Taro Research at the University of Hawaii and its Implication for Other Countries

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Abstract

The paper presents a research program geared towards the improvement of taro. The program outlines the areas for taro research to be conducted by the University of Hawaii in cooperation with other taro researchers.

To recognize the importance of taro as a staple food and animal feed, a proposal to create a Pacific Association on Taro (PAT) was forwarded. Each association member will fund its own activities and will participate in cooperative programs.

Introduction

Breakthrough improvements of the major grain crops have increased world food production dramatically during the last two decades. However, with the worldwide energy shortage, and its resultant constraints on agricultural chemicals, water, and other energy requirements for highly intense agricultural production, major new developments in grain crop production are less likely to occur during the next decade. Furthermore, the advances in grain production have not brought significant benefits to areas where root crops have traditionally been the major staples. Therefore, emphasis need to be directed toward root crops, such as taro (*Colocasia esculenta*), which is a staple food in many developing nations in Asia and Pacific.

Taro is one of the major staple foods where both the leaf and underground parts are equally important. Within the last 50 years, several investigators have confirmed the superiority of taro over other starch staples. The digestibility of taro starch has been estimated to be 98.8 % (Langworthy and Deuel, 1922, Potgieter, 1940). Taro starch with grain size in the 1-3 micron range, is only one-tenth the size of potato starch granules (Payne, Ley, and Akau, 1941), rarely causes food sensitivity problems in children or adults (Feingold, 1942; Coursey, 1968), and can be used as an additive that will render plastic biodegradable (Griffin, 1978). Other industrial utilizations, such as high fructose enriched syrup and gums are also possible. Taro leaf, on a dry weight basis, contains 34 to 52 percent crude protein, and is an excellent vegetable.

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The wet tropics are traditionally importers of animal feeds. Major feed crops, such as corn, sorghum, alfalfa, barley, and others require long days, high temperature and strong solar irradiation and supplemental irrigation during their growing session to achieve their high yield potential. The wet tropical regions do not provide the optimal environment for their production.

To meet the increasing animal feed requirement of the wet tropics, it is necessary to turn to native plants such as taro, which is a long term crop and is extremely tolerant to wide variations in soil moisture. Taro leaves are rich in crude protein, and can be harvested a number of times during its life cycle to produce high grade feed. The fact that taro corms are excellent energy feed requires no further discussion.

The Potential of Taro

It is clear that taro will remain an important staple crop in some places of the world. The potential of growth as a staple crop, however, is quite limited. The preference for taro, and other root crops, as a staple food is related to ethnic background, and there is some indication that as the society becomes more affluent, the population has a tendency to reduce its dependence on taro. Processed taro products, such as flour, bread, noodles, chips, and cookies are technically feasible, and limited marketing success can be projected, but an uphill struggle in market development must first be won.

Industrial utilization of taro and taro starch will depend upon its price competitiveness. Both long term research programs and strong developmental assistance are required to transform a basically subsistence farming practice into an agricultural enterprise that can penetrate the industrial market.

The development of the taro crop to meet the increasing demand of animal feed in the wet tropics seems to offer the best chance for a major breakthrough for the next 3 to 5 years.

Therefore, the University of Hawaii is currently emphasizing two areas of research and development activities in our taro research:

1. Upland taro as a staple food supply. A large portion of the existing research work on taro at the Hawaii Agricultural Experiment Station has been directed toward paddy taro production. Nevertheless, about 260 taro accessions have been collected at the Lyon Arboretum and 160 are kept at the Kauai Branch Station for selection trials.

In addition to increasing our existing germplasm collection and field trials, one of the major efforts will be to develop a comprehensive cropping system for upland taro. This will include cultivar selection, agronomic management practices, pest, disease, and weed control, proper use and timing of fertilizers, and economic studies of production scheduling to assure year-round steady supply.

