbs/sq ft		1.31	0.33	0.39	0.40	0.39	1.66
I lbs/acre		57,199	14,527	16,796	17,250	17,023	72,179

Block No.	Plant No.	Tonga	Niu Kini	Fiasega	Laugola	Fiatama	Acc 18
II	1	8.0	5.0	12.0	2.5	21.0	4.0
II	2	58.0	7.0	11.5	15.0	7.0	5.5
II	3	53.5	2.0	4.5	3.0	16.5	76.0
II	4	51.0	8.0	14.0	20.0	7.0	41.0
II Avg Wt		42.5	5.5	10.5	10.1	12.9	31.6
II lbs/sq ft		1.77	0.23	0.44	0.42	0.54	1.32
II lbs/acre		77,173	9,987	19,066	18,385	23,379	57,426

Block No.	Plant No.	Tonga	Niu Kini	Fiasega	Laugola	Fiatama	Acc 18
III	1	42.0	11.0	12.0	7.50	7.5	78.0
III	2	40.5	7.0	8.5	9.0	2.5	28.0
III	3	37.0	3.5	6.0	20.5	11.0	58.0
III	4	30.0	0.5	11.5	32.0	6.5	1.5
III Avg Wt		37.4	5.5	9.5	17.3	6.8	41.4
III lbs/sq ft		1.56	0.23	0.40	0.72	0.28	1.72
III lbs/acre		67,867	9,987	17,250	31,323	12,257	75,130

Block No.	Plant No.	Tonga	Niu Kini	Fiasega	Laugola	Fiatama	Acc 18
IV	1	70.0	24.5	6.0	11.5	7.5	2.0
IV	2	5.0	10.0	20.0	16.5	12.0	52.0
IV	3	50.0	11.0	14.0	9.0	6.5	34.0
IV	4	52.0	3.5	14.0	9.0	6.5	34.0
IV Avg Wt		44.3	12.3	12.9	12.3	9.3	29.5
IV lbs/sq ft		1.84	0.51	0.54	0.51	0.39	1.23
IV lbs/acre		80,351	22,244	23,379	22,244	16,796	53,567

Total	Tonga	Niu Kini	Fiasega	Laugola	Fiatama	Acc 18
Avg Wt	38.9	7.8	10.5	12.3	10.0	35.6
lbs/sq ft	1.62	0.33	0.44	0.51	0.42	1.48
lbs/acre	70,647	14,185	19,112	22,300	18,158	64,576

(Cultivar columns headed "CULTIVAR" in each block.)

Table 2. Comparison of Production from Wetter* and Drier Side of Experimental Plot

WETTER SIDE			CULTIVAR			
Lbs/acre	Tonga	Niu Kini	Fiasega	Laugola	Fiatama	Acc 18
BLOCK I	57,119	14,527	16,796	17,250	17,023	72,130
BLOCK II	77,173	9,987	19,066	18,385	23,379	57,426
AVERAGE	67,146	12,257	17,931	17,818	20,201	64,803

DRIER SIDE			CULTIVAR			
Lbs/acre	Tonga	Niu Kini	Fiasega	Laugola	Fiatama	Acc 18
BLOCK III	67,867	9,987	17,250	31,323	12,257	75,130
BLOCK IV	80,351	22,244	23,379	22,244	16,796	53,567
AVERAGE	74,109	16,116	20,315	26,784	14,527	64,349

*Wetter side received run-off of rain from roof of greenhouse adjacent to the plot. Drainage ditches surrounded the plot, but the drier side was also adjacent to a slope. Rainfall for the year ending May, 1989 was 155 inches.

Figures 1A & 1B. Plants of the cultivar 'Tonga' after one year of growth. Note the spreading habit of the leaves. Flowers are visible near the top of the plant in 1A. Note the shape of the stem after the leaves have been removed in 1B. The stem of this plant extended 8 inches into the ground. Figures 1C & D. Plants of the cultivar 'Accession 18' after one year of growth. Note the more upright form of leaves. Ruler is 18 inches long. Photographs taken in May, 1989.

Figures 2A & B. Plants of the cultivar 'Laufola' after one year of growth. Note the upright form of the leaves that is similar to 'Accession 18'. Figures 2C & D. Plants of the cultivar 'Fiasega' after one year of growth. Note the light colored petioles and leaf veins which are yellow. Ruler is 18 inches long. Photographs taken in May, 1989.

Figures 3A & B. Plants of the cultivar 'Faitama' after one year of growth. Note the production of many keikis at the base of the stem. This cultivar could probably be continuously harvested without replanting. Figures 3C & D. Plants of the cultivar 'Niu Kini'. In 3C the plants have just been planted. The white stake is about 1 foot tall. In 3D the plants after one year of growth. Note the spreading habit of the leaves. The dark colored petioles are purple. Ruler is 18 inches long.

DETERMINATION OF HERBICIDE RESIDUES IN EDIBLE TARO PARTS AND WETLAND FLOOD WATERS

Joseph DeFrank
Department of Horticulture
University of Hawaii-Manoa

Virginia A. Easton-Smith
Department of Horticulture
University of Hawaii-Manoa

Gladys Leong
Department of Agricultural Biochemistry
University of Hawaii-Manoa

Abstract

A preliminary experiment with seven preemergence herbicides identified oxyfluorfen as a promising herbicide for commercial taro (Colocasia esculenta) production in Hawaii. Oxyfluorfen was applied twice at 0.38, 0.56 and 1.11 kg/ha to taro grown under wetland flooded and upland conditions. No oxyfluorfen residues were found in plant tissues (limit of detection 0.02 ppm). Oxyfluorfen levels in water from treated lowland plots was determined. Trace levels present in flood waters immediately after treatment dissipated to undetectable levels (limit of detection, 0.001 ppm) within 24 hours.

Introduction

Taro is a tropical crop grown for edible corms, leaves and stems. The natural habitat of taro is south-eastern Asia and Malaysia (3). In Hawaii, taro is generally classified into two distinct groups. Dasheen (Colocasia esculenta var. antiquorum) is grown for small edible auxiliary corms that are boiled and eaten. Dasheen was promoted by the USDA in 1910 as a promising wetland crop for the southern United States (4). Chinese taro (Colocasia esculenta var. esculenta) is grown in Hawaii for consumption of young leaves and edible main corm (derived from seed pieces). Large corms (3 to 4 kg) are the desired commodity for fresh market and chip production (deep fried slices, similar to potato chips). Taro grown under flooded conditions is cooked and ground into a thick paste (poi) and eaten.

In a preliminary experiment (unpublished data) in Hawaii, seven preemergence herbicides were evaluated on Chinese taro and dasheen. All treatments were applied at 0, 69 and 172 days after planting (DAP). All applications made after planting were directed to the base of plants. Metribuzin (0.6 and 1.1 kg active ingrediant (ai)/ha) caused unacceptable crop injury on Chinese taro which reduced yield. No herbicide treatments adversely affected dasheen yield, which is not in agreement with a previous report (5) showing crop injury with diuron. Short term (35-40 days) activity of diethatyl (2.3 kg ai/ha), pronamide (2.3 kg ai/ha) and metolachlor (2.3 kg ai/ha) prevented their inclusion in subsequent studies. Diuron (1.1 and 2.2 kg ai/ha) and thiobencarb (4.5 kg ai/ha) provided acceptable weed control with no crop injury. However, they were dropped from further study due to problems in obtaining legal use of these materials in the USA. Oxyfluorfen emerged from this study as the most promising herbicide for use in commercial taro production.

The objective of this research was to determine the bioaccumulation of oxyfluorfen in edible taro corms and leaves from plants growing in wetland flooded and upland soils. Oxyfluorfen in wetland flood waters was also determined.

Upland Taro Study

The experiment was conducted on Oahu at the University of Hawaii Waimanalo Research Farm on a Waialua stony silty clay (vertic haplustoll, 2% organic matter and pH 6.3). The experiment began on May 21, 1987. Taro (cv. `Niue') planting material consisted of an axial corm with a 25-30 cm petiole attached. An experimental unit was 2 m wide, 4.6 m long with a double row of taro (within row spacing was 0.5 m and between row spacing was 0.6 m). Oxyfluorfen was applied (7 and 98 DAP) at three rates; 0.38, 0.58, and 1.11 kg ai/ha. The control treatment consisted of hand weeding 25, 48, 70 DAP. Taro leaves and corms were sampled 186 days after the final herbicide application.

In all experiments, herbicides were applied in a spray volume of 350 l/ha at 125 kPa using flat fan spray tips (Spraying Systems Co. Wheaton, IL 61820, USA). Herbicide treatments applied after planting were directed to the base of plants on plots that were weed free. Fertilizer, irrigation and other pesticides were applied as needed for commercial crop production (6). Treatments were replicated four times using a randomized complete block design. Standard procedures (1,2,7) were used for quantifying oxyfluorfen in edible taro leaves, corms and water.

Wetland Taro Study

Oxyfluorfen in Corms:

Both experiments were initiated on the Kauai Rice Experimental Field on the island of Kauai. The soil type was Hanalei silty clay (tropic fluvaquent, 6.6 % organic matter at pH 4.6). Weeds in control plots were removed by hand to avoid competitive effects on the crop. On May 12, 1987, oxyfluorfen was applied to the soil of drained wetland plots (0 and 95 DAP) at three rates; 0.38, 0.56, and 1.11 kg/ha. An experimental unit consisted of enclosed plots (1.8 m wide and 6.1.m long) with a double row of taro (cv.`Lehua Maoli') spaced 0.3 m within the row and 0.6 m between rows. Plots were formed so that water could continuously flow through each plot without cross treatment contamination. Taro corms were sampled for residue analysis 282 days after the final herbicide application.

Oxyfluorfen in Exiting Paddy Flood Waters:

On Sept. 30, 1988, oxyfluorfen was applied (0 and 81 DAP) at 0.56, and 1.11 kg/ha. An experimental unit was 1.8 m wide and 6.1 m long and contained a double row of taro (cv.`Maui Lehua'). Immediately after the second herbicide application flood waters entered treated plots. Water exiting treated plots was sampled 0 and 24 hours after herbicide application. At collection time, samples were passed through a clean sheet of filter paper (D.B. Eaton-Dikeman Co. Filter Paper, 533 cm. grade 615) supported by a stainless steel funnel into glass bottles wrapped with aluminum foil.

Results and Discussion

Two applications of oxyfluorfen on taro grown under upland and flooded wetland cultivation did not result in detectable bioaccumulation in edible leaves (dryland only) or main corms. These data will support the legal use of oxyfluorfen for upland taro production in Hawaii. Oxyfluorfen applied to lowland soil caused trace levels in water exiting plots 0 hours after application (Table 1.), at 24 hours none were detected. Due to strict rules governing pesticides in moving water, trace levels of oxyfluorfen in exiting flood water will preclude legal (in USA) use on lowland taro in the manner documented here. Research will be initiated to develop a wetland cultural practice which will prevent detectable levels of oxyfluorfen in waters leaving treated lowland soils.

Table 1. Oxyfluorfen Concentration in Flood Waters Exiting Treated Lowland Flooded Taro Plots at 0 and 24 Hours After Application[1].

Treatment	Rate (kg ai/ha)	Oxyfluorfen Conc.[2] (ppm)	
		0 Hours	24 Hours
Untreated control	-	ND	ND
Oxyfluorfen	0.38	.008	ND
Oxyfluorfen	0.56	.009	ND

Notes:
ND = None detected
[1] Mean of four replications.
[2] Limit of detection in flood water was 0.001 ppm.

Literature Cited

Adler, I.L. and C. K. Hofmann. 1980. Oxyfluorfen (Chapter 17), in Analytical Methods for Pesticides and Plant Growth Regulators, vol. XI, eds. G. Zweig and J. Sherma. Academic Press.

Adler, I.L., L.D. Haines and B. M. Jones: 1978. Gas-Liquid chromatographic determination of residues from the herbicide 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene. J. Assoc. Official Anal. Chem: 61:636.

Allen, E. F. 1940. The cultivation of Colocasia esculenta (L.) Schott. in Malaya. Malaysian Agr. J. 28:392-399.

Barrett, O. W. and O. F. Cook. 1910. Promising root crops for the South. U.S. Dept. Agri., Bur. Pl. Ind., Bull No. 164.

Kasasian, L. 1967. Chemical weed control in tropical root crops. Trop. Agr. Trin. 44:143-150.

Mitchell, W. C. and P. A. Maddison, 1983. Pest of Taro. Pages 180- 235 in J-K. Wang, ed. Taro, A review of Colocasia esculenta and its potentials., University of Hawaii press, Honolulu.

Pesticide Analytical Manual, vol. II, oxyfluorfen, pesticide reg. sec. 180.381, U.S. Dept. of Health and Human Services, Food and Drug Administration, revised September 1983.

TARO ROOT APHID

Dwight Sato
Cooperative Extension Service
University of Hawaii-Hawaii County CES

Jack Beardsley
Department of Entomology Chairman
University of Hawaii - Manoa

Arnold Hara
Department of Entomology
University of Hawaii - Hawaii County

Abstract

The taro root aphid, Patchiella reaumuri, is one of the most destructive insect pests in dryland taro. Crop damage up to 75% has been known to occur with Chinese taro and up to 100% with dasheen. The taro root aphid is host specific and apparently, it infests only taro and closely related plants of the family Araceae. In Hawaii, this species does not produce winged sexual forms, and reproduction is without fertilization by males. Taro root aphids have been observed to be associated with numerous attending ants, which probably moves the aphids around, enabling them to develop damaging populations.

No effective insecticide is available for use against root aphids on taro. Spread of this insect occurs mainly by planting infested "seed pieces" (hulis).

Description

The taro root aphid, Patchiella reaumuri, is one of the most destructive insect pests in dryland taro. It greatly reduces plant vigor, yield, and quality in dryland taro by sucking sap from taro roots. Crop damage up to 75% has been known with Chinese taro and up to 100% with dasheen. Extensive aphid damage usually have been observed to be coincidental with drought conditions during early plant growth stages.

This aphid is yellow and is usually covered with a mass of fine cottony and waxy threads. Signs of infestation appear sporadically as white mold on the fibrous taro roots. When populations are high, colonies are found both on roots and around the basal portions of leaf sheaths.

The taro root aphid is host-specific. Apparently, it infests only taro and closely related plants of the family Araceae. This aphid has been reported on dryland Chinese taro, dasheen, and Lehua taro on the island of Hawaii and is not known to occur on the other islands. It has not been reported to be a problem with taro grown under wetland conditions. In Hawaii, this species does not produce winged sexual forms and reproduction is without fertilization by males. Taro root aphids have been observed to be associated with numerous attending ants, which probably move the aphids around, enabling them to develop damaging populations.

Control

No effective insecticide is available for use against root aphids on taro. Spread of this insect occurs mainly by the planting of infested "seed pieces" (hulis). It is very important, therefore, to select clean seed pieces and to plant only in unaffected areas. If the proper moisture requirement is met and taro root aphid population is kept low during the early stages of plant growth, crop damage may be minimized. If you realize a heavy infestation, immediately remove and destroy the crop, including all culls or unharvested cormels, being sure to check around the border areas. The ground should be given a thorough and deep cultivation to drive ants away and to promote root degradation. Fallow or rotate with a non-taro type crop for at least one year.

Quarantine regulations in Hawaii prohibit the shipment of taro hulis originating from the Big Island. The purpose is to reduce the risk of pest establishment on the other islands where taro is grown.

References

Blackman, R.L. and V.F. Eastop. 1984. Aphids on the World's Crops: An Identification and Information Guide. Chichester, England: John Wiley & Sons. p 323.

Governor's Agriculture Coordinating Committee 1986. Taro Industry Analysis No. 3.

Metcalf, C.L. and W.P. Flint. 1962. Destructive and Useful Insects: Their Habits and Control. 4th Ed. New York: McGraw-Hill Book Co.

TARO DISEASES

Jeri J. Ooka
Department of Plant Pathology
University of Hawaii - Kauai Branch Station

Abstract

Although taro is susceptible to attack by at least twenty-three pathogens, only a few cause serious reduction in growth and production. Phytophthora blight (Phytophthora colocasiae) and Pythium root and corm rot (Pythium spp.) are the most serious fungal diseases of taro. Phytophthora blight is not yet found in Samoa, the Marquesas, the Society and Cook Islands. Dithane-M45 is available for control of Phytophthora blight. Pythium root and corm rot is found where ever taro is grown. Five Pythium spp. have been implicated as causal agents of the disease. Captan provides good control of the disease. Data to apply for metalaxyl registration on taro for control of Pythium root and corm rots are being collected. Phyllosticta leaf spot (Phyllosticta colocasiophila), Sclerotium blight (Sclerotium rolfsii), Black rot (Ceratocystis fimbriata), Rhizopus rot (Rhizopus stolonifer), Phytophthora root rot (P. palmivora) and Fusarium dry rot (Fusarium solani) are other fungal diseases which may be locally important. Hard rot (unknown etiology) is a major problem in wetland taro culture where it can cause substantial losses. Erwinia spp. may cause bacterial soft rots. Root-knot nematodes (Meloidogyne spp.) cause root galls and corm malformations.

Introduction

Yield loss of taro due to disease is not well known. Individual fields may suffer from little yield loss to as much as 30 percent loss due to Phytophthora colocasiae leaf blight (Trujillo and Aragaki 1964) and up to 100 percent from Pythium root and corm rot (Plucknett, de la Peña, and Obrero 1970). Most yield losses in the wetland taro crop may be traced directly to diseases. On the other hand, in dryland taro cultivation, water, and insects may be more important primary factors in limiting potential yield.

Fungal Diseases

Phytophthora Leaf Blight (Phytophthora colocasiae Rac.)

In the Pacific Basin, Pythium corm rot (Trujillo 1967; Plucknett, de la Peña, and Obrero 1970) and Phytophthora leaf blight (Trujillo 1967; Jackson and Gollifer 1975c) are the most serious diseases of the crop. Raciborski (1900) described Phytophthora colocasiae causing leaf blight in 1900 from Java. The pathogen probably spread from Java to the North Pacific; from Java to the Central Pacific; and from Java to the South Pacific (Trujillo 1967). Movement on the northern route went from Java to Taiwan, where Butler and Kulkarn (1913) reported it in 1911. From Taiwan it is believed to have moved to Japan and then to Hawaii, arriving probably in the early 1920s.

The first observation of the disease from the Philippines was in 1916 (Gomez 1925). Movement into Micronesia then probably came from the Philippines (Trujillo 1967). The most recent spread extends into the South Pacific through New Guinea, Australia, the Solomons, and Fiji, where Parham (1949) reported it present in 1948. The disease has not been reported from Samoa, Tonga, the Cook Islands, the Society Islands, or the Marquesas Islands.

Epidemics of leaf blight may occur throughout the year during rainy, overcast weather when night temperatures are between 20-22 °C and temperatures during the day are from 25-28 °C. Entire fields may be blighted in five to seven days under these conditions (Trujillo 1965; Trujillo and Aragaki 1964).

The early stages of the disease are characterized by small circular water-soaked lesions 1-2 cm in diameter, generally dark brown or purple. A clear amber fluid exudes from the center of the lesion. This liquid turns bright yellow or dark purple when it dries. The lesions rapidly enlarge and take on a zonate appearance. The zonation is the result of the temperature-related growth response of the fungus, with rapid growth during the warm days followed by slow growth during the cooler nights. The sporangia appear as a white fuzz on both sides of the leaf. The ring of sporangia are particularly prominent in the morning before the leaves dry. After initial establishment lesion development is rapid until the leaf is entirely colonized and collapses. Under severe conditions the fungus destroys the leaf petiole as well as the lamina and enters the corm causing a firm cream to brownish rot, with little or no odor. The difference between healthy and diseased tissue is well-defined.

The corm rot phase, although not a problem in Hawaii, limits production in the Marianas and the Caroline Islands. Phytophthora colocasiae is probably the principal cause of storage rots in the Solomon Islands and other islands in Melanesia and Micronesia. Up to 70 percent of the rots in the Solomons are attributed to this fungus (Jackson and Gollifer 1975b). It is not a cause of storage rot in Hawaii.

Copper fungicides applied with low volume spraying equipment are effective in Hawaii for control of this disease. A back-mounted knapsack mist blower can cover up to 12.5 meters horizontally with its valve fully opened and motor accelerated to maximum air speed. For each tank mix 227 g of basic copper to 7.6 liters of water and 14 ml of spreader sticker is used. The spraying should be done on days when wind velocities are less than 8 kph, with the spray directed downwind. Spraying should begin when the taro is 4 months old, with application every week during the rainy weather and every two weeks during the dry weather. Fungicide application should continue until the plants are 9 months old[1].

Copper oxychloride applied weekly at a rate of 2.24 kg ai/38 l/ha with a mist sprayer provided control superior to manzeb and captafol in the Solomon Islands (Jackson and Gollifer 1975a). While captafol provided excellent control of Phytophthora leaf blight, it is phytotoxic to taro and therefore dangerous to use (Berquist 1972, 1974). Manzeb provided good control and had a high residual effect without the phytotoxicity of captafol (Berquist 1972, 1974). Chemical control as developed for Hawaiian conditions is not effective in the wet tropics[2].

