3867

A PROPOSAL FOR THE IMPROVEMENT & DEVELOPMENT OF CASSAVA

A TROPICAL ROOT CROP

JULY 28, 1971

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CIAT
APARTADO AEREO 67-13, CALI, COLOMBIA
CABLES: CINATROP

TABLE OF CONTENTS

A PROPOSAL FOR THE IMPROVEMENT AND DEVELOPMENT OF CASSAVA, A TROPICAL ROOT CROP

INTRODUCTION

Origin and Distribution

Manihot esculenta Crantz, known commonly as cassava, manioc, mandioca, yuca or tapioca, is one of the most important food crops of the tropics. It is claimed to be the major source of carbohydrates for more than 300 million persons. Cassava is an American crop, probably originating in northern South America (Brazil, The Guyanas), with a secondary center of origin in Meso-America (Mexico, Guatemala, Honduras). Its present-day distribution is world-wide in frost-free regions, between 30° north and south latitudes at elevations ranging from sea level to more than 6,000 feet.

Production and Economic Importance

Production statistics are indefinite as a large portion of the cassava crop is consumed without entering into commerce. The table on the next page summarizes data on the world average production during the period 1948-1952 and presents data for 1968.

Africa is the world's largest regional producer, while Brazil produces more cassava than any other single country. In 1966, the European Economic Community (EEC) imported U. S. $57.5 million of dried roots as chips for livestock feed.

CASSAVA PRODUCTION AND YIELD*

	1948-1952 (Average)			1968		
	Area (1000 ha)	Production (1000 ton)	Yield (100 kg/ha)	Area (1000 ha)	Production (1000 ton)	Yield (100 kg/ha)
North & C. America	129	563	44	92	547	60
South America	1,207	15,061	125	2,409	33,179	138
Asia	1,378	9,662	70	2,410	20,911	87
Africa	3,686	23,424	64	4,872	30,869	63
Oceania	8	65	81	11	119	108
Total	6,408	48,775	76	9,794	85,625	87

* From FAO Production Yearbook, 1968

Utilization and Limitations

As an unprocessed food, cassava is consumed as a boiled or fried root, as a crude flour, and sometimes as a fermented paste or in beverages.

The root is palatable, and fresh and dried roots are used to feed animals. Swine and poultry accept cassava when fed fresh, dried or as silage. Commercial products include starch for sizing, laundry starch, adhesives and tapioca.

Fermentation and putrefaction begin shortly after harvest; therefore, cassava can be stored for only a few days in its fresh, wet state. But, it can be dried, and the chips stored for up to a year with little deterioration. Dried chips can be incorporated as a substitute for cereal grains into complete diets for animals.

Yields and Nutritional Value

Compared with the world average yields of 8.7 tons/ha, several countries (Brazil, Bolivia and Paraguay in Latin America; Thailand, Malaysia and Taiwan in Asia; Guinea, Malawi and Mali in Africa; and French Polynesia) report national averages ranging from 14 to 22 tons/ha.

When cassava is well tended as a plantation crop for commercial use, yields of 25 tons/ha are considered acceptable, although from 50 to 80 tons/ha have been reported from individual plantings. It must be recognized, however, that cassava is a long-term crop ranging from 6 to 18 months or longer from planting to harvest.

Generally, cassava varieties are not outstanding nutritionally, except as a source of energy. The roots contain about 30 to 40 per cent dry matter. This consists largely of carbohydrates, relatively small amounts of protein (usually 0.5 to 1.5 per cent) and fractional percentages of fats, vitamins, and minerals. Of 385 cultivars collected in Colombia, several contain 7.25 per cent crude protein (base on N x 6.25 calculations with 0 per cent moisture content). But, it is probable that as much as 50 per cent of the total nitrogen present in cassava may be non-protein nitrogen and of unknown value for single-stomach animals.

Preliminary amino acid analyses of cassava indicate a distribution similar to that of corn, with low levels of methionine. Threonine levels are twice as high as in corn.

Cassava leaves are used to some extent in various tropical areas for human consumption and animal feed. Analyses of the leaves of some varieties show high levels of protein, ranging from 3.7 to 10.7 per cent on a fresh weight basis and 21 to 36 per cent on a dry weight basis. Of the essential amino acids, only methionine is deficient; excellent levels of lysine (5.6 to 8.0 per cent) have been found.

Potential for Future Expansion

Cassava is an important element in the diet of rural and urban populations throughout the tropics. It is a valuable energy source for animal feed, and it is an acceptable source of industrial starch and flour.