2. Exploration of the potential of upland taro as a source of animal feed in the wet tropics. The production of animal feed in the wet tropics has had many problems. Major feeds, such as alfalfa, corn, sorghum, barley, etc., are primarily temperate zone crops which require long days, high temperature, strong solar radiation, and sufficient supplemental irrigation during their growing season. Taro is a long-term crop, a crop which can be kept in the ground for longer than two years, and is extremely tolerant of wide variations in available moisture. Taro tops are rich in protein, taro leaves have been shown to have 34 to 52 percent (dry weight basis) of crude protein, and can be

harvested a number of times during its life to produce high grade feed. Preliminary investigations have shown that irritant level in taro leaves can be reduced sufficiently by the normal artificial drying process employed in the drying of alfalfa. The high moisture content of the taro tops, up to 88 percent (wet basis), makes field drying of taro tops difficult, and somewhat unreliable under prevailing conditions in the wet tropics. Artificial drying may be too costly, unless alternate energy sources, such as geothermal, are available. But ensiling is an alternative to drying. Silage can reach a temperature of 180°F, and it is possible that under such conditions, the irritant level of taro tops can be sufficiently reduced. Another alternative is cultivar selection. Taro leaves have been used as vegetables, and several cultivars have been known to cause little or no irritation when consumed.

Research Plan

To accomplish the above, a multidisciplinary research team has been assembled that includes the following components: Economic Analysis, Systems Analysis, Agricultural Engineering, Entomology, Plant Pathology, Agricultural Biochemistry, Food Science, Agronomy, Project Coordination.

Economic Analysis. The major emphasis in determining the economic potential for alternative upland taro production systems will be on the cost of producing raw materials for further processing. This approach will be used because the cost of raw materials plays a major role in determining the potential market for alternative uses. Enterprise budget analysis will be used to evaluate alternative production systems. The evaluation will consider at least two different scales of operation. These different scales will in turn require the examination of various mechanization levels and possibly different cultural practices. Several target yields will be considered in the analysis.

The economic analysis must be done with inputs from all components in order to accurately project the current practices as well as the proposed modifications. Optimum cultural practices will be studied in order to determine the potential of taro as a raw material for feed or food. Costs of various processing techniques will be included so that their economic potentials can be determined by comparing the unit cost of taro products to the costs of those products which would compete with taro products in the market.

In this manner, a target price can be established, and ways to reach that price can be identified and detailed.

Systems Analysis. Work already completed at the University of the Hawaii indicated that high level of benefits can be obtained by proper scheduling of field operations. In addition to increased yields on a yearly basis, more efficient use of input resources can occur simultaneously. These can be achieved by application of systems analysis techniques to field operation schedules with consideration of constraints to the operating system. Constraints that should be considered must be determined based on the peculiarities of the local system to be studied. The socio-economic situation and goals of the region (i.e., steady employment, availability of skilled labor, etc.) must be determined and accommodated if a development plan is to be successfully implemented.

These techniques have previously been applied to wetland taro and sweet potato production systems. The results of simulation of these two systems indicates that significant (in the order to 10-15%) increases in output can be achieved by properly scheduling the use of a given level of inputs. Through the use of systems analysis techniques, the effects of improvements achieved by other components can also be quantified and new foci for research identified. (Wang and Steinke, 1978) Development of dryland taro production system models will take place in conjunction with the agronomy, disease control, economic, and entomology components. The model will be applied to determine the potential for using taro as a food and/or feed.

Work will also proceed in conjunction with the economic analysis group on modelling production systems for dryland taro for animal feed. This will serve to quantify present research and further identify bottlenecks and impediments to commercial viability of the product.

Agricultural Engineering. Several different drying temperatures and final moisture contents will be tested to determine the least expensive way of eliminating the acridity factor.

Laboratory scale ensiling experiments will be conducted to examine its potential for reducing the acridity level in taro leaves and corms. This will be determined by running several laboratory trials and chemical analysis and rat colony feeding trials. If the taro leaf silage proves to be non-acrid, it would solve both the acridity and storage problems.