Dithane M-45 for control of Phytophthora leaf blight may be applied at 7 to 14 day interval until danger of infection is past at a rate of 1.5 to 2 lbs per acre in 50 to 100 gallons of water with enough Triton B-1956 for through wetting. No more than 25 application to a single crop are permitted and application must be discontinued when plant are 9 months old.

Deshmukh and Chibber (1960) reported the variety Ahina to be resistant to the blight. Paharia and Mathur (1964) found the variety Poonampat to be immune and Sakin V to be resistant to blight in their tests. No resistance has been reported elsewhere in the Pacific Basin (Parris 1941; Hicks 1967).

Increasing planting distance from 46 cm to 75 cm reduces blight incidence in Hawaii (Parris 1941). Sanitation by pruning and removing infected leaves biweekly appears to help reduce disease incidence in the Solomons (Jackson and Gollifer 1975a). Exclusion through quarantine will protect areas still free of the pathogen.

Pythium Rot (Pythium aphanidermatum Fitzpatrick, P. graminicola Subramaniam, P. splendens Brown, P. irregulare Buisman, P. myriotylum Drechsler, P. carolinianum Matthews, P. ultimum Trow.)

Pythium root and corm rot is probably the most widely distributed disease of the crop. Soft rot has been reported from New Caledonia, New Hebrides (Dumbleton 1954), Hawaii (Sedgwick 1902; Carpenter 1919; Parris 1939) Samoa, and Palau (Trujillo 1967), the Solomon Islands (Jackson and Gollifer 1975a), and Puerto Rico (Alvarez-Garcia and Cortes-Monllor 1971). This disease was probably spread with the introduction of the crop. Pythium aphanidermatum, P. graminicola, and P. splendens have been observed to cause losses of up to 80 percent in Palau, Samoa, and Hawaii (Trujillo 1967). Bugnicourt (1954) has reported heavy losses in New Caledonia due to P. irregulare. Jackson and Gollifer (1975a) find P. myriotylum persistently associated with soft rot in the Solomons, while Ooka and Uchida (1985 reported it from Hawaii and Kertz-Moehlendik et al. (1983) found it in Western Samoa. Ooka and Yamamoto (1979) have noted a prevalence of P. carolinianum in soft rotted material in Hawaii.

Conditions required for the occurrence of epidemics of corm soft rot are still only vaguely understood. Warm and stagnant water in the paddies of wet-grown taro as well as poor field sanitation have been suggested as important factors contributing to the high incidence of soft rot (Parris 1941; Plucknett and de la Peña 1971; Plucknett, de la Peña, and Obrero 1970).

The normally firm flesh of the corm is transformed into a soft, mushy, often malodorous mass. In wetland culture, the root system is destroyed except for a small fringe near the apex of the corm. Diseased plants are easily removed from the soil by hand. The plants become stunted, with leaf stalks shortened and leaf blades curled and crinkled, yellowish and spotted. Upon the demise of the main corm the lateral cormels develop roots and remain clustered around the cavity left by the disintegration of the main corm. The skin of the diseased corm usually remains intact until complete disintegration of the corm interior has taken place. When the corm is cut open there is usually a sharp line of demarcation between the healthy and diseased tissue. Newly planted huli may be killed before they are able to produce leaves or may be severely stunted.

Pythium rot caused by P. splendens is white, dry, and crumbling with a sharply defined, irregular boundary between healthy and decayed tissue. A zone of light brown undecayed tissue is often present in front of the rot.

The severity of soft rot may be reduced in soil by incorporating 112 kg Captan 50 WP/ha into the acid soils before planting. Captan is inactivated in alkaline soils. Huli should be selected carefully to avoid those showing any Pythium infection. The selected huli should then be dipped into a Captan suspension to provide them with protection for a few days after planting (Trujillo 1967). However, chemical control measures utilizing Captan are not always successful in reducing losses (Plucknett and de la Peña 1971; Plucknett, de la Peña, and Obrero 1970). Currently, Captan is being supported for registration by IR-4 for use on taro. Parris (1941) found that copper sulfate at doses effective for soft rot control was phytotoxic.

Resistance to Pythium rot occurs in the Hawaiian varieties Kai Kea and Kai Uliuli (Parris 1941). Others exhibiting some field resistance to soft rot are Piko Uaua and Lehua Maoli[3]. The cultivar Oga is tolerant to root attacks in the Solomons and is recommended for areas where Pythium root rot is known to be a problem (Jackson and Gollifer 1975b).

Phyllosticta Leaf Spot (Phyllosticta colocasiophila Weedon)

Phyllosticta leaf spot can often be seen on dryland taro in Hawaii, especially in the high rainfall areas of the islands. It is also known in American Samoa.

Cloudy, rainy weather for a protracted time (2-3 weeks) accompanied by cool winds is conducive to infection and disease development. The disease is limited by hot days and dry cool nights.

The spots on the leaves vary from 8 mm to 25 mm or more and are oval or irregular in shape. The young spots are buff to reddish brown. Older spots are dark brown with a chlorotic region surrounding the lesion. The centers of the infected area frequently rot out to produce a shot-hole type lesion. Phyllosticta spots generally resemble those caused by Phytophthora colocasiae, except for the absence of sporangia produced on Phytophthora colocasiae lesions.

No control is recommended unless Phyllosticta spot is continuously present and causing significant defoliation. Collecting and burning the diseased leaves seems to be of some value. The Hawaiian variety Manini Uliuli is resistant to fungal penetration through the unbroken epidermis (Parris 1941).

Cladosporium Leaf Spot (Cladosporium colocasiae Sawada)

Cladosporium colocasiae causes a relatively innocuous disease common on dryland taro in Hawaii (Parris 1941). Bugnicourt (1958) reports that C. colocasiae is frequently present in the planting of taro in irrigated terraces of New Caledonia. According to Trujillo (1967), it is present in the New Hebrides, Western and American Samoa, the Carolines, and the Marianas.

The disease attacks both wetland and upland taro and occurs mainly on the older leaves. On the upper surface the spot appears as a diffuse light yellow to copper area. On the lower leaf surface the spots are dark brown due to superficial hyphae, sporophores, and conidia of the fungus. The lesions are generally 5-10 mm in diameter.

Since no economic loss has been attributed to the disease, no control measures are needed (Parris 1941).

Sclerotium or Southern Blight (Sclerotium rolfsii Sacc.). Sexual stage: Pellicularia rolfsii (Curze) West (syn. Corticium rolfsii Curzi)

Sclerotium blight is generally a problem of dryland taro, although wetland taro is frequently infected. This disease has been reported in Fiji (Dumbleton 1954), the Philippines (Fajardo and Mendoza 1935), Hawaii (Parris 1941), and India (Goyal et al. 1974). This disease appears to be one of over mature corms and plant stress. Sclerotia abundantly produced on infected corms persist in the soil, causing serious outbreaks of the disease in warm, wet weather following a significant dry spell. They also float on the water of paddies, infecting the dead petioles of the taro when the opportunity presents itself and subsequently invading the corm and producing a rot in the field and in storage under some conditions.

Affected plants are usually stunted and the corms are rotted at the base where abundant sclerotia of the pathogen develop. The sclerotia are small, almost spherical lemon yellow to dark brown bodies resembling cabbage seeds. The rotted tissue is ocherous to brown and soft with a tendency to stringiness. A dense white mycelium may cover the tissue. In the wetland culture the rot frequently starts at the waterline on the corm rather than at its base.

Sclerotium rot of the corm is generally a shallow surface rot occurring below the external mycelial coating of S. rolfsii and occasionally penetrating deeply into the corm as a light pink soft rot with distinct margins. Sclerotia are produced in four to six days.

Sclerotium rolfsii may survive saprophytically on plant debris or as Sclerotia in the soil. When sufficient moisture is present sclerotia germinate and infect young or old roots, dead leaf petioles, and over mature corms. The disease is usually serious during warm wet periods. Flooding of paddy fields in early stages of disease development is an excellent cultural control method in Hawaii. For dryland taro, harvesting the taro before it becomes over mature will reduce losses to this disease. Burying plant debris after harvest by deep plowing is suggested for controlling this disease in other crops (Graham, Kreitlow, and Faulkner 1972; Brandes, Cordero, and Skiles 1959).

There are no chemicals registered for control of Sclerotium rot on taro in the United States (Trujillo 1967).

Spongy Black Rot (Botryodiplodia theobromae Pat.)

Botryodiplodia theobromae causes a spongy rot, occasionally becoming dry and powdery, ranging in color from cream to grayish brown and frequently becoming dark blue to black with an indistinct margin between healthy and diseased tissue. The fungus is capable of invading undamaged corms under conditions of high relative humidity.

Black Rot (Ceratocystis fimbriata Ell. and Halst.)

Ceratocystis fimbriata causes a soft dark to charcoal black rot with a fragrant banana odor, starting from natural or mechanical wounds in corms.

Rhizopus Rot (Rhizopus stolonifer Sacc.)

In Hawaii, Rhizopus stolonifer has caused serious losses in corms stored at moderate temperatures and high humidities while they were awaiting shipment.

Rhizopus rot is a white to cream colored soft rot ranging in consistency from cheesy to watery with a slight yeasty odor. The skin of the corm generally remains intact until the rot is very advanced. External development of mycelium is sparse, however, sporulation at breaks in the skin and wounds resulting from the removal of cormels are extensive, covering these areas with a black powdery layer.

Losses to this disease can be minimized through removal of the roots and soil from the corm, rinsing the corms well with clean water, and dipping them into a 0.5 percent solution of NaOCl for approximately one minute, air drying, and storing the corms in a cool, clean area of approximately 50 percent relative humidity (Ooka 1981).

Fusarium Dry Rot (Fusarium solani [Mars.] Syn. and Hans., Fusarium spp.)

Fusarium dry rot is a brown rot, mostly dry and powdery but sometimes becoming wet and soft in later stages, with a distinct margin between healthy and diseased tissues.

Viral Diseases

Dasheen Mosaic

Dasheen mosaic virus, a flexuous rod 750 nm, was initially described in 1970 as a polyvirus infecting members of the Araceae (Zettler et al. 1970). It has since been detected in taro in Florida (Hartman and Zettler 1972); Egypt (Abo El-Nil and Zettler 1976); Puerto Rico (Alconero and Zettler 1971); Venezuela (De Brot and Ordosgiotti 1974); Japan (Toyama 1975); the Netherlands (van Hoof 1971); the Solomon Islands (Gollifer and Brown 1972; Kenten and Woods 1973); Fiji (Abo El-Nil, Zettler, and Hiebert 1975); and Hawaii[4]. While it has not been documented as reducing yield in taro, it has been shown to adversely affect the growth of Caladium, Dieffenbachia, Philodendron (Hartman and Zettler 1974), and new cocoyam (Volin and Zettler 1976). The virus is well characterized (Hartman 1974; Zettler et al. 1970). Purification techniques for the virus and production of virus specific antisera have been developed (Abo El-Nil, Zettler, and Hiebert 1975).

It is a stylet-borne virus carried by aphids (Myzus persicae Sulzer, Aphis craccivora Koch., A. gossypii Glov.). The foliar symptoms include a dispersed and veinal mosaic pattern on the leaves. Leaf distortion is generally mild to moderate. Plants generally become asymptomatic three to four months after initial symptom expression. Symptom expression seems to be more pronounced during the cooler months of the year in Hawaii. Apparently this virus does not cause appreciable yield reduction in the varieties grown commercially, and the quality of the corm is not affected. Varietal resistance appears to be a good method for reducing the incidence of this disease in taro.

Alomae and Bobone

Gollifer and Brown (1972) described for the first time two virus diseases from the Solomon Islands. Alomae, a disease apparently caused by two bacilliform viruses, results in the death of susceptible cultivars (Kenten and Woods 1973; James, Kenten, and Woods 1973). At present this disease is confined to Papua New Guinea and the island of Malaita in the Solomons (Gollifer et al. 1975). The etiology of Alomae requires additional studies. A purification technique to get virus preparations suitable for production of virus-specific antisera as well as for use in biochemically and physically characterizing the particles needs to be developed. Vectors and host ranges, especially of the small bacilliform particles, need to be clarified.

Early symptoms of Alomae are a usually conspicuous feathery mosaic of the leaves. Young leaves are often crinkled and fail to open normally. Laminae of malformed leaves are thickened with hypertrophied veins. As the disease progresses, leaves fail to open and begin to die at the tip. Necrosis moves down the petiole and the plant dies.

Bobone is similar to Alomae except that the plants affected tend to be more stunted with curled, twisted leaves. The distorted foliage remains dark green. Recovery occurs in four to six weeks. Plant with Bobone contain only the large bacilliform virus.

These diseases are perpetuated by planting infected taro huli and possible transmission of the virus particles by insect vectors from older plantings to new plantings. It is suspected that the large bacilliform virus particle is transmitted by the taro planthopper, Tarophagus proserpina (Kirk); the smaller bacilliform particle could be transmitted by mealybugs.

Rouging plants infected with Bobone and Alomae to reduce the reservoir of pathogens and the use of resistant varieties appears to be the most practical approach to controlling these diseases.

Bacterial Diseases

Bacterial Soft Rot (Erwinia carotovora [L.R. Jones] Holland; E. chrysanthemi Burkholder, Mcfadden, and Dinock)

Bacterial soft rot is a strong smelling watery soft rot ranging in color from white to dark blue. Wounds and bruises caused by the feeding of insects and other animals and those inflicted at harvest are the most common infection courts for this disease. Abundant moisture is required for invasion of the bacteria.

Control measures therefore include careful handling of corms to minimize injury at harvest, air drying of corms, and storage at low temperatures of only the sound corms.

Bacterial Leaf Spot (Xanthomonas campestris pv dieffenbachiae)

The bacterial leaf spot of taro reported from India (Asthana 1946) and present in Hawaii is not important. It is characterized by yellow or brown-necrotic marginal and sub-marginal lesions of the leaf lamina with tan or pale yellow interveinal bleaching extending toward the piko of the leaf.

Nematode Diseases

While several nematode species are commonly reported on taro, little work has been done on the effect of these invertebrates on taro yield. The following nematodes have been reported on taro or dasheen in Hawaii: Pratylenchus sp. (Rabbe, Connors, Martinez 1981); Helicotylenchus sp. (Plant Disease Clinic [PDC] 1981); H. dihystera (Cobb) Sher (Holtzmann[5]); Rotylenchulus reniformis (PDC 1980, 1981; Holtzmann[6]); Meloidogyne sp. (Parris 1940; Rabbe, Connors, Martinez 1981; PDC 1980); M. incognita (Kofoid-White) Chitwood (Holtzmann[7]); M. javanica (Treub) Chitwood (Holtzmann[8]); Longidarus sylphus Thorne (Holtzmann[9]); and Tylenchorhynchus sp. (PDC 1981). Meloidogyne spp. (Byars 1917; Nirula 1959), Pratylenchus sp. (Kumar and Souza 1969), and Aphelechoides sp. (Tandon and Singh 1974) have been reported on taro or dasheen elsewhere.

Root-knot nematodes (Meloidogyne spp.) damage dryland taro when the crop is planted in infested soils. Galls on the root and swelling and malformations on the corm are characteristic of attack by this nematode. Severe attacks will stunt the plants and render it chlorotic.

Fumigation with dichloropropene, fenamiphos, of D-D (Nemafene) is desirable for control of root-knot nematodes in heavily infected soils. These chemicals are not registered in the United States for use on taro. Other root and corm feeding nematodes may also be controlled by soil fumigation. Treatment of dasheen corms with water at 50°C for 40 minutes kills the nematodes in the corms (Byars 1917). This treatment provides clean planting material.

Diseases of Uncertain Cause

Taro hard rot or "guava seed" is of unknown etiology and only reported from Hawaii where it may cause losses of up to 100 percent (Bowers 1967; HAES 1938; Parris 1941). Trujillo (1967) suggests that damage caused to feeder roots and large roots by Pythium spp. may be responsible for the problem. Hard rot incidence is high were the occurrence of Pythium corm rot is low and vice versa (Parris 1941; Trujillo 1967). It has also been reported that the use of planting material from infected corms increases the disease incidence in the subsequent crop (Parris 1941). This observation suggests a systemic biotic infection. Unfortunately, light microscopy and standard mycological isolation procedures have not produced positive indication of a fungal pathogen thus far (Takahashi 1953, Ooka[10]). Suboptimal levels of oxygen in the paddies have also been advanced as a cause of this condition (HAES 1920). However, taro in dryland culture sometimes exhibits similar symptoms in situations unlikely to be oxygen deficient (Ooka[11]).

The disease destroys the vascular system of the corm, starting with the root traces and working progressively inward. The healthy corm has a smooth skin. The skin of a diseased corm, on the other hand, is bark-like, 3 to 6 mm thick, deeply furrowed, crumbly, and coarse.

Affected areas of the corm are woody and appear dull. They are filled with walled off vascular elements tan to reddish brown in color, very much like the seed cavity of a cross-sectioned guava (Psidium guajava), thus giving the disease its local name "guava seed". In advanced stages of hard rot all that remains of the corm is a hardened, dark brown to black skeletal framework. Damage to roots by high salt concentration, whether through intrusion by salt water in paddies lying near sea level or induced by the application of commercial fertilizers may account for the stratification of the affected areas and the general limiting of the damage to the lower one-third of the corm.

Cultural practices to avoid root injury during corm development should be emphasized. There is some indication that liming of the fields is beneficial. Four varieties in the Mana group and Kai Kea are immune to hard rot. Kai Uliuli is resistant to both Pythium rot and hard rot (Parris 1941). Ooka[12] found Hapuu and Manini Kea to have little hard rot.

Abiotic Diseases

Physiological

Starch, present in normal corms, is deficient or absent in those with "loliloli", a term used in Hawaii to describe a physiological disorder of taro. While the normal corm is firm, crisp, and resilient to the touch, loliloli taro is soft and spongy and water exudes when affected parts are squeezed.

Loliloli taro is the result of withdrawal of starch from the corm. This starch is converted into sugar, which is used by the plant to develop new leaves and other parts. Any action that encourages resumption of vegetative growth in mature taro is likely to result in loliloli taro; therefore, use of nitrogenous fertilizers after the corm has formed or the natural growth-decadence of the plant has started should be avoided to reduce chances of loliloli taro occurring.

Notes
[1]. E.E. Trujillo 1975 personal communication.
[2]. E.E. Trujillo 1978 personal communication.
[3]. J.J. Ooka 1978, unpublished data, University of Hawaii, Honolulu.
[4]. J.J. Ooka 1980, unpublished data, University of Hawaii, Honolulu.
[5]. O.V. Holtzmann 1980: personal communication on nematodes.
[6]. Ibid.
[7]. Ibid.
[8]. Ibid.
[9]. Ibid.
[10]. Ooka 1978.
[11]. Ibid.
[12]. Ibid.

Literature Citations

Abo El-Nil, M.M., and Zettler, F.W. 1976. Natural occurrence of dasheen mosaic virus in Egyptian taro Colocasia antiquorum. Plant Dis. Rep. 60:281-285.

Abo El-Nil, M.M., Zettler, F.W., and Hiebert, E. 1975. Purification of dasheen mosaic virus. Proc. Amer. Phytopathol. Soc. 2:73.

Alconero, R., and Zettler, F.W. 1971. Virus infections of Colocasia and Xanthosoma in Puerto Rico. Plant Dis. Rep. 55:506-508.

Alvarez-Garcia, L.A. and A. Cortes-Monllor. 1971. Currutaca: A Pythium soft rot of Xanthosoma and Colocasia spp. in Puerto Rico. J. Agr. Univ. Puerto Rico 55:78-84.

Asthana, R.P. 1946. Bacterial leaf-spot of arum. Curr. Sci. (Bangalore) 15:356.

Bergquist, R.R. 1972. Efficacy of fungicides for control of Phytophthora leafblight of taro. Ann. Bot. (London) 36:281-287.

Bergquist, R.R. 1974. Effect of fungicide rate, spray interval, timing of sprayapplication and precipitation in relation to control of Phytophthora leaf blight of taro. Ann. Bot. (London) 38:213-221.

Bowers, F.A. 1967. Agricultural history of taro. Univ. Hawaii Coop. Ext. Serv.Misc. Publ. 36:8-13.

Brandes, G.A., Cordero, T.M., and Skiles, R.L., eds. 1959. Compendium of plantdiseases. Philadelphia: Rohm and Haas.

Bugnicourt, F. 1954. Phytopathologie. Courr. Cherch. 8:159-186.

Butler, E.J., and Kulkarn, G.S. 1913. Colocasia blight caused by Phytophthora colocasiae Rac. Mem. Dept. Agr. in India, Bot. Ser. 5:233- 259.

Byars, L.P. 1917. A nematode disease of the dasheen and its control by hot water treatment. Phytopathology 7:66.

Carpenter, C.W. 1919. Preliminary report on root rot in Hawaii. Hawaii Agr. Exp.Sta. Press Bull. 54.

De Brot, E.A., and Ordosgiotti, A. 1974. Dasheen mosaic virus infection on Colocasia and Xanthosoma in Venezuela. Plant Dis. Rep. 58:1032-1034.