Population is increasing rapidly in the tropics. This additional population will require food. Cassava is well adapted to a wide range of ecological conditions throughout the tropics. Research to improve the yield potential, to increase the total production and to improve the nutritional quality will help to meet food demands, will facilitate an expansion in the production of high-protein animal products, and will contribute to more efficient industrial processing.

STATUS OF RESEARCH, CURRENT LIMITATIONS AND NEEDS

Agronomy

Limited knowledge is available on response of varietal types to improved cultural practices. Cassava appears to respond to P_2O_5 and K_2O, but this may be related more to native soil fertility than to a fertilizer-by-variety interaction.

High levels of technology have rarely been investigated with either improved varieties or non-improved types. Some information exists, this being derived from research with non-improved varieties and low levels of inputs.

Apparently the research on planting methods has defined the type of planting stock most suitable for propagation. However, variable results have been obtained from systems of placement of stakes in the ground.

Research in agronomic practices has been location-limited. Extended agronomic research is required to develop the production systems that will increase cassava yields and production in the tropics. This applies not only to non-improved varieties but also improved materials as they become available, under high levels of technology and in coordination with other disciplines, such as agricultural engineering and agricultural economics. This research must seek to determine the range of adaptation and productivity of improved cultivars by putting them into international tests with different ecological stresses.

Varietal Improvement

Although varieties differ in yielding ability and in many other desirable characteristics, relatively little work has been done in breeding cassava.

The genus Manihot is said to have some 128 species, all native to the new world. The majority of these probably are cultivars rather than distinct species.

It is possible that cassava has hybridized naturally with wild relatives, giving rise to new types that might easily be considered new species. There is a need to establish a sound basis for breeding improved cassava by studying the cultivated and wild related species. This requires thorough collection, introduction, and evaluation of cassava cultivars and related species.

Fairly large collections of the cultivated species M. esculenta Crantz are located in Brazil, Malagasy, Uganda, Congo, Puerto Rico, Colombia and India. A comprehensive living collection of the near and distantly related species in the genera Manihot does not exist anywhere.

Past breeding efforts have relied mostly on selection procedures, with workers evaluating their collections and distributing planting stocks of the better ones. Limited breeding, by hybridization within the cultivated species and by inter-specific crosses, has been achieved in Brazil, India, Indonesia, Malagasy and East Africa.

During the period 1932 to 1942, attempts were made in Indonesia to increase root protein content through intra-specific crosses in M. esculenta and inter-specific crosses with M. saxicola. Some resulting clones initially contained more than 2 per cent protein but regressed to normal levels (0.8 to 1.5 per cent) after continued propagation. It was concluded that little chance exists to increase protein content through selection following hybridization. In view of the significantly higher protein content found in some cassava collections, it would seem worthwhile to repeat this work. Some of the wild types may have a relatively high protein content and would possibly be useful in a breeding program.

A more successful breeding project has been conducted in Malagasy where breeders sought resistance to mosaic, a serious virus disease. Numerous partially controlled pollinizations resulted in 15,000 to 20,000 seedlings per year. These were screened for mosaic resistance and starch content. The resulting varieties were resistant to mosaic, had an increased adaptability to infertile soils, and yielded from 12 to 30 tons/ha more than the original varieties.

Three wild species from Brazil, M. glaziovii, M. catingae and M. dichotoma, have been crossed with cultivated varieties in attempts to develop more productive and more disease-resistant varieties. The results of these efforts show that, although certain difficulties have been encountered, it is possible to achieve progress in the form of higher yield potential, virus tolerance, content and quality of starch, and adaptation to particular soil types and low rainfall.

About a dozen species are apparently closely related to M. esculenta. These include M. carthaginensis, M. aesculifolia, M. palmata, M. tweediana and M. saxicola, but little is known of the inheritance patterns and heritability of the most economically important characteristics. Some of these have shown continuous variation when studied for breeding purposes.

The hybridization efforts for improving specific characteristics of cassava have depended heavily on the few wild species available to the breeders. The potential of the wild species of Manihot to contribute to the development of superior cultivars has not been evaluated. This points to the need to collect and evaluate the interrelationships of the species by morphological, cytological and biochemical approaches.

Utilization Research

Cassava has received some attention in aspects of its utilization as a food for humans, feed for animals, and as a product for industrial processing of starch, flour (tapioca), protein-enriched foodstuffs, adhesives, and glucose.