Entomology. Insects are one of the limiting factors in the production of taro. The major insect pests in Hawaii are the taro leafhopper, *Tarophagus prosperina;* the root aphid, *Pemphigus* spp., which is limited to the island of Hawaii; and miscellaneous aphids on the leaves. Mites have not developed into a problem on taro, but further data is needed to be sure.

Biological and chemical control measures have been used to a limited extent for control of the insect problems. A predacious mirid egg sucking bug, *Cyrtorhinus fulvus* Knight, has given good biological control of the taro leafhopper. Ladybird beetles, aphid lions, green lacewings, syrophid fly larvae and hymenopterous parasites have been reported at various times feeding on the aphids of corn, sorghum and taro, but have not been effective in controlling the aphid populations.

Chemical control measures have not given effective control of insect pests of wetland taro, but show some promise for dryland taro. Six insecticides, *Bacillus thuringiensis,* carbaryl, diazinon, dimethoate, malathion, and methomyl are registered through SLNR. Because the tops as well as the corms will be fed to cattle, further studies on pesticide residues on tops and corms and long-term feeding studies on cattle may be required by the EPA for registration of the pesticide.

No effective control measures have been developed for the taro root aphid, the most serious pest of dryland taro. Further research is needed to actually determine the species. A bioclimatic cabinet will be used to rear root aphids at the lower temperatures (50-65^{O}) to produce alate forms needed for positive identification. Systematists cannot identify the apterous forms to the species level.

Hawaii has one of the best collections of aroid germplasm in the world. Research will be conducted under field and laboratory conditions to determine if any of the dryland taro cultivars have either a tolerance or a resistance to the pest insect species. Insect resistant varieties are the most ecologically acceptable and economical control measures for the future development of taro as a forage crop. New accessions of germplasm should be screened for aphid, mite, and leafhopper resistance.

Field plantings will be utilized to develop efficacy, pesticide residue and phytotoxicity data to be used in petitions for future pesticide registration. New germplasm accession should be processed through a regular pesticide screening program for phytotoxicity symptoms before large scale field plots are attempted.

Because beneficial organisms are effective in controlling the taro leafhopper, the field plots will be utilized to develop data on parasite, predator-prey relationships, and the effects of insecticide applications on these non-target beneficial organisms. The data will be used to develop an integrated pest management program for taro production.

Plant Pathology. Epidemiology of disease is a most important part of the taro program. The particular set of conditions, both biotic and abiotic, conducive to disease development coupled with knowledge of pathogen ecology are valuable in determining the most efficient control strategy in many cases. Epidemiology also may form the basis for identification of unknown casual agents, as well as provide background for successful systems of disease forecasting and epidemic modelling.

For the present, corm soft rot will continue to receive substantial attention. The pathogen-host-environment interactions are still incompletely understood especially as the host reacts to abiotic and biotic elements of the taro paddy exclusive of the pathogen. Similarly, the pathogen's reaction and survival in the absence of the host needs elaboration. As the soft rot work is completed, the epidemiology of foliar diseases will be examined. It is anticipated that basic epidemiology on most foliar diseases present in Hawaii can be rapidly developed.

Taro hard rot provides a challenging epidemiological and etiological problem. The conditions for disease increase, occurrence and the causal agent are not established. The effort placed on this problem is proceeding at a subdued level and will probably need to remain at this level until the soft rot and foliar objectives have been accomplished. Some abiotic factors and early mycological involvement will be examined as etiological agents during this period of low activity.