Deshmukh, M.J., and K.N. Chibber. 1960. Field resistance to blight (Phytophthora colocasiae Rac.) in Colocasia antiquorum, Schott. Curr. Sci.(Bangalore) 29:320-321.

Dumbleton, L.J. 1954. A list of plant diseases recorded in South Pacific territories. South Pacific Commission Technical Paper 78.

Fajardo, T.G., and Mendoza, J.M. 1935. Studies on the Sclerotium rolfsii Sacc.Philipp. J. Agric. 1935, pp. 387-425.

Gollifer, D.E. and Brown, J.F. 1972. Virus diseases of Colocasia esculenta in the British Solomon Islands. Plant Dis. Rep., 56:597-599.

Gollifer, D.E., Jackson, G.V.H., Dabek, A.J., Plumb, R.T., and May, Y.Y. 1975.Taro viruses in the Solomon Islands: symptoms and transmission. South Pacific Commission Working Paper 20. Presented at the Regional Meeting on the Production of Root Crops, 24-29 November 1975, Suva, Fiji.

Gomez, E.T. 1925. Blight of Gabi (Phytophthora colocasiae Rac.) in the Philippines. Philipp. Agr. 14:429-440.

Goyal, J.P., Naik, S.M., Pathak, V.N., Sharma, H.C., and Prasada, R. 1974. Evaluation of some modern fungicides for the control of Sclerotium rolfssi Sacc.inciting the tuber rot of Colocasia antiquorum L. (Arvi). Nova Hedwigia Beiheftezur 47:205-210.

Graham, J.H., Kreitlow, K.W., Faulkner, L.R. 1972. Diseases. In: Alfalfa science and Technology, ed. C.H. Hanson, pp. 497-526. Amer. Soc. Agron., no. 15.

Hawaii Agricultural Experiment Station. 1920. Taro. Rep. Hawaii Agr. Exp. Sta.,pp. 39-40.

Hawaii Agricultural Experiment Station. 1938. Taro. Rep. Hawaii Agr. Exp. Sta., pp. 36-38, 86-87.

Handy, E.S.C. 1940. The Hawaiian planter. I. His plants and areas of cultivation. Bull. Bernice P. Bishop Mus. (Honolulu) 161:6-130.

Hartman, R.D. 1974. Dasheen mosaic virus and other phytopathogens eliminated from caladium, taro and cocoyam. Phytopathology 64:237-240.

Hartman, R.D., and F.W. Zettler, 1972. Dasheen mosaic virus infections in commercial plantings of aroids in Florida. Phytopathology 62:804.

Hartman, R.D., and F.W. Zettler, 1974. Effects of dasheen mosaic virus on yieldsof caladium, dieffenbachia, philodendron. Phytopathology 64:768.

Hicks, P.G. 1967. Resistance of Colocasia esculenta to leaf blight caused by Phytophthora colocasiae. Papua New Guinea Agr. J. 19:1-4.

Jackson, G.V.H. and D.E. Gollifer. 1975a. Disease and pest problems of taro (Colocasia esculenta L. Scott) in the British Solomon Islands. Pest Articlesand News Summaries (PANS) 21:45-53.

Jackson, G.V.H. and D.E. Gollifer. 1975b. Storage rots of taro (Colocasia esculenta) in the British Solomon Islands. Ann. Appl. Biol. 80:217-230.

Jackson, G.V.H. and D.E. Gollifer. 1975c. Studies on the taro leaf blight fungus Phytophthora colocasiae in the Solomon Islands. South Pacific Commission Working Paper 18. Presented at the Regional Meeting on the Production of Root Crops,24-29 November 1975, Suva, Fiji.

James, M., Kenton, R.H., and Woods, R.E. 1973. Virus-like particles associated with taro diseases of Colocasia esculenta (L.) Schott in the Solomon Islands. J.Gen. Virology 21:145-153.

Kenten, R.H., and Woods, R.E. 1973. Viruses of Colocasia esculenta and Xanthosmoma sagitifolium. PANS 19:38-41.

Kerz-Moehlendick, F.H., Fliege, F.H., and Schloesser, E. 1983. The occurrence of Pythium species as causative organisms of losses due to root and corm rot of taro, Colocasia esculenta (L.) Schott, in Western Samoa. Alafua Agric. Bull.8(2):129-137.

Kumar, C.R.M., and Souza, D. 1969. A note on Paratylenchus mutabilis Colbran 1968 (Nematoda: Criconematidae) from India. Curr. Sci. (Bangalore) 38:71- 72.

Nirula, N.K. 1959. Root knot nematode on Colocasia. Curr. Sci. (Bangalore)28:125-126.

Ooka, J.J. 1981. Rhizopus stolonifer rot of taro. Phytopathology 71:246.

Ooka, J.J. and Uchida, J.Y. 1985. Taro root and corm rot caused by Pythium myriotylum. Phytopathology 75(11):1316.

Ooka, J.J. and B. Yamamoto. 1979. Pythium root and corm rot of Colocasia esculenta in Hawaii. Phytopathology 69:918.

Paharia, K.D., and P.N. Mathur. 1964. Screening of Colocasia varieties for resistance to Colocasia blight (Phytophthora colocasiae Racib.). Sci. Cult.30:44-46.

Parham, B.E.V. 1949. Annual report of the economic botanist for the year 1948.Fiji Legislative Coun. Paper 24:31-35.

Parris, G.K. 1939. Diseases of taro. In: Report of the Hawaii Agr. Exp. Sta.1938, pp. 36-38.

Parris, G.K. 1940. A check list of fungi, bacteria, nematodes and viruses occurring in Hawaii and their hosts. Plant Dis. Rep. Suppl. 121:11-12.

Parris, G.K. 1941. Diseases of taro in Hawaii and their control. Hawaii Agr. Exp. Sta. Circ. No. 18. 29 pp.

Plant Disease Clinic. 1980. Plant disease clinic report. Univ. Hawaii Coop. Ext.Serv., with the U.S. Dept. of Agr., Honolulu, Hawaii.

Plant Disease Clinic. 1981. Plant disease clinic report. Univ. Hawaii Coop. Ext.Serv., with the U.S. Dept. of Agr., Honolulu, Hawaii.

Plucknett, D.L. and de la Peña, R.S. 1971. Taro production in Hawaii. World Crops 23:244-249.

Plucknett, D.L., de la Peña, R.S., and Obrero, F. 1970. Taro (Colocasia esculenta), a review. Field Crop Abst. 23:413-426.

Rabbe, R.D., Conners, I.L., and Martinez, A.P. 1981. Checklist of plant diseases in Hawaii. HITAHR Information Text Series 022. 313 pp.

Ridings, W.H. and R.D. Hartman. 1976. Pathogenicity of Pythium myriotylum and other species of Pythium to caladium derived from shoot-tip culture. Phytopathology 66:704-709.

Sedgwick, T.F. 1902. The root rot of taro. Hawaii Agr. Exp. Sta. Bull. No. 2.

Steiner, K.G. 1981. A root rot of macabo (Xanthosoma sp.) in Cameroun, associated with Pythium myriotylum. Zeitschrift fur Pflanzendrankheiten und Pflanzenschutz 88:608-613.

Takahashi, M. 1953. Report of taro diseases in Hawaii. Mimeographed report to the Hawaii Territorial House (HR no. 28).

Tandon, R.S., and Singh, S.P. 1974. Two new species of the genus Aphelenchoides Fischer (Nematoda, Aphelenchoididae) from the roots of Colocasia antiquorum Schott. Indian J. Entomol. 36:44-50.

Toyama, A. 1975. Expression of mosaic symptoms on taro plants from Dasheen mosaic virus infected corms. Ann. Phytopathol. Soc. Japan 41:506-507.

Trujillo, E.E. 1965. Effects of humidity and temperature on Phytophthora blight of taro. Phytopathology 55:183-188.

Trujillo, E.E. 1967. Diseases of the genus Colocasia in the Pacific area and their control. Proc. Int. Symposium on Tropical Root Crops. Vol. 2(IV):13-19.

Trujillo, E.E., and Aragaki, M. 1964. Taro blight and its control. Hawaii FarmSci. 13:11-13.

Uchida, J.Y. and M. Aragaki. 1979. Ceratocystis blight of Sygonium podophyllum. Plant Disease Reporter 63:1053-1056.

van Hoof, H.A. 1971. Zantedeschia aethiopica. In: Ann. Rep. Inst.Plantenziektenk, pp. 87-88. Onderzoek, Binnenhaven 12, Wageningen, The Netherlands.

Zettler, F.W., Foxe, M.J., Hartman, R.D., Edwardson, J.R., and Christie, R.C.1970. Filamentous viruses infecting dasheen and other araceous plants. Phytopathology 60:893-897.

Disclaimer

Mention of a trademark or a proprietary product done not imply approval or recommendation by the Hawaii Institute of Agriculture and Human Resources, University of Hawaii or the United States Department of Agriculture, to the exclusion of others that may be suitable. All pesticide materials should be used in accordance with label instructions, or manufactures' directions.

RESPONSE OF CHINESE TARO (Colocasia esculenta (L.) Schott var. 'Bun Long') TO NITROGEN AND POTASSIUM FERTILIZATION

James A. Silva
Department of Agronomy and Soil Science
University of Hawaii - Manoa

Dwight Sato
Cooperative Extension Service
University of Hawaii - Hawaii County CES

Ping Sun Leung
Department of Agriculture and Resource Economics
University of Hawaii - Manoa

George Santos
Hawaii Community College
University of Hawaii - Hilo

James Kuniyoshi
Beaumont Research Center
University of Hawaii - Hawaii County

Abstract

The response of Chinese Taro (Colocasia esculenta (L.) Schott variety 'Bun Long') to 12 treatment combinations of nitrogen (N) and potassium (K) was determined on a crop grown for 9 months. Nitrogen had the greatest effect on weight of number 1 corms while K had relatively little effect. The highest yields were obtained with the higher rates of N (>320 lb N/acre) at all rates of K. A predicted net revenue of $16,200 to $17,000 may be achieved with applications of 460 and 600 lb N (1000 and 1305 lb Urea) per acre at all rates of K and also with 320 lb N and 600 lb K (695 lb urea and 1185 lb muriate of potash) per acre. A tentative fertilizer recommendation for the highest net revenue is 460 lb N (1000 lb urea) and 600 lb K (1185 lb muriate of potash) per acre. A tentative adequate range for leaf N at 3 months is 4.3 to 4.5 per cent and for leaf K is 4.1 to 4.3 per cent.

Introduction

Chinese Taro (Colocasia esculenta (L.) Schott variety 'Bun Long'), has been grown on the Hilo Coast for several years and is principally used for making taro chips. Some of it is also sold on the fresh market in Hawaii and shipped to the fresh market on the Mainland USA. A project funded by the Governor's Agriculture Coordinating Committee (GACC) is studying the fertility requirements of Chinese Taro to determine if yields can be increased by improved fertilization and also to develop management practices that will produce economically feasible yields. The results reported here are those of a single nitrogen (N) by potassium (K) fertilizer experiment and the conclusions are tentative until they are confirmed by additional experiments.

Experimental Procedures

The N by K experiment was conducted at the Waianuenue farm laboratory plots of the College of Agriculture at Hilo. This land had not been previously planted to edible ginger and was situated at the 500 foot elevation. The soil was classified as the Hilo Series of the Typic Hydrandepts. The experimental area was fumigated with methyl bromide several weeks before planting. The preplant soil analysis[1] is given below:

pH:	5.4 - 5.5	K :	32.1 - 56.0 ppm
P :	23.8 - 27.6 ppm	Ca:	130.9 - 297.3 ppm
Mg:	57.0 - 122.3 ppm		

[1]pH - 1:1 soil:water; P - Modified Truog extractant; K,Ca, Mg - N ammonium acetate, pH 7.0.

The fertilizer treatments were added as urea for nitrogen and muriate of potash for potassium. The total amount of fertilizer for each treatment was divided into 6 equal doses which were applied at planting and at monthly intervals to 5 months after planting. From 2.1 to 2.6 tons of crushed coral (calcium carbonate) per acre were broadcast before planting and incorporated to raise soil pH to 6.0. Treble superphosphate (510 lb per acre) and magnesium sulfate (1013 lb per acre) were banded in 6-inch deep furrows and tilled into the top 6 inches of soil along with the preplant nitrogen and potassium applications. The experiment was installed in a randomized complete block design with 3 replicates.

Hulis (planting material) were 1 to 3 inches in diameter at the base and were planted approximately 4 inches deep on March 19, 1987. Hulis were spaced 1 foot apart within rows and 3 feet apart between rows which gave a plant population of 14,520 plants per acre. The experiment was harvested on December 15, 1987, 9 months after planting, and 25 plants were collected from each plot (9 x 24 ft). The average corm weights were recorded for each plot and the data presented are the averages over the three replicates.

Results and Discussion

Observed Corm Yield

The observed average corm yields for each treatment combination are presented in Table 1 where it is apparent that the highest yields were generally achieved with N applications between 320 and 600 lbs per acre at all K levels. Thus N had a greater effect on corm yield than did K in this experiment. The highest marketable yield (44,425 lb per acre) was achieved with the combination of 460 lb N and 460 lb K per acre. While the highest number 1 corm yield (43,506 lb per acre) was attained with 320 lb N and 600 lb K per acre.

Predicted Yield and Revenue

Yield prediction equations were developed which included applied N and K in a quadratic model. The predicted number 1 corm yields are presented in Table 2 in which the highest yields (38,636 to 39,873 lb per acre) are found with 600 lb N per acre with all rates of K as well as with 460 lb N with 460 and 600 lb K per acre. In the case of the highest predicted off-grade corms (Table 3), N levels of 460 and 600 lb per acre at all rates of K and also 320 lb N per acre with 460 and 600 lb K per acre produced yields of 3,000 lb per acre or greater. The increase in predicted number 1 corm yields with increasing urea applications is shown in Figure 1 in which the highest yields are achieved with urea over 1000 lbs per acre at the highest muriate of potash level (1185 lb per acre).

The predicted net revenue shown in Table 4 was calculated on the basis of the cost of urea and muriate of potash only. The predicted total marketable yield was assumed to be composed of 87% number 1 corms and 7% off-grade corms, which was the average for this experiment. It was assumed that the price of number 1 corms was $.40 per lb and the price of off-grade corms was $.35 per lb. Predicted net revenue of over $16,200 per acre was achieved with 460 and 600 lb N (1000 and 1305 lb urea) per acre at all rates of K and also with 320 lb N and 600 lb K (695 lb urea and 1185 lb muriate of potash) per acre. Predicted net revenue increased more rapidly with increased N application than with increased K application which follows from the greater effect of N than K on the observed yields. The highest predicted net revenue was $17,008 per acre with 460 N and 600 K.

Leaf Tissue Analysis

Samples of the most recent fully expanded leaves were collected at 8, 15, 25, and 36 weeks after planting and it was found that the nutrient levels of the 15-week sample were the most closely related to corm yield. The macronutrient concentrations in the 15-week samples are presented in Table 5. The optimum range of leaf N appeared to be between 4.3 and 4.5 %, while the optimum range for leaf K appeared to be between 4.1 and 4.3 %. These levels are in the ranges proposed by Plucknett and de la Peña, 1971. Phosphorus levels are above the adequate levels reported by these workers and in the range of those reported by de la Peña et al, 1979. Leaf Ca levels are lower than those given by de la Peña et al, 1979, even though over 2 tons of lime had been applied and pH was at 6.0 and above. Leaf Mg appeared adequate. Micronutrients determined in leaf tissue were generally comparable to those of de la Peña et al, 1979, except for Cu and Zn which were about one-half the levels reported (Table 6). Analysis of leaf tissue at about 3 months for N and K, in particular can be a useful management tool which indicates the nutrient status of a crop of taro when there is still time to make additional applications to correct deficiencies which could improve yields.

Supplementary Treatments

Four supplementary treatments were included in the experiment to obtain a first approximation of the response of taro at this site to phosphorus, lime (pH), and boron. The treatments shown below were replicated 3 times.

Trt.	--------------lb/acre----------------				lb/acre		
No.	Urea	(N)	Muriate	(K)	Treb. Sup Phos.	pH	Borax
13	695	320	630	320	0	6.0	0
14	695	320	630	320	510	5.2	0
15	695	320	630	320	510	6.5	0
16	695	320	630	320	510	6.0	5
"Standard" treatment (7)							
7	695	320	630	320	510	6.0	0

Figure 2 indicates that there was little difference in the average weight of number 1 corms produced per acre among the supplementary treatments and compared to treatment 7. This suggests that taro will not respond to treble super phosphate applications on this soil with modified Truog phosphorus levels of 23.8 to 27.6 ppm. It also suggests that taro was not very sensitive to pH on this soil. Finally, the addition of boron did not appear to be needed. An interesting finding, however, was that the per cent rotted corms was lowest with pH 6.5 (Figure 3). One must be careful in interpreting this because the percent rotted corms was higher with pH 6.0 than with pH 5.2 so this result may have been due to chance. Leaf Ca reflected the amounts of Ca applied to the various treatments (Figure 4).

Rainfall

The weekly rainfall during the crop period is presented in Appendix 1. The total rainfall measured for the crop was 144.9 inches which was distributed as follows: 48.4 inches at the end of the first three months, 41.1 inches during the next three months, and 55.4 inches during the last three months.

Tentative Fertilizer Recommendation

On the basis of the predicted yields and predicted net revenue per acre of marketable corms, the highest return for N and K fertilizer application is estimated to be with the application of 460 lb N (1000 lb urea) and 600 lb K (1185 lb muriate of potash) per acre. If the crop receives adequate rainfall, a total marketable yield of 40,000 lb per acre is predicted with 14,520 plants per acre (1 x 3 ft spacing). Individual corms would be expected to average about 3 lb. This fertilizer recommendation may be expressed as 2000 lb/acre/crop of a 23-0-36 formulation. It must be remembered that these predictions are based on only one experiment in one location so may not be directly applicable to other locations and weather conditions. However, they do provide an estimate of what may be possible. It should be noted in Table 4 that returns of over $16,200 per acre are predicted with N applications of 460 to 600 lbs per acre (1000 to 1305 lb urea) and a range of K (muriate of potash) applications as well as with 320 lb N and 600 lb K (695 lb urea and 1185 lb muriate of potash) per acre.

Acknowledgements

The source of research funds for this project was the Governor's Agriculture Coordinating Committee. The experimental plots were provided by the College of Agriculture at Hilo, and assistance in supplying the seed material for this experiment was obtained from the Hawaii Dryland Taro Association.

References

Plucknett, D.L. and R.S. de la Peña. 1971. Taro Production in Hawaii. World Crops. Sept/Oct 1971.

de la Peña, R., P. Vander Zaag, and R.L. Fox. 1979. The comparative phosphorus requirements of flooded and non-flooded taro. Provisional Report No. 5. Taro and Cocoyam. International Foundation for Science. p.223-237.

Table 1. Observed Average Corm Yields by Treatment

	Test Treatment (lbs per acre)				Corm Yield (lbs per acre)[1]		
	Urea	(N)	Muriate	(K)	No. 1	Off-grade	Marketable
1.	0	(0)	0	(0)	19,562	3,912	23,474
2.	110	(50)	100	(50)	32,978	492	33,470
3.	695	(320)	100	(50)	40,199	1,132	41,331
4.	1305	(600)	100	(50)	36,791	2,874	39,665
5.	415	(190)	375	(190)	30,292	2,713	33,005
6.	110	(50)	630	(320)	31,595	2,829	34,424
7.	695	(320)	630	(320)	31,547	4,895	36,442
8.	1305	(600)	630	(320)	40,949	602	41,551
9.	1000	(460)	910	(460)	42,056	2,369	44,425
10.	110	(50)	1185	(600)	35,750	1,577	37,327
11.	695	(320)	1185	(600)	43,506	622	44,128
12.	1305	(600)	1185	(600)	39,116	4,278	43,394

[1] Yield per acre is based on 14,520 plants per acre and adjusted by percent no. 1 and percent off-grade in each treatment.

Table 2. Predicted Yield per Acre of No.1 Corms.[1]

Lbs per Acre: Muriate (K)		Lbs per Acre: Urea (N)					
		0(0)	100(50)	415(190)	695(320)	1000(460)	1305(600)
0	(0)	26,615	28,541	33,126	36,320	38,613	39,718
100	(50)	26,692	28,583	33,071	36,175	38,371	39,378
375	(100)	27,244	29,038	33,254	36,104	38,028	38,764
630	(320)	28,200	29,904	33,867	36,482	38,153	38,636
910	(460)	29,707	31,314	35,004	37,367	38,766	38,975
1185	(600)	31,710	33,219	36,637	38,747	39,873	39,811

[1]Based on 14,520 plants per acre with 87% no.1 corms.

Table 3. Predicted Yield per Acre of Off-grade Corms.[1]

Lbs per Acre: Muriate (K)		Lbs per Acre: Urea (N)					
		0 (0)	100(50)	415(190)	695(320)	1000(460)	1305(600)
0	(0)	2,141	2,296	2,665	2,922	3,107	3,196
100	(50)	2,148	2,300	2,661	2,911	3,087	3,168
375	(100)	2,192	2,336	2,676	2,905	3,060	3,119
630	(320)	2,269	2,406	2,725	2,935	3,070	3,108
910	(460)	2,390	2,520	2,816	3,007	3,119	3,136
1185	(600)	2,551	2,673	2,948	3,118	3,208	3,203

[1]Based on 14,520 plants per acre with 7% off-grade corms.