As food for humans, cassava is used in fried, boiled or fermented forms. Gari is a popular food made of dry granular cassava in Nigeria, and methods have been improved for commercial industrial preparation. In Brazil, roasted mandioca flour is popular, and some efforts have been made to improve the processing.

Recent industrial research in cassava utilization shows that this starchy root can be used efficiently as a substratum for the production of protein-enriched cassava by such single-celled micro-organisms as Candida utilis, *Rhodotorula gracilis* and *Hansenula saturnus*. Protein-enriched cassava may contain 15 to 35 per cent crude protein (dry basis and determined by Kjeldahl analysis). These findings could be applied in commercial scale operations as particularly complicated or expensive equipment is not required.

Cassava has been fed fresh-chopped, dried, as silage and as flour to swine, poultry, and beef and dairy cattle with good results. Feeding trials at CIAT have demonstrated that cassava roots can be used as the major source of carbohydrates for swine throughout the life-cycle which includes the growing-finishing period (20-90 Kg) gestation and lactation.

Cassava in the form of fresh-chopped roots, dried meal or silage can supply up to 60 per cent of the daily ration for the pig. These levels are much higher than those reported in Europe which normally vary from 3 to 10 per cent of the diet, although levels of up to 25 per cent have been used. Higher levels of use depress gain, feed consumption and efficiency of conversion. These effects may be related to such factors as poor digestibility and energy utilization, hydrocyanic acid toxicity, poor utilization of the protein fraction, or possibly a deficiency of essential fatty acids.

Preliminary digestion and metabolism studies indicate that, in general, the dry matter digestibility of sun-dried cassava meal is similar to that of corn or soybean meal.

As the varieties used in these swine-feeding trials contained only low levels of hydrocyanic acid and as boiled and dried cassava meal fed to chicks did not affect their response, the depression noted in the CIAT studies does not appear to result from HCN toxicity.

When 60 per cent cassava meal from the variety Llanera is used in pig diets, there is a small depression in gain even when the protein of cassava is calculated at 2.5 per cent (not 5.5 or 6.0 per cent) crude protein. This depression can be overcome by supplementing the diet with either methionine or 10 per cent animal fat. The methionine deficiency of the diet may exist for two reasons: first, soy-bean meal, which was used to supplement the diet, is low in methionine and, second, cassava contains little, if any, methionine. This is a simple methionine deficiency. On the other hand, there may be a more complex methionine deficiency related to non-toxic levels of HCN. (Clark in 1935 reported that methionine would combine with hydrocyanic acid to form thiocynates, making the methionine unavailable to the animal.) The studies using cooked cassava in chick diets provide evidence in favor of a simple methionine deficiency.

Available data indicate that cassava is a good source of energy for pigs during all phases of the life cycle. CIAT is attempting to develop simplified diets based on various forms of cassava, including sun-dried meal and silage.

When 45 per cent sun-dried cassava meal was used in the diets of 4- to 9-week old chicks, a depression in growth and feed conversion occurred even when the diets were supplemented with methionine. There was an improvement when 6 per cent fat was included.

In a second experiment with chicks 1 day to 9 weeks old, cooked and raw cassava meal were compared, with and without methionine, molasses and fat. Cooking did not improve either gains or feed conversion. These results support those of the pig diet studies as well as the assumption that the HCN level does not affect gains in diets using the Llanera variety.

None of the treatments (methionine, fat or molasses) alone were effective in improving gains. When raw meals plus both methionine and fat were used, gains obtained were equal to those of the control in which corn was used in the diet instead of cassava meal.

In summary, research with chicks indicates that HCN in the Llanera variety is not a limiting factor, and that either energy or protein (amino acid) deficiencies, or both, are involved in growth depressions when high levels of cassava are used.

Increases in population are creating additional demands for foods, not only for fresh consumption but also for meals or flour. Additional research is required to develop new cassava products with prolonged shelf life and that can be easily prepared. Food mixes are needed, that basically contain derivatives of cassava, but in which the nutritive value is balanced with protein from other foods.

Fermentation methods to enrich the protein content of cassava products will probably offer a quick, practical and economical breakthrough to help overcome the protein deficiencies present in the tropics.

Research is also needed in methods of extraction and production techniques for starches with the specific qualities demanded by industry.

The leaves of cassava are richer than the roots in protein content and quality. The possibility of using cassava foliage as food or in feed rations requires more study.