All methods of control need to be considered in the taro program. A first step in this process is to index existing varieties for resistance to various diseases. This process is well underway for Pythium root and corm rot. The unknown etiology and inability to reproduce hard rot at will, make rapid indexing for hard rot resistance impossible. Data on this will have to be collected from field trials and will not be as precise as that obtained for soft rot. Rapid assays of varieties for resistance are possible for *Phytophthora* leaf blight, *Phyllosticta* spot, and *Cladosporium* spot. With resistance in existing varieties identified it may be possible to replace current commercial varieties with existing varieties or to initiate a breeding program for varietal imporvement. Chemical for control may be identified through a program of continuous screening of candidate compounds in the laboratory, greenhouse, and fields. Many compounds are available which will kill the Pythium pathogen causing taro soft rot. Field trials for disease control efficacy and application for EPA approved use on taro will have to be initiated.

Acridity and Processing. The level of acridity must be lowered to an acceptable level before taro can be used as either a food or a feed. Causes of acridity in taro must be isolated and identified. Either physical, chemical, or biochemical methods of reducing the level of acridity to acceptable levels must be found and proven to be economically feasible. It is also hoped to develop a procedure to quantify acridity.

Characterization of acrid principles will provide bases for the quantitative measurement of the acridity by chemical or biochemical assay, which is essential in future genetic selection and breeding programs. It would lead to the establishment of effective methods of treatment, by which the responsible chemicals can be destroyed with minimum damage to the nutrient values. The chemical study of acridity will be considered as an integral part of the fundamental research efforts in order to solve problems associated with the taro production, utilization, and food delivery system.

From preliminary experiments on taro corms, the acrid principles are soluble in non-polar solvents such as chloroform and could be separated by thin-layer and column chromatography. The acridity is, therefore, caused partially or entirely by non-polar organic compounds of relatively small molecular weight. Samples (e.g., leaves, petioles, and corms) will be freeze dried and extracted with $CHCl_3$. Active fractions will be isolated by various chromatographic techniques including high performance liquefied chromatography (HPLC). Physical methods of identification such as UV, IR, NMR, and MS spectrometry will be used to identify the purified active compounds.

A rat colony will be established and tested in order to determine whether "food preference" behavior can be used as a routine bioassay procedure for the qualitative determination of acridity. Feed for the rat colony will be obtained from drying and silage experiments conducted in conjunction with the engineering group.

Cubing experiments will be conducted with both taro leaves with and without the addition of a binder. Whole plant cubing will also be carried out, with the hope that the starch and gums from the taro corm will serve as a binder for the cubes, and add food value to the product. Analysis of the nutrient values of the product in several different forms will be determined both through very limited rat feeding trials and through chemical analysis.

Several samples will also be freeze dried to preserve the acridity at its original levels as a control. Several methods of artificial drying and sample preparation will then be compared against the freeze drying to determine the effects of artificial drying on sample quality factors such as acridity, nutritive value, further processing necessary for consumption, storability, and other factors.

Agronomy. Taro is an adaptable crop. It can be produced in lowland paddy fields and in humid, high rainfall, elevated lands. It has a flexible harvest schedule and high yield potential when fertilized and managed properly. Its environmental requirements differ from those of other major root and tuber crops such as cassava and sweet potato. Therefore, it offers a complementary planning alternative in agricultural development.

To develop the agricultural potential of taro, production efficiency must be increased through (1) better management practices, (2) use of high yielding varieties or selections, (3) control of pests and diseases including weeds, and (4) proper use and timing of fertilizers.

Field experiments will be conducted to determine the most efficient fertilization practices for both upland and lowland taro. These experiments will involve the use of various nutrient sources, rates of application, and methods of timing of application. Slow-release or controlled-release sources, especially for nitrogen, will be studied together with the use of various soil amendments and their effects on the nutrition, growth, and yield of taro.

Experiments on liming and optimum pH requirement of taro will be established under both upland and lowland conditions. Effects of lime on nutrition of taro, especially on phosphorus and the micronutrients will be studied.

Research on soil fertility and plant nutrition will include the determination of the critical levels of nutrient concentrations in the plant tissues for maximum yield. Culture solution techniques will be utilized to study basic nutrient requirements of different accessions at various stages of growth.