Table 4. Predicted Net Revenue per Acre of Marketable Corms.[1]

Lbs per Acre: Muriate (K)		Lbs per Acre: Urea (N)					
		0(0)	100(50)	415(190)	695(320)	1000(460)	1305(600)
0	(0)	$11,396	$12,217	$14,172	$15,532	$16,506	$16,971
100	(50)	$11,425	$12,232	$14,146	$15,467	$16,399	$16,823
375	(100)	$11,653	$12,418	$14,215	$15,428	$16,244	$16,551
630	(320)	$12,054	$12,781	$14,469	$15,582	$16,289	$16,488
910	(460)	$12,691	$13,376	$14,948	$15,952	$16,543	$16,625
1185	(600)	$13,539	$14,183	$15,638	$16,534	$17,008	$16,973

[1]Based on 14,520 plants per acre with 87% no.1 corms and 7% off-grades. The price of no.1 corms is $0.40 and of off-grades is $0.35. The cost of Urea is $250.29/ton and of Muriate of Potash is $249.26/ton.

Table 5. Analysis of Leaf Tissue at 15 Weeks: Macronutrients

Treatment (lb/acre) No.	Urea	Muriate	N	P	K	Ca	Mg	Na
			%					
1	0	0	3.78	0.32	3.24	0.73	0.45	0.03
2	110	100	4.24	0.28	2.84	0.78	0.45	0.05
3	695	100	4.22	0.32	3.62	1.00	0.46	0.02
4	1305	100	4.49	0.32	4.10	0.96	0.40	0.02
5	415	375	4.22	0.28	3.58	0.90	0.35	0.02
6	110	630	4.55	0.30	3.18	1.00	0.44	0.02
7	695	630	4.40	0.32	3.70	0.74	0.36	0.02
8	1305	630	4.32	0.33	4.34	0.70	0.33	0.04
9	1000	910	4.26	0.30	4.39	0.84	0.33	0.02
10	110	630	4.32	0.33	4.19	0.76	0.32	0.03
11	695	630	4.52	0.28	4.30	0.80	0.29	0.03
12	1305	630	4.30	0.25	4.42	0.80	0.32	0.02

Table 6. Analysis of Leaf Tissue at 15 Weeks: Micronutrients

Treatment (lb/acre) No.	Urea	Muriate	Mn	Fe	Cu	Zn	B	Al
			ppm					
1	0	0	235	81	14	29	22	41
2	110	100	274	84	15	28	19	152
3	695	100	374	85	14	28	28	48
4	1305	100	299	80	14	29	25	28
5	415	375	238	75	12	23	23	64
6	110	630	384	76	12	24	25	46
7	695	630	245	69	13	32	22	46
8	1305	630	310	88	14	30	22	120
9	1000	910	402	106	12	30	24	108
10	110	630	297	82	10	28	23	96
11	695	630	316	79	12	26	24	94
12	1305	630	414	95	10	26	24	86

Figure 1. Avg. Weight No.1 Corm per Acre

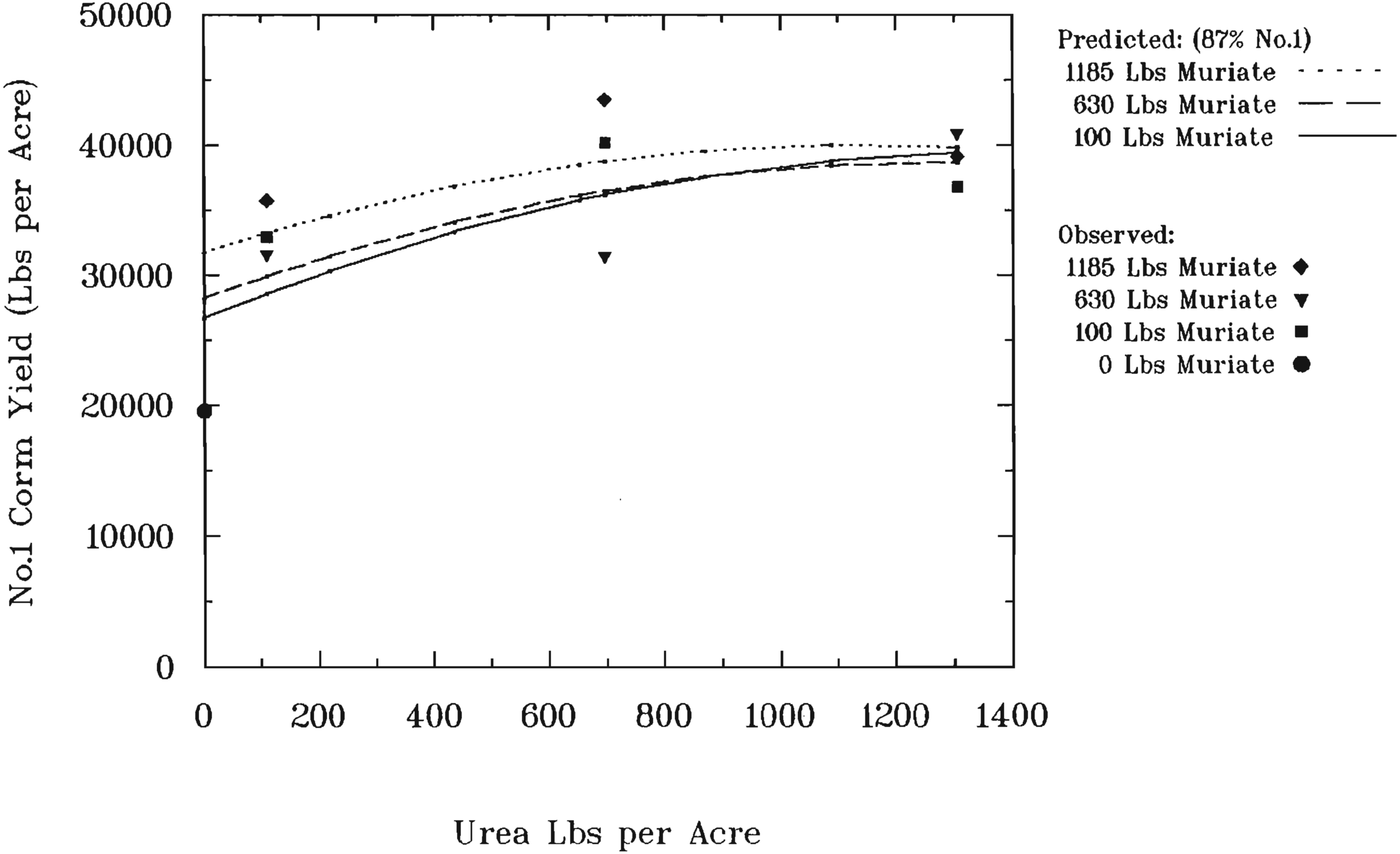


Figure 2.

Avg. Wt. Number 1 Corms vs Sup Trts

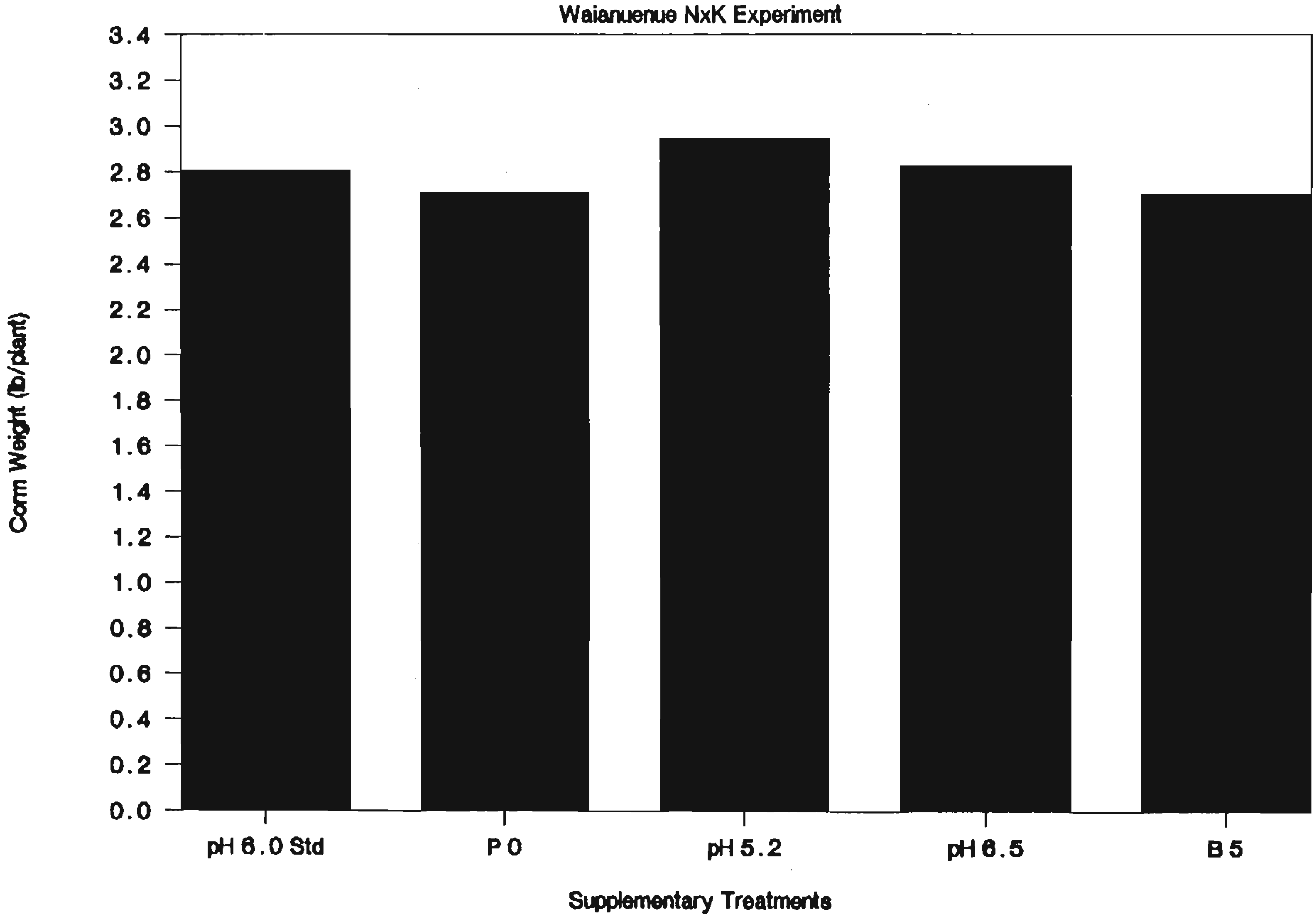
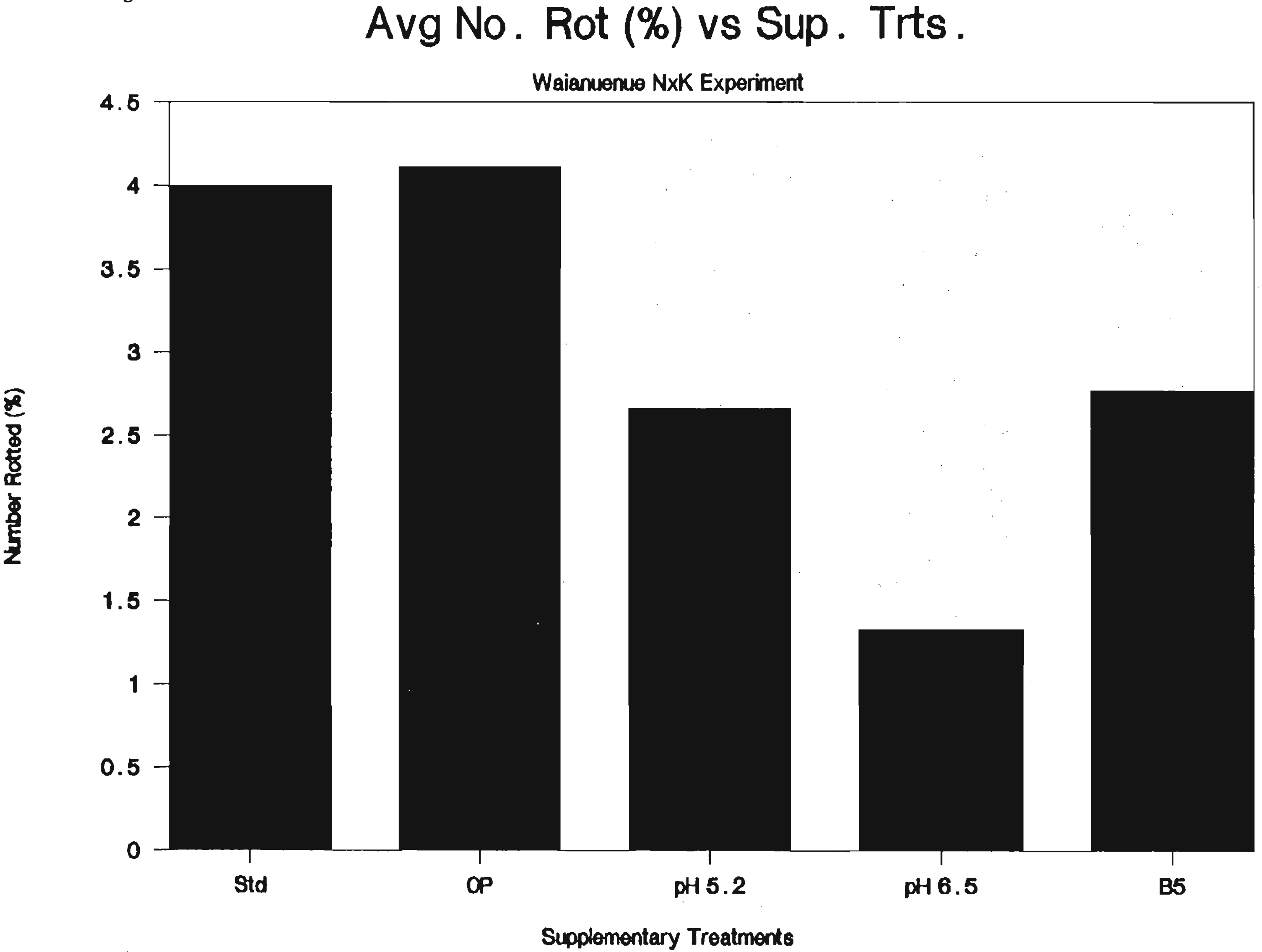
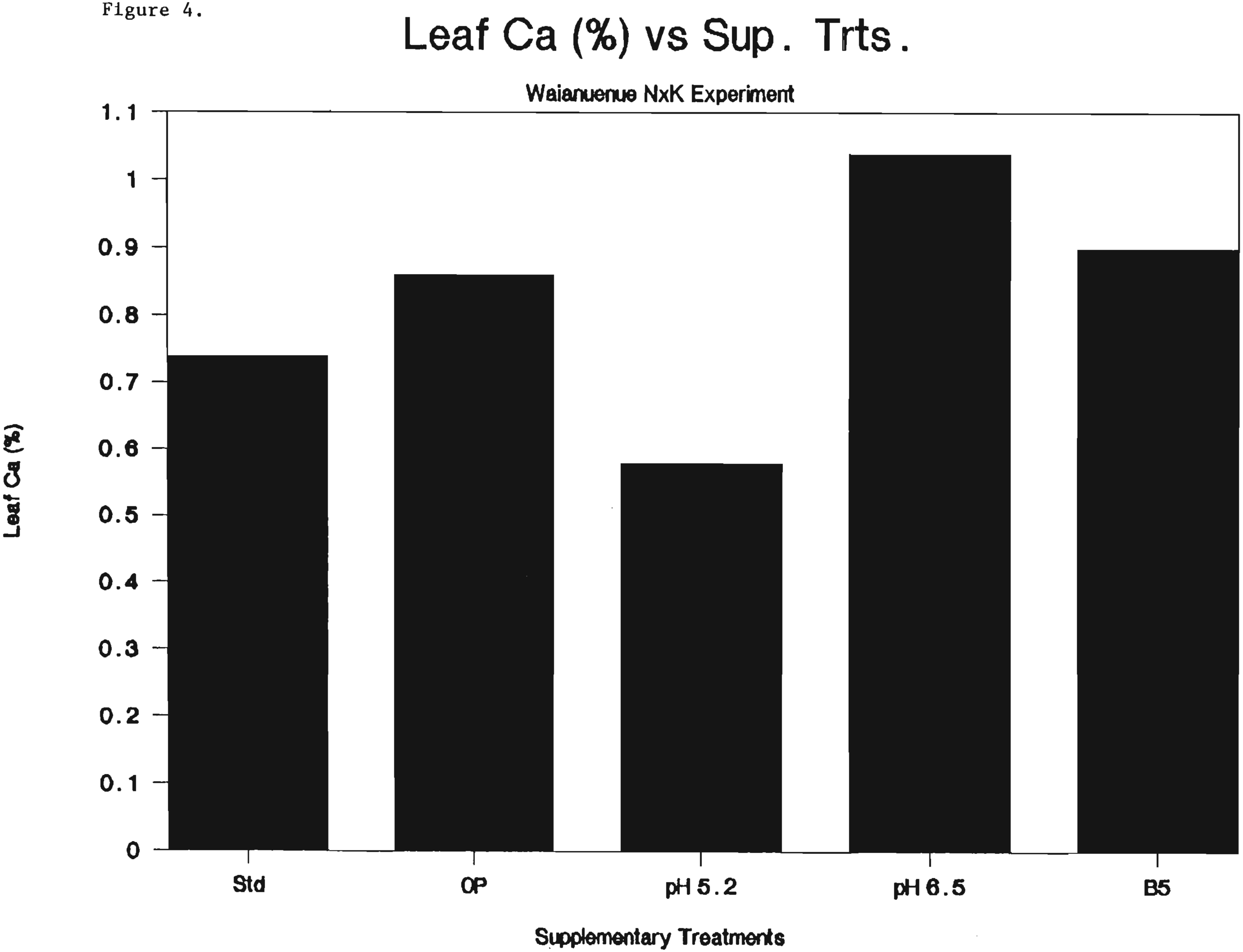


Figure 3.



Avg No. Rot (%) vs Sup. Trts.
Waianuenue NxK Experiment
Number Rotted (%)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Std
OP
pH 5.2
pH 6.5
B5
Supplementary Treatments

Figure 4.

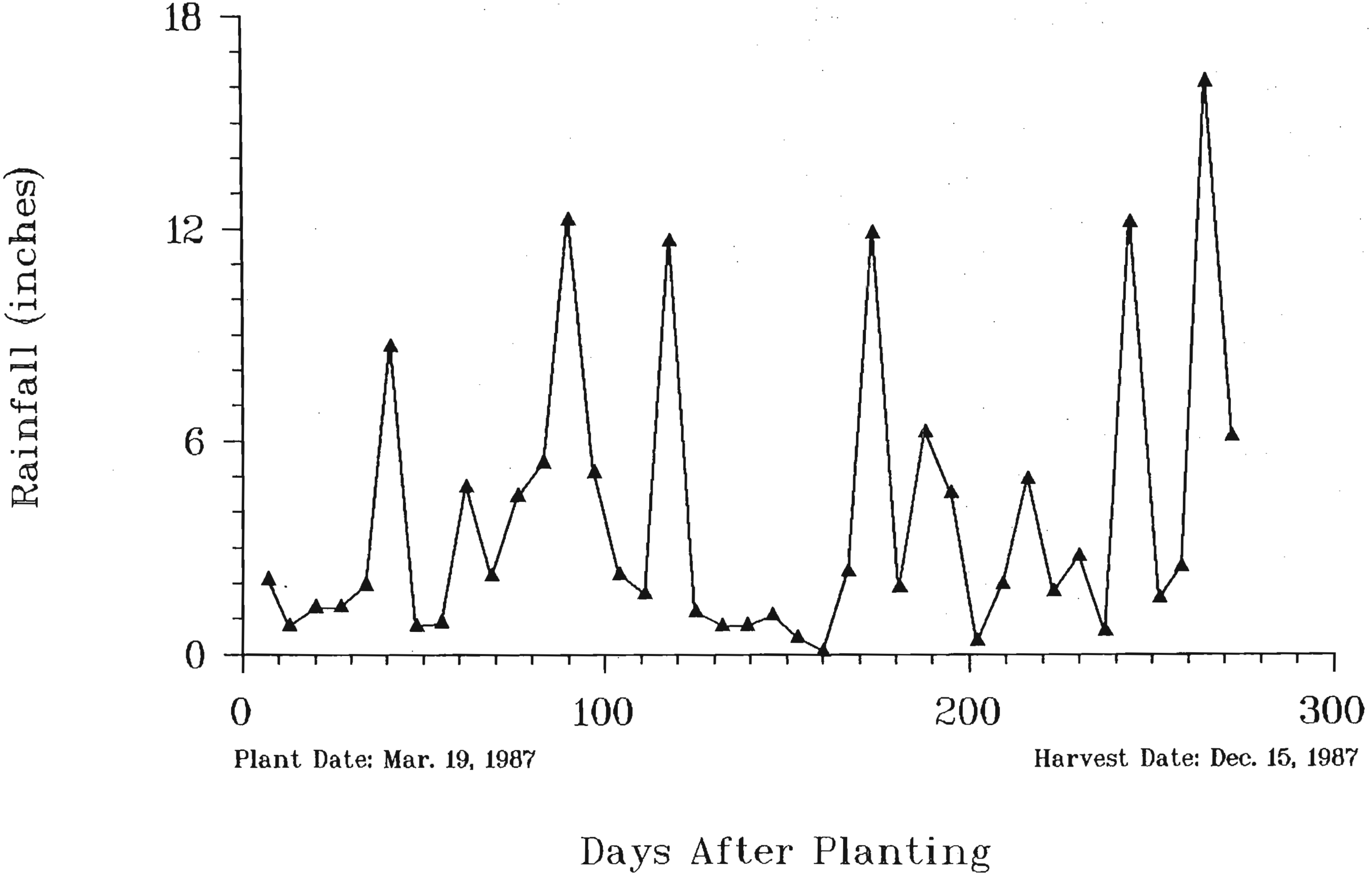

Leaf Ca (%) vs Sup. Trts.
Waianuenue NxK Experiment
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Leaf Ca (%)
Std
OP
pH 5.2
pH 6.5
B5
Supplementary Treatments

69

Appendix 1.

Weekly Rainfall vs DAP

Nitrogen x Potassium Test



PHOSPHORUS FERTILIZATION FOR DRYLAND TARO

Dwight Sato
Cooperative Extension Service
University of Hawaii - Hawaii County CES

James Silva
Department of Agronomy and Soil Science
University of Hawaii - Manoa

James Kuniyoshi
Beaumont Research Center
University of Hawaii - Hawaii County CES

Abstract

This report summarizes the results of a single experiment in determining the phosphorus requirement for Chinese taro. Based upon the predicted results, 3,571 lbs treble superphosphate gave the highest no.1 and marketable corm yields. The maximum predicted net revenue of marketable corms, $13,608, was attained at 3,061 lbs of treble superphosphate per acre. This was a 20 percent increase in net revenue as compared to applying no treble superphosphate. For Hilo soils with approximately 46 ppm available phosphorus, the preliminary recommendation for treble superphosphate is 3,061 lbs per 14,520 plants per acre as a pre-plant application.

Introduction

A phosphorus fertilization experiment was conducted in Hilo, Hawaii, with Chinese taro (<u>Colocasia</u> <u>esculenta</u> (L.) Schott variety 'Bun Long'). Four rates of applied phosphorus, in a randomized complete block design, with three replicates, were compared to determine the amount of fertilizer required to achieve the maximum and economic yield for dryland taro. The test site which had not been previously planted to edible ginger, was at an elevation of approximately 500 feet and the taro was grown under rainfed conditions.

The experimental setup is described in Appendix 1.

Observed Corm Yield

The observed no.1 and marketable corm yield per acre increased slightly with increasing treble superphosphate (Table 1). The highest observed average yield of no.1 corms (32,622 lb/acre) and marketable corms (32,912 lb/acre) were produced with the application of 5,051 lbs treble superphosphate per acre. The maximum average corm size, 2.49 lb, was attained at 1,684 lb treble superphoshate per acre. The off-grade corm yield decreased with increasing treble superphosphate but the differences were not statistically significant.

Predicted Corm Yield

Prediction equations were derived from the observed data and the predicted yields are listed in Table 2. The maximum predicted marketable yield (35,546 lb per acre) was attained at 3,571 lb treble superphosphate per acre. On the basis of only the cost of treble superphosphate, the maximum predicted net revenue ($13,608) was attained at 3,061 lb treble superphosphate per acre (Table 3). The difference between the maximum and the lowest net revenue is $2,291. This is a 20 percent increase in net revenue.

The observed and predicted average no.1 corm yield per acre with increasing treble superphosphate is shown in Figure 1. The predicted percent no.1 corms with increasing treble superphosphate is shown in Figure 2. Phosphorus appears to have a role in increasing percent no.1 corms.

Tissue Analysis

In each treatment, the most recent, fully expanded leaves were sampled at 8, 17, 26, and 34 weeks after planting. Leaf phosphorus levels at 17 weeks were the most closely related to yield.

Above the level of 0.38 to 0.39 percent leaf phosphorus, yields are not expected to increase with application of phosphorus fertilizer. This may be considered the adequate level of leaf phosphorus for taro. The other nutrients appeared to be at adequate levels.

Soil Analysis

The pre-plant phosphorus level, 46 ppm, may have been close to adequate for Chinese taro because additional phosphorus only slightly increased corm yield as can be seen in the slopes of the observed and predicted yields per acre (Figure 1). In addition, the initial available phosphorus in the 0 lb per acre treble superphosphate treatment did not change very much at the end of the crop cycle. On the basis of the amounts of phosphorus in the post-harvest soil analysis (Appendix 1), available phosphorus can build up with high treble superphosphate applications and that the residual phosphorus would probably be adequate to support subsequent taro plantings. Treble super-phosphate (0-45-0) has 20 percent phosphorus and 13 percent calcium. Therefore, calcium is also an added nutrient along with treble superphosphate as is shown in the post-harvest soil analysis. If pH adjustment is not necessary, calcium nutrition could be supported with high treble superphosphate applications.

Rainfall

The weekly rainfall during the cropping period is shown in Appendix 2. The total amount of rain measured for this crop was 143.7 inches. At the end of the first three months, 29.9 inches were recorded; the second three months, 40.3 inches; and for the last three months, 73.5 inches.

Preliminary Treble Superphosphate Recommendation

For Hilo soils, with approximately 46 ppm available phosphorus, the preliminary recommendation for treble super-phosphate is 3,061 lb per 14,520 plants per acre as a preplant application.

References

dela Peña, R. S., P. Vander Zaag and R.L. Fox. 1980. The Comparative Phosphorus Requirements of Flooded and Non-Flooded Taro. Proc. 5th Int. Symp. on Tropical Root and Tuber Crop, pp 671-681.

Kagbo, R.B., R.S. dela Peña, D.L. Plucknett and R.L. Fox. 1977. Mineral Nutrition of Taro (Colocasia esculenta) with Special Reference to Petiolar Phosphorus Level and Phosphate Fertilizers. Proc. of the 3rd Symp. of the Int. Soc. for Tropical Root Crops. Ed. Colin L.A. Leakey, pp 138-144.

Table 1. Observed Average Corm Yields by Treatments

Lbs per Acre: TSP	(P)[2]	Avg.lbs No.1 Corm	Corm Yield (Lbs per Acre):[1] No.1	Off-grade	Marketable
0	(0)	2.11	28,028	1,210	29,418
561	(110)	2.45	28,992	629	29,621
1,684	(330)	>2.49	31,750	484	32,234
5,051	(990)	2.31	>32,622	290	>32,912

[1] Based upon 14,520 plants per acre and adjusted for No.1 and off-grade yield by treatment.
[2] Treble superphosphate and phosphorus.

Table 2. Predicted Corm Yield per Acre

Lbs per Acre: TSP	(P)[2]	Corm Yield (Lbs per Acre):[1] No.1	Off-grade	Marketable
0	(0)	27,381	1,042	28,423
510	(100)	29,240	1,112	30,352
1,020	(200)	30,807	1,167	31,974
1,531	(300)	32,090	1,208	33,298
2,041	(400)	33,090	1,235	34,325
2,551	(500)	33,802	1,247	35,049
3,061	(600)	34,216	1,246	35,462
3,571	(700)	>34,316	1,230	>35,546
4,082	(800)	34,081	1,200	35,281
4,592	(900)	33,482	1,156	34,638
5,102	(1000)	32,488	1,097	33,585

[1] Based upon 14,520 plants per acre, predicted % no.1 corms and 3.3 % average off-grade corms.
[2] Treble superphosphate and phosphorus.

Table 3. Predicted Revenue per Acre based on Marketable Corms[1]

Lbs per Acre: TSP	(P)[2]	Gross Revenue[3]	Fertilizer Cost[4]	Net Revenue
0	(0)	$11,317	$0	$11,317
510	(100)	$12,085	$86	$11,999
1,020	(200)	$12,731	$172	$12,560
1,531	(300)	$13,259	$257	$13,001
2,041	(400)	$13,668	$343	$13,325
2,551	(500)	$13,957	$429	$13,528
3,061	(600)	$14,122	$515	>$13,608
3,571	(700)	$14,157	$600	$13,556
4,082	(800)	$14,052	$686	$13,366
4,592	(900)	$13,797	$772	$13,025
5,102	(1000)	$13,379	$858	$12,521

[1] Based upon 14,520 plants per acre, predicted % no.1 corms and 3.3 % average off-grade corms.
[2] Treble superphosphate and phosphorus.
[3] Price per lb for no.1 corms is $0.40 and off-grade is $0.35.
[4] Cost of Treble superphosphate is $13.45 per 80 lb bag.

Figure 1.

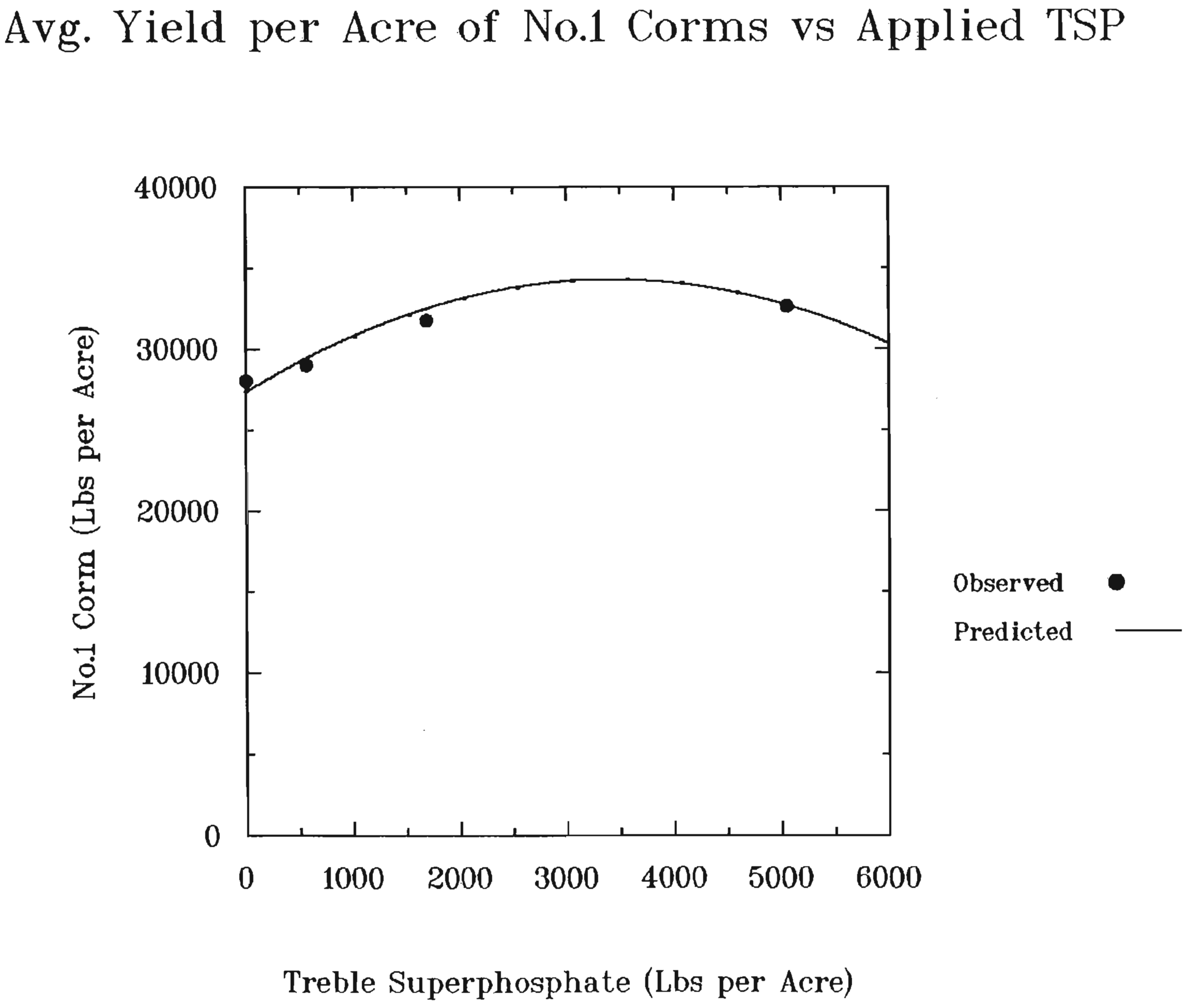
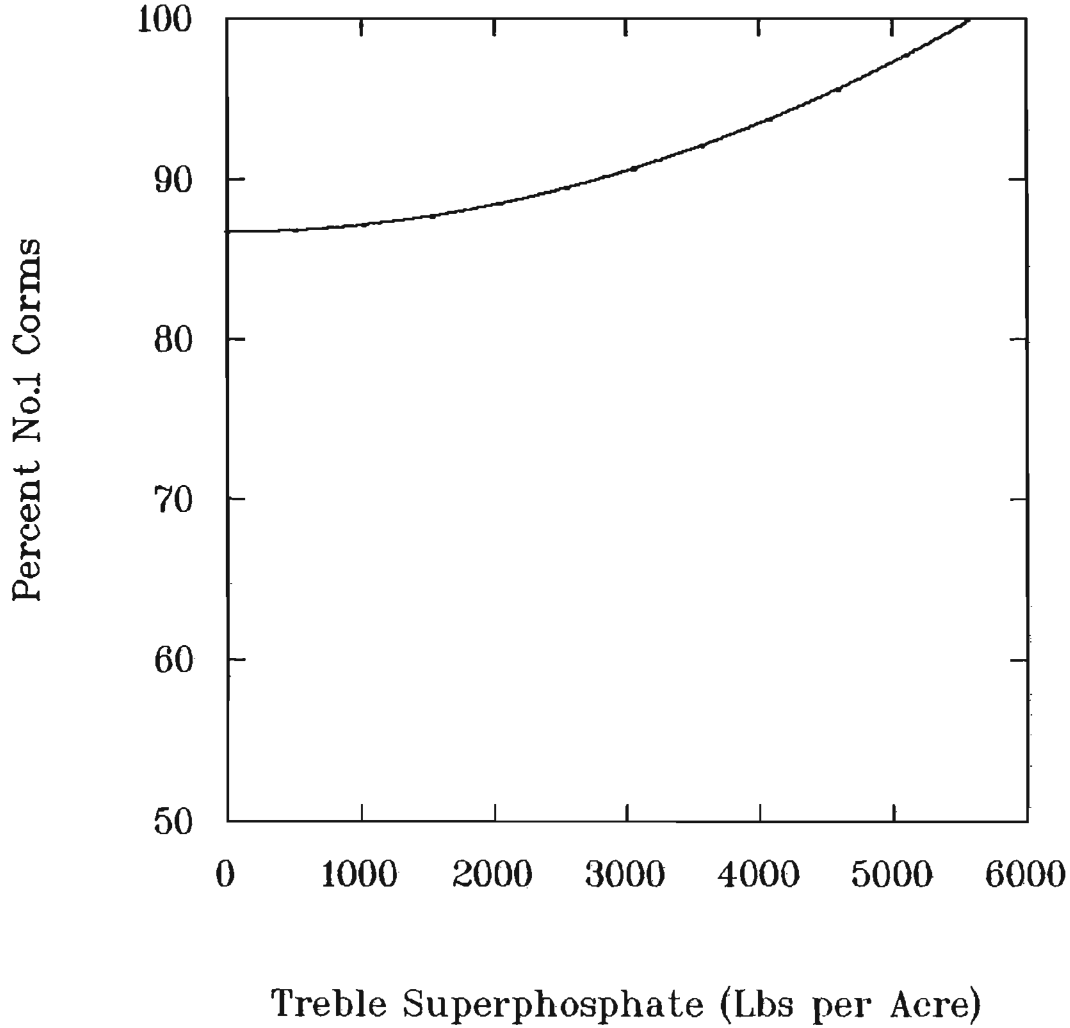

Avg. Yield per Acre of No.1 Corms vs Applied TSP
40000
30000
20000
10000
0
0
1000
2000
3000
4000
5000
6000
No.1 Corm (Lbs per Acre)
Treble Superphosphate (Lbs per Acre)
Observed
Predicted

Figure 2.

Predicted Percent No.1 Corms vs Applied TSP



Appendix 1. Experimental Setup

The total amount of treble superphosphate for each treatment was banded and tilled in 6 inch-deep furrows prior to planting. Applications of 695 lbs urea per acre and 630 lbs muriate of potash per acre were divided into six equal doses and banded at monthly intervals. The first dose of nitrogen and potassium was applied at pre-plant and tilled with the phosphorus treatment. Approximately 1 to 2 tons per acre of crushed coral (calcium carbonate) was broadcast and incorporated to raise soil pH to 6.

The soil on which this experiment was conducted is classified as the Hilo series. The pre-plant soil analysis, sampled November 10, 1987 and the post-harvest soil analysis, sampled January 25, 1989 were averaged and are presented below.

Pre-plant Soil Analysis:[1]

pH	P ppm	K ppm	Ca ppm	Mg ppm[2]
5.6	46	66	367	165

[1] pH - 1:1 soil:water; P - Modified Truog extractant; K,Ca,Mg, - N ammonium acetate, pH 7.0
[2] P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium

Post-harvest Soil Analysis:[1]

Lbs per Acre:						
TSP	(P)[2]	pH	P ppm	K ppm	Ca ppm	Mg ppm[3]
0	(0)	5.9	41	173	773	147
561	(110)	5.9	64	167	843	167
1,684	(330)	6.0	137	127	1227	180
5,051	(990)	6.1	508	147	1773	187

[1] pH - 1:1 soil:water; P - Modified Truog extractant; K,Ca,Mg, - N ammonium acetate, pH 7.0
[2] Treble superphosphate and phosphorus.
[3] P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium

Seed material (hulis) which were about 2 inches in diameter at the base were planted approximately 4 inches deep. Hulis were spaced 1 foot apart within rows and 3 feet apart between rows (population of 14,520 plants per acre). Twenty-five plants were harvested from each plot (9 x 27 ft), 9 months after planting. The average corm weights per plot were recorded and the data reported were averaged over three replicates. The planting date was April 25, 1988 and the harvest date was January 23, 1989.

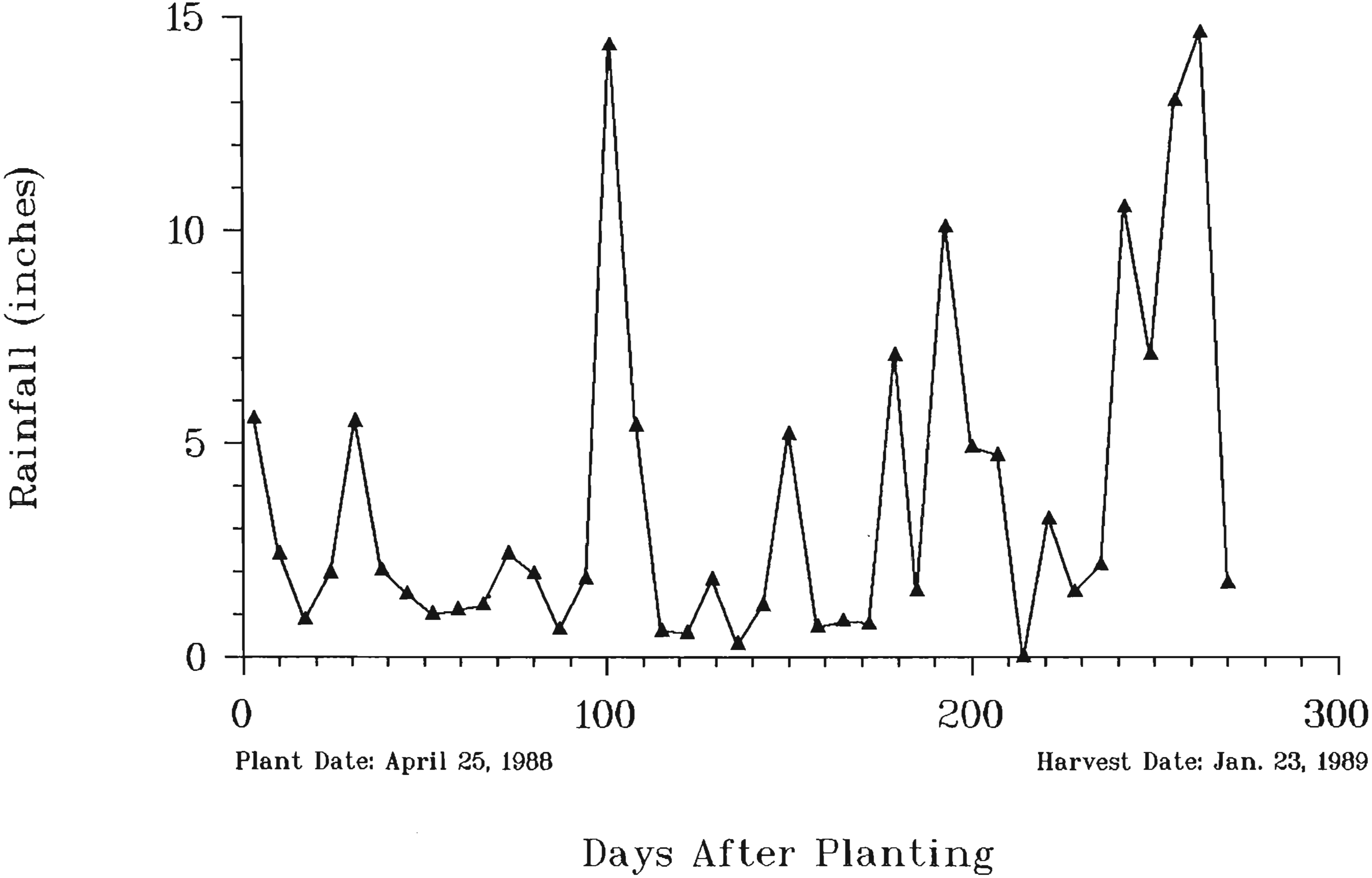
Acknowledgements:

Research funds for this project was provided by the Governor's Agriculture Coordinating Committee, The College of Agriculture at Hilo provided the farm laboratory plots, and Hawaii Dryland Taro Association assisted with providing seed material for this experiment.