Water management, especially flow rate and temperature, continuous and intermittent flooding, depth of flooding, frequency and intensity of irrigation in upland, etc., will be studied to determine the optimal water use and consumptive use of water by upland and lowland taro.

The hundreds of existing but classified and undescribed cultivars of taro from various location will be collected into a systematized germplasm bank or collection. All materials in the germplasm collection will be described and characterized. An intensive multiplication program will be initiated to make materials available for research, such as field trials and various screening studies.

The genetic potential of the various cultivars will be evaluated, especially their high yielding ability, resistance to pests and diseases, special adaptation to various ecological zones, eating quality, and other food or feed uses.

To aid researchers in the improvement of the crop through hybridization or breeding, the flowering behavior of the germplasm materials will be ascertained. Various methods of inducing flowering, especially on cultivars with desirable agronomic characteristics will be studied.

The methodology for the hybridization of taro germplasm will be studied. Chromosome counts will be performed on all materials and all materials grouped according to the number of chromosomes. Various techniques of inducing polyploidy such as colchicine treatments will be used to produce materials with higher yield potentials.

Climatic factors which affect growth and production will be studied under controlled conditions using growth chambers and greenhouse techniques. Time of planting of germplasm materials such as the dasheens which are strongly affected by climatic changes and undergo dormancy at maturity will also be studied.

Project Coordination. In a multidisciplinary research effort, the coordination of research efforts between components is extremely important. The sharing of information gleaned from literature research, new developments, and the effect on other components of research progress by one component must be shared in order to successfully complete the research plan. In order to insure this interchange, meetings of all project researchers will be held at least once every three months. At these meetings, each component will give a brief report of its research activities and plans. Through discussions at these meetings, more efficient research can be conducted.

Pacific Association on Taro

Aroids are extremely important in many areas of the world. In the past, research needs of the aroids have not been given high priority by funding agencies. However, the United States Government has finally begun to recognize the importance of collaborative work on aroids and additional funding support is expected under Title XII of the 1975 Foreign Aid Act. A consortium on root crops has been initiated by a number of leading universities, including the University of Hawaii.

The availability of large scale funding from the United States Government is expected to be at least two years away. In the meantime, it is proposed that the importance of root crops in general and taro in particular be recognized by the formation of a Pacific Association on Taro (PAT). Taro is an extremely important crop in the Pacific region, including Western Samoa, American Samoa, Fiji, Guam, New Hebrides, Papua New Guinea, the Solomon Islands, Tonga, the Trust Territories of the Pacific Islands, Indonesia, and Hawaii. The Food and Agriculture Organization of the United Nations has recognized this by authorizing a $1.5 million project to develop root crop production and utilization in the Pacific.

Each association member will fund its own activity, and will participate in cooperative programs of its own choosing. An annual meeting will be held. The PEACESAT satellite voice communication network will be utilized extensively to facilitate communication between consortium members.

The Pacific Association on Taro will provide a basic organizational building block which can be readily incorporated into a large root crop consortium at the appropriate time. In the meantime, it will serve to expand field testing capability and to make results of project research available to the Pacific island nations with very little added costs.

Implications

The University of Hawaii is currently embarking upon the research program outlined above. The problem of animal feed availability is one that many researchers are investigating. Similarly, a comprehensive cropping system for taro will also benefit many areas of the world.

The insect and disease problems we are facing, may and probably have already occurred elsewhere. Acridity is a problem that many researchers have spent a great deal of time on. And increased yields due to proper scheduling or improved agronomic practices are always welcome.

The Pacific Association on Taro that we are proposing will benefit all of us very soon. During our first meeting, to be held here in conjunction with this symposium, we hope to establish some sort of role for PAT, either as a separate entity, a division of the International Tropical Root Crop Society, or even under the International Foundation of Science. The gathering of researchers here can benefit from a formal organization for information exchange.

At the University of Hawaii we are pursuing an active course in taro research. We are always happy to share our results and work in progress and welcome cooperation with any or all other taro researchers.

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