Appendix 2.

Weekly Rainfall vs DAP

Phosphorus Fertility



PRELIMINARY RESULTS OF DRYLAND TARO SPACING AND FERTILIZER TIMING

Dwight Sato
Cooperative Extension Service
University of Hawaii - Hawaii County CES

James A. Silva
Department of Agronomy and Soil Science
University of Hawaii - Manoa

Abstract

Five plant spacing treatments and four fertilizer timing treatments were applied to Chinese taro grown for 9 months on land previously cropped to edible ginger. From our preliminary interpretation of the results, a 1 x 3 or 1 x 4 plant spacing appears to be the most appropriate. There were no differences between the fertilizer timing treatments, indicating that total fertilizer requirements can be applied early in the growth cycle of taro.

Pre-Plant Soil Analysis

The pre-plant soil analyses for both the taro spacing and fertilizer timing experiments are listed below in Table 1. Both experiments were conducted in the same vicinity and therefore the soil nutrient profiles were expected to be very similar. Edible ginger was grown previously to the taro experiments and therefore levels of phosphorus and calcium were high. We considered the starting phosphorus and calcium levels to be adequate and therefore only with 695 lbs urea per acre and 630 lbs muriate of potash per acre were applied in both experiments.

Table 1. Pre-plant Soil Analysis

	Spacing Test	Timing Test
pH	6.12	6.29
P ppm	281.0	291.7
K ppm	71.3	70.0
Ca ppm	1,353.3	1,460.0
Mg ppm	69.0	76.7

Taro Spacing

This test was done to determine an appropriate spacing pattern or planting density for dryland taro. The planting date was August 1988 and Chinese taro was grown for 9 months before harvesting. The plant spacing treatments and averaged results are listed in Table 2. The average weight per plant (2.47 to 3.99 lb) and percent no. 1 corms (67 to 97 %) increased as plant density decreased. Conversely, yield per acre decreased (36,145 to 21,159 lb) as plant density decreased.

Table 2. Taro Plant Spacing and Yield of No.1 Corms

		Average:		
Treatment	Plants/Acre	Lb/Plant	% No.1	Yield/Acre
2 x 4 ft	5,445	3.99	97	21,159
1 x 4 ft	10,890	3.01	87	28,159
1 x 3 ft	14,520	2.57	76	28,488
1x1 x 4 ft	17,424	2.55	71	31,812
0.5 x 4 ft	21,780	2.47	67	36,145

The no.1 taro corms were identified as corms which were greater than 1.25 lb and without any rot. Of the corms not identified as being no.1, most of them were not rotten but undersized. Figure 1 shows the average yield per acre for each treatment and Figure 2 shows the predicted yield per acre. Figure 3 shows the average weight per plant for each treatment and Figure 4 shows the predicted weight per plant. Both predicted yield and weight per plant had a straight line relationship to plant spacing.

Discussion on Plant Spacing

The proper plant spacing for a particular farm operation would not only depend on the final yield per acre but on other decision factors. These could be the type of tractor equipment a farmer chooses to use, the uniformity of individual corm size to meet the demand of the type of market (retail, restaurant, supermarket, chipping, etc.), the weed maintenance program, the amount of hulis a farmer needs to prepare for an acre, and the time of year that a field is planted.

Considering that most farmers use a hand drawn tiller to cultivate rows, a spacing of 1 x 3 to 1 x 4 feet would be appropriate. The approximate yield of no.1 corms per acre would be about 28,000 lb with an individual corm size of about 3 lb. The percentage of no.1 corms would probably range in the 80 percent range which is considered good. Weeding would be required 2 or 3 times during the early growth stages. Approximately 12,000 hulis would be required for an acre and this is considered a reasonable proportion.

The wider spacing treatments yielded very high averages of percent no.1 corms, while the closer spacing treatments yielded very low averages of percent no.1 corms. Taro is commonly known to be a poor competitor in culture and a low amount of sunlight interception per plant observed in the early growth stage of taro is suspected as a limiting factor for attaining the best level of percent no.1 corms. We suggest that farmers consider planting with a wider spacing during the winter months and a narrower spacing during the summer months to optimize quality and production.

Fertilizer Timing

This test was done to determine the best frequency of fertilizer application for dryland taro. All fertilizer timing treatments received the same amount of total fertilizer per crop (695 lb urea per acre and 630 lb muriate of potash per acre) but applied at different rates by month. The plant spacing used was 1 x 3 feet. The planting date was late September 1988 and Chinese taro was grown for 9 months before harvesting. The averaged results of no.1 corms are listed in Table 3. Figure 5 is a graph of the yield per acre of no.1 corms vs fertilizer timing.

The results show that there were no differences between the fertilizer timing treatments as measured in lb per plant, % no.1 corms, and yield per acre. The percent no.1 corms were all very low and this probably affected the final yield. Again the corms not identified as no.1 were undersized rather than rotten.

Table 3. Fertilizer Timing and Yield of No.1 Corms

	Average:		
Treatment[1]	Lb/Plant	% No.1	Yield/acre
Planting	2.43	68	23,969
p 2 4	2.48	60	21,724
p 1 3 5	2.37	66	23,004
p 1 2 3 4 5	2.47	65	23,422

[1] Planting = all fertilizer applied at planting. p 2 4 = total amount of fertilizer was applied 3 times; at planting, 2 months after planting, and 4 months after planting, etc.

Discussion on Fertilizer Timing

Results indicate that for land previously cropped to edible ginger, total applications of nitrogen and potassium can be applied early in the crop growth cycle. A follow-up test is being planned but on non-ginger cropped land to see if significant differences from different fertilizer increments can be demonstrated.

The yields and percent no.1 corms for this experiment, although planted in the same location as the spacing test, were very much lower. Several factors may have contributed to the depressed yields. One is the later season in which the timing test was planted. There was a steeper drop in temperature early in the crop at the onset of the winter months but from other tests with even lower starting temperatures, yields were approximately 30,000 lb per acre.

Another seasonal factor, although not measured, may have been the amount of shade or sunlight plants received during the cropping period. The average percent no.1 corms as seen in the timing test (65%) were very close to the average percent no.1 corms in the densest spacing treatment (67%) which probably received the most shade. As suspected from the spacing test, the amount of sunlight interception per plant in the early growth stages of taro may probably be one of the major limiting factors for optimal percent no.1 corms.

Another possible factor was the source of hulis used in planting the different tests. In our spacing test, all the hulis came from our propagation nursery in which we kept up fertility levels and weed control. The hulis used to plant the fertilizer timing test were obtained from a farmers field which was kept weed free but not fertilized. The nutritional pre-disposition of the planting material may also be part of the reason for having low or high yields.

References

Kagbo, Robert B., D.L.Plucknett, and W.G. Sanford. 1980. Yield and Related Components of Flooded Taro as Affected by Land Preparation, Planting Density, and Planting Depth. Proc. 5th Int. Symp. on Trop. Root and Tuber Crops (1978), pp 629-635.

Reynolds, S.G. and P. Netram. 1977. The Effect of Rainfall and Time of Planting on Yield of Taro in Western Samoa. Proc. of the 3rd Symp. of the Int. Soc. for Tropical Root Crops. Ed. Colin L.A. Leakey, pp 374-376.

Sivan, P. 1977. Effects of Spacing in Taro. Proc. of the 3rd Symp. of the Int. Soc. for Tropical Root Crops. Ed. Colin L.A. Leakey, pp 377-381.

Figure 1. TARO SPACING: YIELD PER ACRE

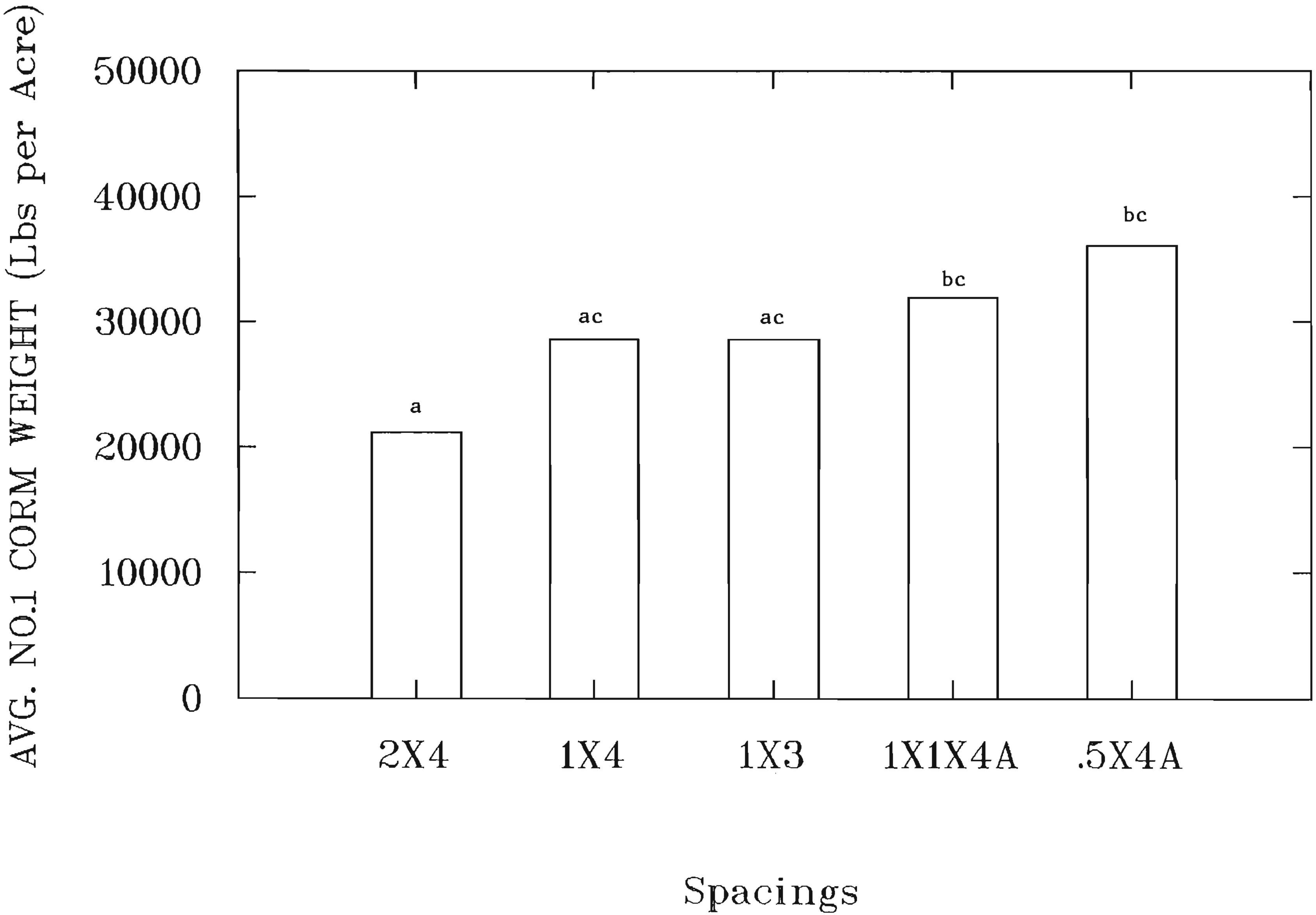


Figure 2.

Predicted Yield per Acre vs Plant Spacing

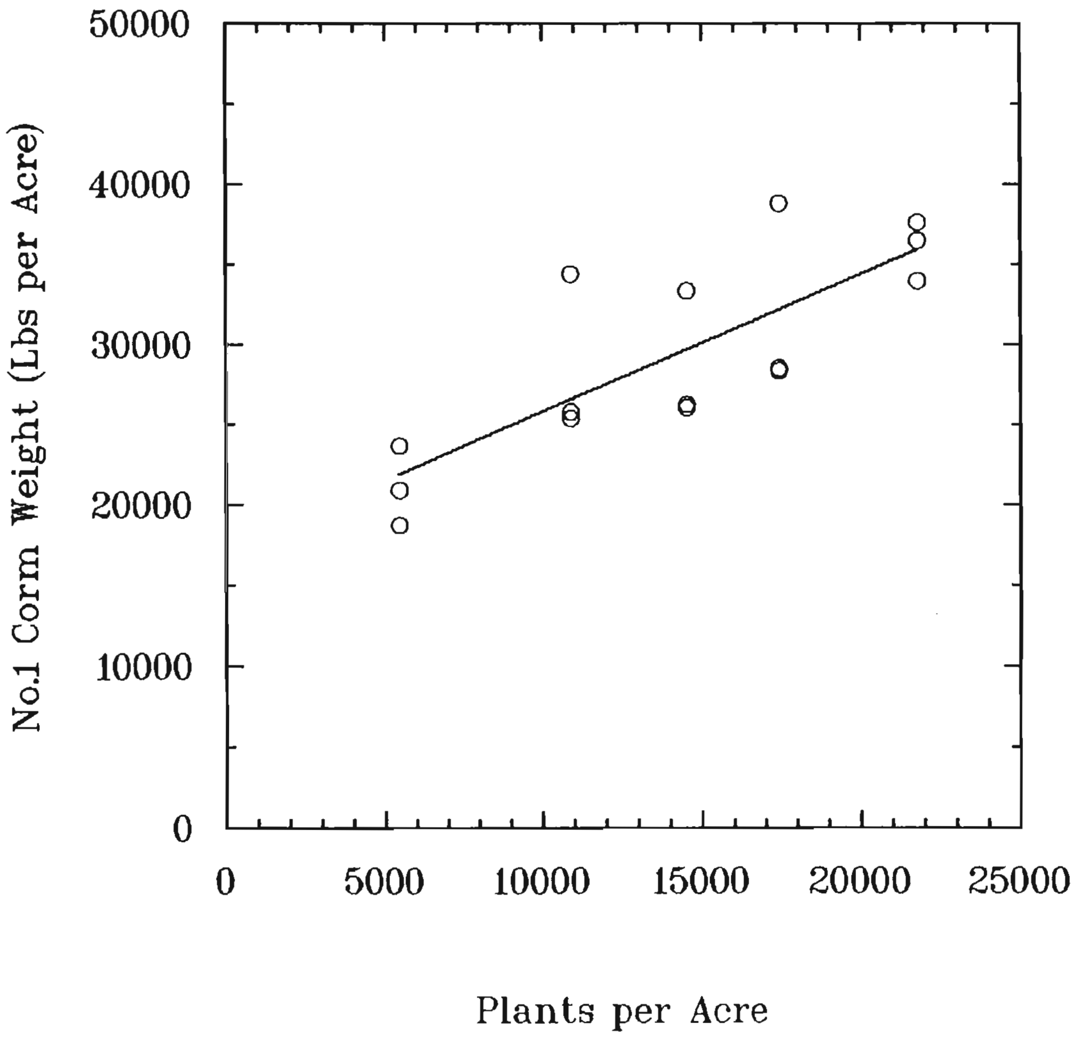


Figure 3.

TARO SPACING: LB PER PLANT

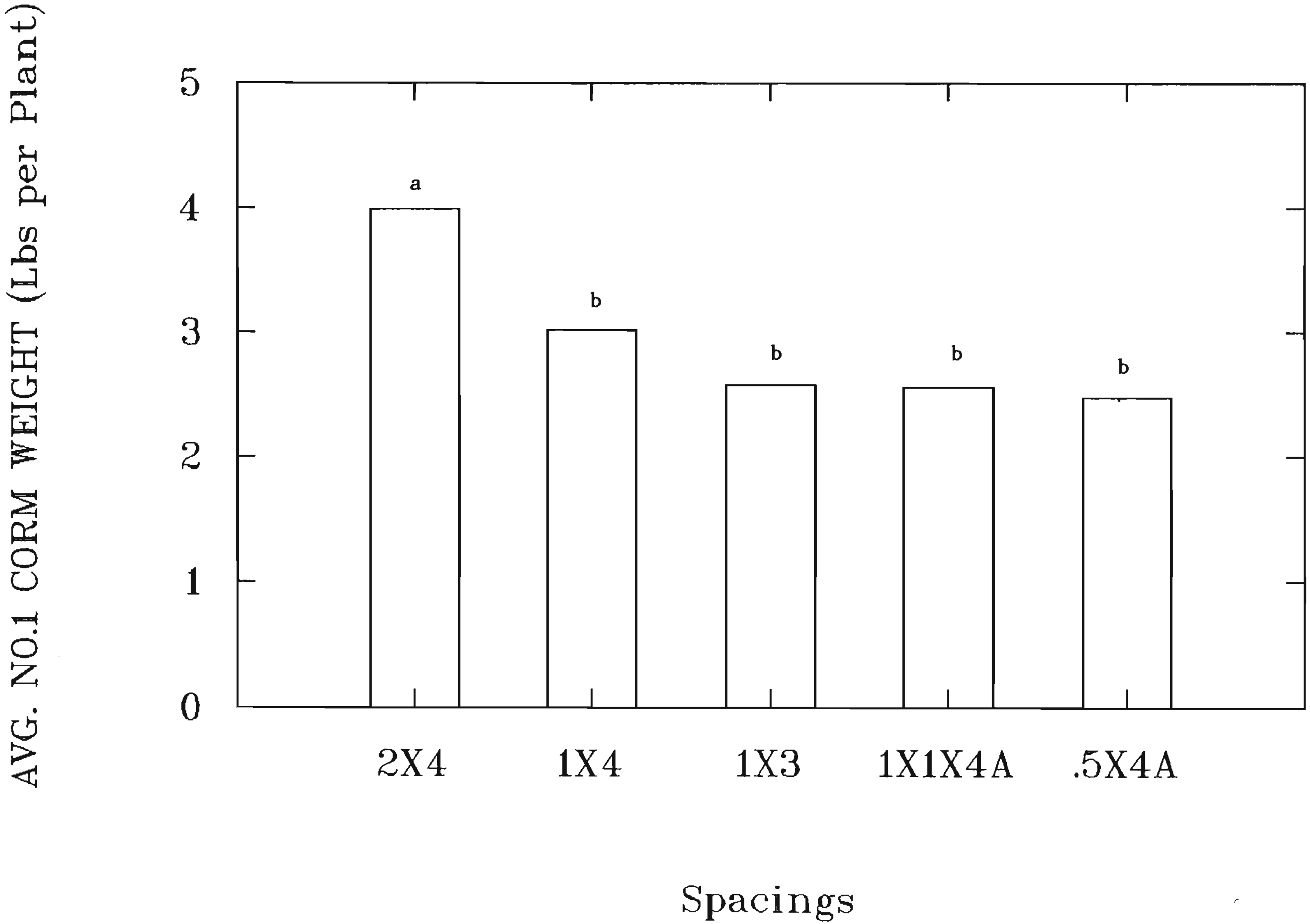


Figure 4.

Predicted No.1 Corm Weight per Plant vs Plant Spacing

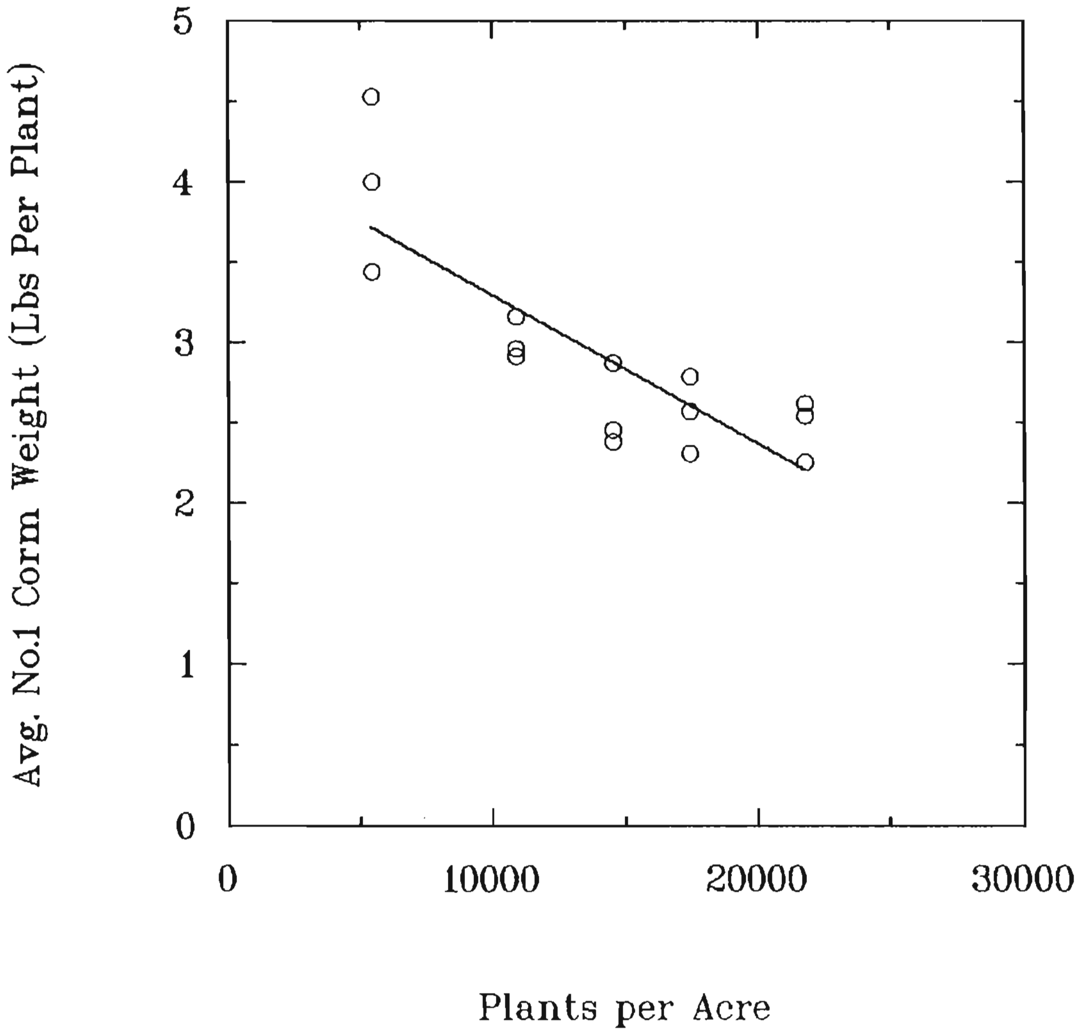
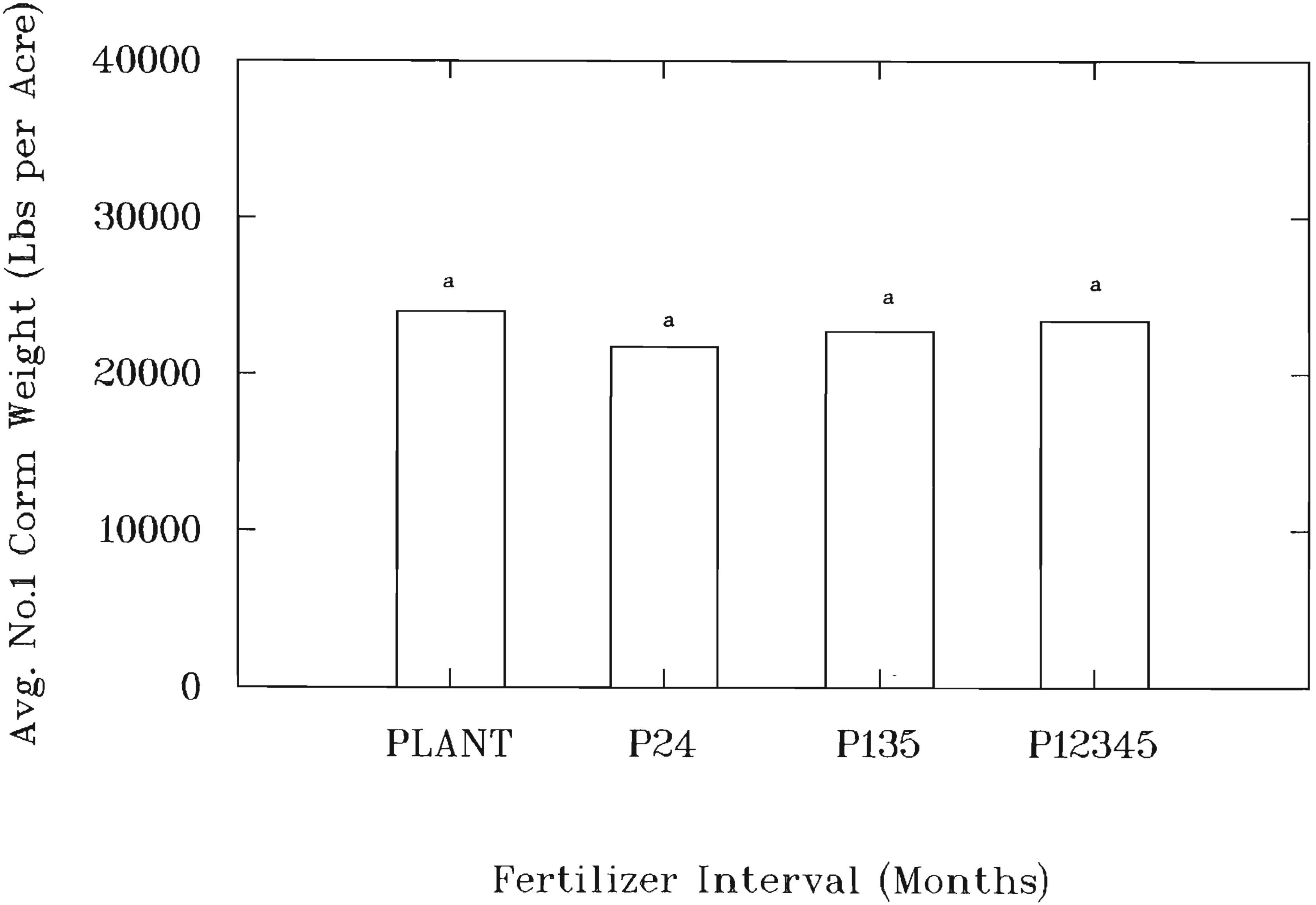


Figure 5.

TARO FERTILIZER TIMING



DRYLAND TARO PRODUCTION

George Santos
Hawaii Community College
University of Hawaii-Hilo

Abstract

Critical steps of growing a successful crop of dryland taro are discussed. The sequence of steps are pre-plant land preparation, planting, weed control, fertilization, pest control, and harvesting. This article will provide you an excellent basis in producing dryland taro if you are new to taro farming. You will also benefit from specific concepts and improve your existing cultural practices if you are an experienced taro farmer.

Pre-plant Land Preparation

The first step in preparing land for a Chinese taro planting involves the removal of trash. This can be accomplished by:

1) Bulldozing which is fast but expensive.
2) Microbial decomposition which involves mowing and roto-tilling into the soil.
3) Removal with a spring toothed cultivator.

The second step includes plowing, an operation which provides improved drainage but more importantly, aids in weed control. Adequate depth in plowing is indicated by the emergence of orange colored soil which is typically found 12 to 16 inches deep in soils along the Hamakua Coast. It is imperative that upon plowing, no trash remains on the soil surface. Completely covering the trash ensures good weed control, one of the most important considerations in the culture of dryland taro. In addition, it is also important that the plowed soil remains undisturbed for a minimum of 3 to 4 weeks. This will allow adequate time for microbial breakdown of the trash which further aids in weed control. The above steps, if done correctly, should result in lower production costs and a higher yield.

Liming at 10 to 12 tons per acre with crushed coral is generally considered the third step in field preparation. I have found this rate of lime application to produce fewer diseased corms, less off-grade corms, and increased plant vigor.

It should be also be noted that lime is to be applied <u>after</u> plowing and not before. The converse would result in an even layer of lime 12 to 16 inches deep that would not be of much benefit either to the soil or the crop.

The next operation involves the use of a tractor drawn tiller that breaks down lumps of soil and incorporates the lime. This operation prepares the soil for the fifth and last operation.

Forming of furrows for planting is the final operation and is usually done to allow for row spaces of between 3 to 4 feet. Some farmers have equipment designed for tilling and row forming in one operation, thereby lowering production costs.

Planting

Taro rarely produces true seed, so a plant by division is used and the local term, "huli", is used to indicate a planting material consisting of corm and stem tissue approximately 12 to 18 inches in length. Hulis are laid on the banks of furrows at right angles to the length of the furrows and covered by an hand drawn tiller. Covering hulis by a hand drawn tiller increases speed of the planting operation and reduces dislodging of hulis in the event of heavy rains.

Planting taro as describe above is proven to be faster than a mechanical transplanter which requires 2 people to operate (driver for tractor and planter for implement).

An item to keep in mind when planting is row spacing. Row spaces greater than 4 feet allows sunlight penetration below the taro leaf canopy. Sunlight induces weeds to germinate thus raising the cost of production.

Weed Control

The pre-emergent herbicide, Goal, will soon be registered for use in taro and will prove to be a boon for taro growers. This product suppresses weed seeds from germinating from 4 to 8 weeks. Goal may also be used as an early post-emergent directed contact spray.

Another herbicide that will be registered in the near future is Gramoxone. This will be especially beneficial in spot controlling established patches of hono-hono grass and crab-grass.

Current methods of minimizing weeds in taro includes:

1) Proper field preparation.
2) Tilling newly emerged weed seedlings with a hand drawn tiller on a periodic basis.
3) Early establishment of leaf canopy cover by frequent applications of fertilizer and adequate irrigation.

Fertilization

My experience shows that pre-plant fertilization of taro with nitrogen and potassium is not necessary or warranted possibly because of the absence of functional leaves and roots for 3 to 4 weeks. If the phosphorus level is very low, a pre-plant banded application can be made. Considering the economics of taro growing, avoid the use of dolomite, chicken manure, hydrated lime, or other costly soil amendments.

A complete fertilizer should be used for the first two months after planting with subsequent applications of 17-0-34, 21-0-32, or even 16-16-16 every 3 to 4 weeks. Avoid low nitrogen-high phosphorus analyses because money is being wasted.

Upon maturity, as indicated by maximum plant height, a switch to high potassium such as 0-0-61 promotes and maintains good starch development.

Pest Control

Taro leaf blight, a leaf and stem rot disease caused by a fungal pathogen can be devastating during wet periods. Possible effective fungicides are a combination of metalaxyl and manzate, but these are not registered for use on taro. Even if approval were to be established, there still remains the problem of physically applying the fungicides and attaining good coverage over the tall taro plants.

Slugs also damage corms and provide entry for secondary organisms to invade. Many farmers find that hilling corms or raising the soil-line over the corms minimizes the damage caused by slugs. A clean, weed free field also reduces slug populations.

Harvesting

Shrinking of the foliage indicates crop maturity and time to harvest. The corms are fully developed and should be harvested before starches convert to sugar (loli loli condition). Corms with a higher sugar content cannot be adequately used for chip processing because they develop darkened or burned edges. This condition can be alleviated to a degree by potassium fertilization.

After harvesting, corms are trimmed, washed, chlorine dipped, weighed, and bagged. At this point, the product should be delivered to a buyer with access to a chill box.

A HAWAIIAN PERSPECTIVE ON TARO GROWING

George Kahumoku, Jr.
Kealia Farms
Honaunau, Hawaii

This Haku poem which I wrote best describes my feeling for taro:

> Taro six feet tall
> Nodding in the wind
> Brings peace to my soul
> George Kahumoku,Jr. 1978

Origin of Kalo

Taro has been documented in Chinese history 100 B.C. and in Egyptian history 1000 B.C. According to Hawaiian oral history, as passed on by Kupuna Aunty Edith Kanaka'ole and shared with those like myself, the Hawaiian genesis of mankind began when Wakea, the god of the sky, vibrated with Papa, the earth goddess. The result of this first union was a keiki 'alu alu or flabby-fetus-born-dead. This fetus was buried near the south end of the house where the kalo or taro sprung forth called Haloa-naka or long-stalk-trembling by the Gods. Those of us who are familiar with taro may have noticed long taro stalks trembling with a light wind blowing.

A second union between Wakea and Papa produced man. Henceforth, according to Hawaiian oral tradition, the kalo or taro plant is the eldest brother of man. Like the old time Japanese samurai, who believed that the spiritual energy or "mana" was passed on best by the first-born of the first born of the subsequent generations, the Hawaiians believed that the taro or kalo was spiritually superior to man who was second-born. This belief was so strong that only men (not women, because of their monthly cycles) were allowed to work in the taro patch and do the food preparation, including poi pounding. Post-missionary contact and new belief systems gave women more freedom in relationship to food growing and the preparation and eating of taro.

Today, many of the links between taro and man have survived by the Hawaiian language. The word for family, ohana, comes directly from the word "oha", or young shoots of the taro, and "na", the Hawaiian word denoting plurality, or many young shoots. The huli or "keiki" refer to the children in the family. The taro that is mature and ready to harvest is called makua, the Hawaiian word for parent. The taro that has long been harvested and eaten is called kupuna, the Hawaiian word for grandparent.

One of my favorite reasons for planting taro (besides eating) is for the spiritual link to my ancestral older brother, the kalo. It reminds me of where I came from and where I'm going. Taro also needs the inter-relationship with man in order to survive and do well. This show of affection by man, through land clearing, planting, weeding, fertilizing, and mulching completes the cycle which benefits man at harvest. So, by keeping the taro alive and strong, one keeps mankind and the family healthy and strong.

Dryland Kalo Growing in South Kona

During the 1920's to the 1950's according to my Uncle Willie Kahumoku, kalo was grown by our family mostly for home use. In Honaunau, my Uncle Charlie Mokuohai and Aunty Anna farmed about forty acres of taro for commercial poi use and owned Royal Hawaiian Poi. Anyone with extra taro would sell to Royal Hawaiian Poi. The varieties we grew for poi in Kealia, where I now reside, were mainly Lehua Maoli, Lehua Ula ula, Poni, Pala'i'i, Naioea, O'opu kai, and several varieties of piko taro such as Piko Lehua and Piko Keokeo. The table eating varieties we grew were mostly Mana Ulu, Mana Keokeo and Mana 'Ele 'ele. Mana Opelu, Kumu, and Laoloa varieties and one called "pake taro" (not the Bun Long variety) we grew for pig feed and opelu (mackerel fish) chum, as these had less favorable characteristics. They were too itchy to eat, made poi "hu" (rise and overflow), or were huge and/or with lots of keikis.

We fished and planted by the moon. We found that the three nights before the full moon called Po' Akua, Po' Hoku, and Po' Mahea-lani were best for planting taro. We sometimes planted taro on the Hilo or new moon. Other moon phases were used to plant ulu (breadfruit), ko (sugarcane), mai'a (bananas), and 'uala (sweet potato). Like my ancestors, I still use the o'o or digging stick for planting except my o'o is made of spring steel instead of wood. Taro was planted by softening the earth with the o'o and planted maka lua (two eyes or two huli) in a hole twenty four inches wide in rows four feet apart. It was said that the kalo was lonely and would grow better side by side with a friend. Before planting the land was prepared by clearing, slashing, and burning. The huli was ho'omakaukau (made ready before hand). All taro was planted at a slanted 45° angle in a ku or hina fashion. The ku style of planting taro slanted 90° perpendicular towards the sun's path across the sky. The hina style of planting taro placed the huli 90° away from the sun's path across the sky. "Ku" was used for making big corms with little or no keikis, "hina" was used for building up huli and making lots of keikis.

During the early 1900's mango, hau, and kukui trees were planted near the stone walled edges of the fields. Along with ama'u ferns, the young leaves of these trees were used to po'i or mulch from six to twelve inches deep around the newly planted taro once that taro had taken and was standing up (about six to eight weeks after planting). It was the job of the youngsters ages twelve to seventeen to climb the trees and break off the young branches. Even today if you go into the South Kona uplands, one can find huge groves of mango, hau, and kukui planted and used for this purpose. Ti and banana were also planted on the edges of the taro and the leaves were also used for fertilizer and mulching. Before the taro began to cover and canopy the entire ground, around three months old, it was weeded one last time and left alone until harvest. No one was allowed to play or make noise near the kalo patch as it was a sacred place.

The taro grew to six, seven, and even eight feet tall. When the leaves would start to shrink and drop, the corms wound begin to form. When the leaves were three to four feet in height or between six to twelve months old, depending on the variety, the taro was harvested. If not harvested in time certain varieties like Lehua would begin to loliloli or rot. You were considered a good taro farmer if four to five makalua (or holes) harvested filled a one hundred ten pound coffee bag. The taro was then taken home where it was steamed in the imu or on an open fire in a fifty-five gallon drum. The taro was then pounded into pa'i'ai with a stone poi pounder by two folks sitting across from each other straddling one long poi board. It was fun to hear the kupunas' poi pounders "talk" to each other while pounding poi.

Pa'i'ai was really stiff pounded taro with little or no water added. The pa'i'ai was placed in thirty gallon kelemania (earthen crocks) for storage. Poi was then made by putting it into smaller bowls of about two gallons each and fermented according to individual taste. My great-grandmother liked her poi three to four weeks old, white and bubbly, as does my older brother who grew up with our great grandparents.

Today we still grow taro much like our kupunas did except we use commercial fertilizer, pig manure, and macadamia nut and coffee husks along with the mango, ti, and banana leaves for mulch.

Thank-you for this opportunity to share.

SPEAKERS AND PANELISTS

Dr. Chauncey Ching - Director HITAHR
Gilmore 202B
3050 Maile Way
University of Hawaii
Honolulu, HI 96822 948-8131

Dr. Wai-Kit Nip
Food Science & Human Nutrition 70A
1920 Edmonson Rd.
University of Hawaii
Honolulu, HI 96822 948-8210

Jim Hollyer
Agricultural and Resource Economics
Gilmore Hall 112
3050 Maile Way
University of Hawaii
Honolulu, HI 96822 948-8800

Dr. PingSun Leung
Agricultural and Resource Economics
Gilmore Hall 112
3050 Maile Way
University of Hawaii
Honolulu, HI 96822 948-8562

Dr. Ramon dela Peña
Kauai Branch Station
7370-A Kuamoo Rd.
Kapaa, HI 96746 822-4984

Dr. James Silva
Agronomy and Soil Science
Sherman Hall 236
1910 East-West Rd.
University of Hawaii
Honolulu, HI 96822 948-6906

Dwight Sato
Cooperative Extension Service
875 Komohana St.
Hilo, HI 96720 959-9155

Dr. Joe DeFrank
Department of Horticulture
St. John 212C
3190 Maile Way
University of Hawaii
Honolulu, HI 96822 948-8050

Dr. Robert Paull
Plant Molecular Physiology
St. John 516
3190 Maile Way
University of Hawaii
Honolulu, HI 96822 948-7369

Dr. Jeri Ooka
Kauai Branch Station
7370-A Kuamoo Rd.
Kapaa, HI 96746 822-4984

Dr. William Sakai
College of Agriculture
University of Hawaii at Hilo
Hilo, HI 96720 933-3393

George Santos
Hawaii Community College
Agriculture Program
Cooperative Extension Service
875 Komohana St.
Hilo, HI 96720 959-8084

Paul Kierkiewicz
Mauna Kea Agronomics
P.O. Box 1210
Hilo, HI 96720 961-2831

Dr. Robert Coltman
Department of Horticulture
St. John 207
3190 Maile Way
University of Hawaii
Honolulu, HI 96822 948-7934

James Lee
May Produce Company
742 E. Garvey Ave #C
Monterey Park, CA 91754 (818)572-3168

George Kahumoku, Jr.
P.O. Box 388
Honaunau, HI 96726 328-8167

Ted Javellena
5473 Kawaihau Rd.
Kapaa, HI 96746 822-9581

CONTRIBUTORS TO THE TARO PRODUCTS DISPLAY

Shiochi Nagamine
Taro Ko Chips
P.O. Box 322
Hanapepe, HI 96716 335-5586

Alvin Aoki
Big Island Taro Chips
P.O. Box 473
Papaikou, HI 96781 964-1437

Walter Atebara
Atebara Potato Chip Co.
717 Manono St.
Hilo, HI 96720 935-6968

Low International Food
222 Kilauea Ave.
Hilo, HI 96720 969-6652

Ernest Tottori
Honolulu Poi
288 Libby St.
Honolulu , HI 96819 848-2431

VIDEO PRODUCTION STAFF

Doug Hamasaki
Department of Horticulture
St. John 212C
3190 Maile Way
University of Hawaii
Honolulu, HI 96822

Lisa Ferentinos
Agronomy and Soil Science
1910 East-West Rd.
University of Hawaii
Honolulu, HI 96822

COOPERATING ASSOCIATION

Hawaii Dryland Taro Association
C/O 875 Komohana St.
Hilo, HI 96720

CUMULATIVE CONFERENCE CITATION INDEX

Abbott, A. J. and R.K. Atkin (Editors). 1987. Improving Vegetatively Propagated Crops. Academic Press Ltd., London.

Abo El-Nil, M.M., and Zettler, F.W. 1976. Natural occurrence of dasheen mosaic virus in Egyptian taro Colocasia antiquorum. Plant Dis. Rep. 60:281-285.

Abo El-Nil, M.M., Zettler, F.W., and Hiebert, E. 1975. Purification of dasheen mosaic virus. Proc. Amer. Phytopathol. Soc. 2:73.

Adler, I.L. and C. K. Hofmann. 1980. Oxyfluorfen (Chapter 17), in Analytical Methods for Pesticides and Plant Growth Regulators, vol. XI, eds. G. Zweig and J. Sherma. Academic Press.

Adler, I.L., L.D. Haines and B. M. Jones: 1978. Gas-Liquid chromatographic determination of residues from the herbicide 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene. J. Assoc. Official Anal. Chem: 61:636.

Alconero, R., and Zettler, F.W. 1971. Virus infections of Colocasia and Xanthosoma in Puerto Rico. Plant Dis. Rep. 55:506-508.

Allen, E. F. 1940. The cultivation of Colocasia esculenta (L.) Schott. in Malaya. Malaysian Agr. J. 28:392-399.

Alvarez-Garcia, L.A. and A. Cortes-Monllor. 1971. Currutaca: A Pythium soft rot of Xanthosoma and Colocasia spp. in Puerto Rico. J. Agr. Univ. Puerto Rico 55:78-84.

Amin, El.S. 1955. The polysaccharides of *Colocasia antiquorum* (Taro or Colocasia). J. Chem. Soc. Part III. p.2441-2445.

Asthana, R.P. 1946. Bacterial leaf-spot of arum. Curr. Sci. (Bangalore) 15:356.

Barrau, J. 1961. Subsistence agriculture in Polynesia and Micronesia. B. P. Bishop Museum Bulletin 223: 43-67.

Barrett, O. W. and O. F. Cook. 1910. Promising root crops for the South. U.S. Dept. Agri., Bur. Pl. Ind., Bull No. 164.

Bergquist, R.R. 1972. Efficacy of fungicides for control of Phytophthora leafblight of taro. Ann. Bot. (London) 36:281-287.

Bergquist, R.R. 1974. Effect of fungicide rate, spray interval, timing of sprayapplication and precipitation in relation to control of Phytophthora leaf blight of taro. Ann. Bot. (London) 38:213-221.

Betham, R. (1982). Personal communication. Western Samoa, Samoan-German Crop Protection Center-Nuu.

Bilger, L.H. and H.Y. Young. 1935. A chemical investigation of the fermentation occurring in the process of poi manufacture. J. Agric. Res. 51:45.

Blackman, R.L. and V.F. Eastop. 1984. Aphids on the World's Crops: An Identification and Information Guide. Chichester, England: John Wiley & Sons. p 323.

Bowers, F.A. 1967. Agricultural history of taro. Univ. Hawaii Coop. Ext. Serv.Misc. Publ. 36:8-13.

Bradbury, J.H. 1988. The chemical composition of tropical root crops. ASEAN Food J. 4:3-13.

Brandes, G.A., Cordero, T.M., and Skiles, R.L., eds. 1959. Compendium of plantdiseases. Philadelphia: Rohm and Haas.

Browne, M.W. 1923. Cold storage of carrots, beets and dasheens. Ice and Refrig. 64:361-362.

Bugnicourt, F. 1954. Phytopathologie. Courr. Cherch. 8:159-186.

Butler, E.J., and Kulkarn, G.S. 1913. Colocasia blight caused by Phytophthora colocasiae Rac. Mem. Dept. Agr. in India, Bot. Ser. 5:233- 259.

Byars, L.P. 1917. A nematode disease of the dasheen and its control by hot water treatment. Phytopathology 7:66.

Carpenter, C.W. 1919. Preliminary report on root rot in Hawaii. Hawaii Agr. Exp.Sta. Press Bull. 54.

Ching, K.W. 1969. Some aspects of the physiological ontogeny of starch, total sugar, protein, leaf and corm of *Colocasia esculenta*. Univ. of Hawaii MSc Thesis.

Ching, K.W. 1970. Development of starch, protein, leaf and corm in *Colocasia esculenta*. Proc. 2nd Intl. Symp. Trop. Root & Tuber Crops. Honolulu, HI, Donald L. Plucknett (ed). P143-146.

Coursey, D. G. 1968. The edible aroids. World Crops 20(4):25-30.

Cox, L.J., Nakamoto, S.T., Marutani, H.K., and Leung, P.S. 1988. *A User's Manual for the Vegetable-Crop Budget Template*, Research Extension Series 091, Hawaii Institute of Tropical Agriculture and Human Resources.

De Brot, E.A., and Ordosgiotti, A. 1974. Dasheen mosaic virus infection on Colocasia and Xanthosoma in Venezuela. Plant Dis. Rep. 58:1032-1034.

de la Peña, R., P. Vander Zaag, and R.L. Fox. 1979. The comparative phosphorus requirements of flooded and non-flooded taro. Provisional Report No. 5. Taro and Cocoyam. International Foundation for Science. p.223-237.

de la Peña, R.S. 1970. The Edible Aroids in the Asian-Pacific Area. Proceedings of the Second International Symposium on Tropical Root and Tuber Crops 1:136-140.

dela Peña, R. S., P. Vander Zaag and R.L. Fox. 1980. The Comparative Phosphorus Requirements of Flooded and Non-Flooded Taro. Proc. 5th Int. Symp. on Tropical Root and Tuber Crop, pp 671-681.

Deshmukh, M.J., and K.N. Chibber. 1960. Field resistance to blight (Phytophthora colocasiae Rac.) in Colocasia antiquorum, Schott. Curr. Sci.(Bangalore) 29:320-321.

Dumbleton, L.J. 1954. A list of plant diseases recorded in South Pacific territories. South Pacific Commission Technical Paper 78.

Fajardo, T.G., and Mendoza, J.M. 1935. Studies on the Sclerotium rolfsii Sacc.Philipp. J. Agric. 1935, pp. 387-425.

FAO (Food and Agriculture Organization of the United Nations). 1987. FAO Production Yearbook. Rome: FAO.

Gollifer, D.E. and Brown, J.F. 1972. Virus diseases of Colocasia esculenta in the British Solomon Islands. Plant Dis. Rep., 56:597-599.

Gollifer, D.E., Jackson, G.V.H., Dabek, A.J., Plumb, R.T., and May, Y.Y. 1975.Taro viruses in the Solomon Islands: symptoms and transmission. South Pacific Commission Working Paper 20. Presented at the Regional Meeting on the Production of Root Crops, 24-29 November 1975, Suva, Fiji.

Gomez, E.T. 1925. Blight of Gabi (Phytophthora colocasiae Rac.) in the Philippines. Philipp. Agr. 14:429-440.

Governor's Agriculture Coordinating Committee 1986. Taro Industry Analysis No. 3.

Goyal, J.P., Naik, S.M., Pathak, V.N., Sharma, H.C., and Prasada, R. 1974. Evaluation of some modern fungicides for the control of Sclerotium rolfssi Sacc.inciting the tuber rot of Colocasia antiquorum L. (Arvi). Nova Hedwigia Beiheftezur 47:205-210.

Graham, J.H., Kreitlow, K.W., Faulkner, L.R. 1972. Diseases. In: Alfalfa science and Technology, ed. C.H. Hanson, pp. 497-526. Amer. Soc. Agron., no. 15.

Handy, E.S.C. 1940. The Hawaiian planter. I. His plants and areas of cultivation. Bull. Bernice P. Bishop Mus. (Honolulu) 161:6-130.

Hartman, R.D. 1974. Dasheen mosaic virus and other phytopathogens eliminated from caladium, taro and cocoyam. Phytopathology 64:237-240.

Hartman, R.D., and F.W. Zettler, 1972. Dasheen mosaic virus infections in commercial plantings of aroids in Florida. Phytopathology 62:804.

Hartman, R.D., and F.W. Zettler, 1974. Effects of dasheen mosaic virus on yieldsof caladium, dieffenbachia, philodendron. Phytopathology 64:768.

Hawaii Agricultural Experiment Station. 1920. Taro. Rep. Hawaii Agr. Exp. Sta.,pp. 39-40.

Hawaii Agricultural Experiment Station. 1938. Taro. Rep. Hawaii Agr. Exp. Sta., pp. 36-38, 86-87.

Hawaii Agricultural Statistics Service. 1989. Hawaii Vegetables Annual Summary. Honolulu, Hawaii.

Hawkes, J.G. 1987. World Strategies for Collecting, Preserving and Using Genetic Resources. In: A.J. Abbott and R.K. Atkins (Eds.). Improving Vegetatively Propagated Crops. Academic Press Ltd., London pp. 285-301.

Hayes, H.K. and F.R. Immer. 1942. Methods of Plant Breeding. McGraw-Hill Book Co., New York.

Hicks, P.G. 1967. Resistance of Colocasia esculenta to leaf blight caused by Phytophthora colocasiae. Papua New Guinea Agr. J. 19:1-4.

IRRI. 1967. The International Rice Research Institute Annual Report, 1966. Manila Philippines.

Jackson, G.V.H. and D.E. Gollifer. 1975a. Disease and pest problems of taro (Colocasia esculenta L. Scott) in the British Solomon Islands. Pest Articlesand News Summaries (PANS) 21:45-53.

Jackson, G.V.H. and D.E. Gollifer. 1975b. Storage rots of taro (Colocasia esculenta) in the British Solomon Islands. Ann. Appl. Biol. 80:217-230.

Jackson, G.V.H. and D.E. Gollifer. 1975c. Studies on the taro leaf blight fungus Phytophthora colocasiae in the Solomon Islands. South Pacific Commission Working Paper 18. Presented at the Regional Meeting on the Production of Root Crops,24-29 November 1975, Suva, Fiji.

James, M., Kenton, R.H., and Woods, R.E. 1973. Virus-like particles associated with taro diseases of Colocasia esculenta (L.) Schott in the Solomon Islands. J.Gen. Virology 21:145-153.

Kagbo, R.B., R.S. dela Peña, D.L. Plunknett and R.L. Fox. 1977. Mineral Nutrition of Taro (Colocasia esculenta) with Special Reference to Petiolar Phosphorus Level and Phosphate Fertilizers. Proc. of the 3rd Symp. of the Int. Soc. for Tropical Root Crops. Ed. Colin L.A. Leakey, pp 138-144.

Kagbo, Robert B., D.L.Plucknett, and W.G. Sanford. 1980. Yield and Related Components of Flooded Taro as Affected by Land Preparation, Planting Density, and Planting Depth. Proc. 5th Int. Symp. on Trop. Root and Tuber Crops (1978), pp 629-635.

Kasasian, L. 1967. Chemical weed control in tropical root crops. Trop. Agr. Trin. 44:143-150.

Kenten, R.H., and Woods, R.E. 1973. Viruses of Colocasia esculenta and Xanthosmoma sagitifolium. PANS 19:38-41.

Kerz-Moehlendick, F.H., Fliege, F.H., and Schloesser, E. 1983. The occurrence of Pythium species as causative organisms of losses due to root and corm rot of taro, Colocasia esculenta (L.) Schott, in Western Samoa. Alafua Agric. Bull.8(2):129-137.

Kumar, C.R.M., and Souza, D. 1969. A note on Paratylenchus mutabilis Colbran 1968 (Nematoda: Criconematidae) from India. Curr. Sci. (Bangalore) 38:71- 72.

Kundu, B. C. 1967. Some edible rhizomatous and tuberous crops of India. Proceedings of the International Symposium on Tropical Root Crops 1: 124-130.

Market News Service, Hawaii State Department of Agriculture, 1988. Honolulu Arrivals, Fresh Fruit and Vegetables 1988. Honolulu, Hawaii.

Martin, J. H., W. H. Leonard, and D. L. Stamp. 1976. Principles of Field Crop Production, Third Edition. Macmillan Publishing Co., New York. p. 430.

Martin, J.H. and W.H. Leonard. 1949. Principles of Field Crop Production. The MacMillan Co., New York.

Marutani, H.K. 1984. *Cost and Return of Dry Land Taro Production in Hawaii: 1984*, Farm Management Report No. 17, Hawaii Institute of Tropical Agriculture and Human Resources.

Metcalf, C.L. and W.P. Flint. 1962. Destructive and Useful Insects: Their Habits and Control. 4th Ed. New York: McGraw-Hill Book Co.

Migvar, L. 1968. How to grow taros, yams, cassava, and sweet potatoes. Mariana Islands, Division of Agriculture, Department of Research and Development, Trust Territories of the Pacific Islands, Agriculture Extension Bulletin, Number 7, pp. 7-8.

Mitchell, W. C. and P. A. Maddison, 1983. Pest of Taro. Pages 180- 235 in J-K. Wang, ed. Taro, A review of Colocasia esculenta and its potentials., University of Hawaii press, Honolulu.

Nirula, N.K. 1959. Root knot nematode on Colocasia. Curr. Sci. (Bangalore)28:125-126.

Ooka, J.J. 1981. Rhizopus stolonifer rot of taro. Phytopathology 71:246.

Ooka, J.J. and B. Yamamoto. 1979. Pythium root and corm rot of Colocasia esculenta in Hawaii. Phytopathology 69:918.

Ooka, J.J. and Uchida, J.Y. 1985. Taro root and corm rot caused by Pythium myriotylum. Phytopathology 75(11):1316.

Paharia, K.D., and P.N. Mathur. 1964. Screening of Colocasia varieties for resistance to Colocasia blight (Phytophthora colocasiae Racib.). Sci. Cult.30:44-46.

Parham, B.E.V. 1949. Annual report of the economic botanist for the year 1948.Fiji Legislative Coun. Paper 24:31-35.

Parris, G.K. 1939. Diseases of taro. In: Report of the Hawaii Agr. Exp. Sta.1938, pp. 36-38.

Parris, G.K. 1940. A check list of fungi, bacteria, nematodes and viruses occurring in Hawaii and their hosts. Plant Dis. Rep. Suppl. 121:11-12.

Parris, G.K. 1941. Diseases of taro in Hawaii and their control. Hawaii Agr. Exp. Sta. Circ. No. 18. 29 pp.

Payne, J.H., G.J. Ley and G. Akau. 1941. Processing and chemical investigations of taro. Hawaii Agric. Exp. Stn. Bull. No. 86.

Pesticide Analytical Manual, vol. II, oxyfluorfen, pesticide reg. sec. 180.381, U.S. Dept. of Health and Human Services, Food and Drug Administration, revised September 1983.

Plant Disease Clinic. 1980. Plant disease clinic report. Univ. Hawaii Coop. Ext.Serv., with the U.S. Dept. of Agr., Honolulu, Hawaii.

Plant Disease Clinic. 1981. Plant disease clinic report. Univ. Hawaii Coop. Ext.Serv., with the U.S. Dept. of Agr., Honolulu, Hawaii.

Plucknett, D. L. 1970. Colocasia, Xanthosoma, Alocasia, Cyrtosperma, and Amorphophallus. Proceedings of the Second International Symposium on tropical Root and Tuber Crops 2: 127-135.

Plucknett, D. L. 1976. Edible aroids. In Evolution of Crop Plants (N. W. Simmonds, ed.). Longman, London and New York, pp. 10-12.

Plucknett, D.L. and R.S. de la Peña. 1971. Taro Production in Hawaii. World Crops. 23(5): 244-249.

Plucknett, D.L., R.S.de la Peña and F.P. Obrero. 1970. Taro (Colocasia esculenta), a Review. Field Crops Abstracts. 23: 413-426.
Rabbe, R.D., Conners, I.L., and Martinez, A.P. 1981. Checklist of plant diseases in Hawaii. HITAHR Information Text Series 022. 313 pp.
Rashid, M. M. 1980. Personal communication. Bangladesh Agricultural Research Institute, Dacca, Bangladesh.
Rashid, M. M., and H. J. Daunicht. 1979. Chemical composition of nine edible aroid cultivars of Bangladesh. Scientia Horticulturae 10: 127-134.
Reynolds, S.G. and P. Netram. 1977. The Effect of Rainfall and Time of Planting on Yield of Taro in Western Samoa. Proc. of the 3rd Symp. of the Int. Soc. for Tropical Root Crops. Ed. Colin L.A. Leakey, pp 374-376.
Ridings, W.H. and R.D. Hartman. 1976. Pathogenicity of Pythium myriotylum and other species of Pythium to caladium derived from shoot-tip culture. Phytopathology 66:704-709.
Sakai, W. S. 1983. Aroid Root Crops: Alocasia, Cyrtosperma, and Amorphophallus, In Handbook of Tropical Foods (H. T. Chan, Jr., ed.). Marcel Dekker, New York. pp. 29-83.
Sato, D., Silva, J., Leung, P.S., Santos, G., and Kuniyoshi, J. 1989. *Nitrogen and Potassium Fertilization for Dryland Taro*, A GACC Taro Fertility Progress Report No. 1, Hawaii Institute of Tropical Agriculture and Human Resources.
Sedgwick, T.F. 1902. The root rot of taro. Hawaii Agr. Exp. Sta. Bull. No. 2.
Sivan, P. 1977. Effects of Spacing in Taro. Proc. of the 3rd Symp. of the Int. Soc. for Tropical Root Crops. Ed. Colin L.A. Leakey, pp 377-381.
Soyza, D. J. de. 1938. Yam cultivation in the Kegalla district. Tropical Agriculture Magazine of the Ceylon Agricultural Society 90(2): 73-75.
Standal, B.R. 1970. The nature of poi carbohydrates. Proc. 2nd Intl. Symp. Trop. Root & Tuber Crops, Honolulu, HI, Donald L. Plucknett (ed). p146-148.
Steiner, K.G. 1981. A root rot of macabo (Xanthosoma sp.) in Cameroun, associated with Pythium myriotylum. Zeitschrift fur Pflanzendrankheiten und Pflanzenschutz 88:608-613.
Takahashi, M. 1953. Report of taro diseases in Hawaii. Mimeographed report to the Hawaii Territorial House (HR no. 28).
Tandon, R.S., and Singh, S.P. 1974. Two new species of the genus Aphelenchoides Fischer (Nematoda, Aphelenchoididae) from the roots of Colocasia antiquorum Schott. Indian J. Entomol. 36:44-50.
Toyama, A. 1975. Expression of mosaic symptoms on taro plants from Dasheen mosaic virus infected corms. Ann. Phytopathol. Soc. Japan 41:506-507.
Trujillo, E.E. 1965. Effects of humidity and temperature on Phytophthora blight of taro. Phytopathology 55:183-188.
Trujillo, E.E. 1967. Diseases of the genus Colocasia in the Pacific area and their control. Proc. Int. Symposium on Tropical Root Crops. Vol. 2(IV):13-19.
Trujillo, E.E., and Aragaki, M. 1964. Taro blight and its control. Hawaii FarmSci. 13:11-13.
U.S. Department of Agriculture, Economic Research Division, Commodity Economics Division. U.S. Imports of Fruits and Vegetables Under Plant Quarantine Regulations, Fiscal Year 1986. Washington, D.C.
Uchida, J.Y. and M. Aragaki. 1979. Ceratocystis blight of Sygonium podophyllum. Plant Disease Reporter 63:1053-1056.
van Hoof, H.A. 1971. Zantedeschia aethiopica. In: Ann. Rep. Inst.Plantenziektenk, pp. 87-88. Onderzoek, Binnenhaven 12, Wageningen, The Netherlands.
Watson, J. 1979. Importing root crops from the South Pacific Islands for New Zealand markets. In Small-Scale Processing and Storage of Tropical Root Crops (D. L. Plucknett, ed.). Westview Press, Boulder, Colorado.
Whitney, L.D., F.A.I. Bowers and M. Takahashi. 1939. Taro Varieties in Hawaii. Hawaii Agricultural Experiment Station Bulletin No.84.
Wilson, J.E. and W.J. Cable. 1984. Promotion of Flowering, Seed Production and Seedling Screening in Minor Edible Aroids. In: Symposium of the International Society for Tropical Root Crops, 6th Proceedings. Lima. 1983. International Potato Center. pp. 151-156.
Yokoyama, K., J. Hollyer, S. Nakamoto, K. Wanitprapha. 1989. Taro Economic Fact Sheet. Department of Agricultural and Resource Economics, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa.

Yokoyama, K., K. Wanitprapha, S. Nakamoto, P.S. Leung, J. Roecklein. 1988. U.S. Import Statistics for Agricultural Commodities, 1981-1986. Transaction Publishers, New Brunswick, New Jersey, 1988.
Zettler, F.W., Foxe, M.J., Hartman, R.D., Edwardson, J.R., and Christie, R.C.1970. Filamentous viruses infecting dasheen and other araceous plants. Phytopathology 60:893-897.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Noel P. Kefford, Director and Dean, Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu, Hawaii 96822. An Equal Opportunity Employer providing programs and services to the citizens of Hawaii without regard to race, color, national origin, or sex.

RESEARCH EXTENSION SERIES 114—1/90(800)