Adverse effects have been reported in humans whose main energy source is cassava. Several health problems, such as poliomyelitis, nervous and pellagroid diseases, have been associated with the possibility of cumulative or chronic poisoning due to the HCN content of cassava. Also, sun-dried cassava may become contaminated during the drying process with harmful fungi and bacteria.

The encouraging results obtained in using cassava in feeding rations indicate the great potential for providing high quality protein at reasonable costs. Research on using cassava as a feedstuff requires continued effort to develop efficient systems for cassava utilization by livestock.

THE PROPOSED CASSAVA RESEARCH AND DEVELOPMENT PROGRAM OF CIAT

CIAT as an International Research and Training Organization

The mission of the Centro Internacional de Agricultura Tropical is to accelerate agricultural and economic development and to increase agricultural production and productivity to improve the diets and welfare of the people of the world. To accomplish this mission, CIAT works in concert with governments, educational and research institutions, and private enterprise.

CIAT seeks to achieve its goals through research, training, and stimulation and strengthening of national capacities in these areas. Initially, CIAT has concentrated its efforts and resources on six somewhat neglected agricultural products for lowland farming systems --beef, swine, corn, rice, food legumes, and tropical root crops. Its work with legumes and root crops, to date, has been exploratory, and in the case of cassava, limited to collection of germ plasm.

CIAT's goal in working with these agricultural products is to develop, as quickly as possible, new, highly productive and profitable agricultural production systems for farmers of the lowland tropics, especially in the Western Hemisphere.

Development of these systems, however, takes into account issues other than the technological problems. Work in agricultural economics and other social aspects of agriculture considers not only the profitability of production practices on the farm, but also matters of inter-commodity competition, of public policy as it affects development of tropical areas, and of marketing problems. Of particular concern is the suitability and adaptability of the technology to the small farmer.

In cooperation with national agencies, research is undertaken to identify factors which are obstacles to rapid adoption of new agricultural technology by various farmer groups and to demonstrate more efficient ways of bringing about technical and social change in rural areas.

The research program is closely integrated with training and communication activities which help mobilize, energize, and qualify the personnel and organizations in the lowland tropics necessary and instrumental to establishing the production systems developed and to realization of the productivity goals.

Successful introduction of new varieties and practices depends upon taking a broad, system-wide approach to development. Critical factors, in addition to the appropriateness of the technology, for the intended farmers and areas, include the availability of credit, inputs, advisory or educational services, transportation and communication, and appropriate storage, processing, and marketing facilities. Such basic issues are discussed and explored with national agencies when and where appropriate and are the topics of various conferences and symposia for national leaders in policy and agricultural research and development.

CIAT attacks the problems of a multiple-commodity agriculture with a multi-disciplinary team approach, giving primary attention to defining and resolving the problems or barriers to increased productivity and production. The organizational structure, divided into professional groups which, in turn, staff the commodity teams, permits a concentration of knowledge and expertise while at the same time facilitating an exchange of information about the problems of the lowland tropics as experienced through work on other commodities.

The unique qualifications of CIAT to undertake a program such as outlined in this proposal include this multi-disciplinary team approach, the limitation in commodities for which it has direct concern, the concentration of research and training efforts on the lowland tropics, the continuity of program and staffing which its basic support assures, and the complementary nature of all of its activities in building a research and training network among national institutions in the lowland tropics.

Objectives of the Proposed Cassava Program

The following objectives are outlined for CIAT's proposed cassava program:

a. To increase yields and reduce costs of cassava production through plant improvement and the development of low cost production systems for human food, animal feed and industrial use.

b. To explore the possibilities for improving the levels of high quality protein in cassava through plant improvement.

c. To survey, identify, evaluate and develop economic control methods for major diseases, pests and weeds of cassava.

d. To serve as an international resource center for germ plasm and as an information center for integration of information on disease, insect and weed problems, as well as for production and utilization systems.

e. To provide practical training in cassava varietal improvement and testing, crop production methodology, plant protection techniques and cassava utilization for young scientists and agriculturists from major cassava-producing nations.

To achieve these objectives, a multi-disciplinary team research and training effort will be developed.

Appropriate Areas of Activities

Agricultural Economics

The Common Market countries of Germany, The Netherlands and Belgium are the main importers of cassava for animal feed, although other EEC countries do import small amounts for the same purpose. This market has developed in the EEC as a result of high internal feed-grain prices which are protected by high tariffs. At the same time, tariff rates on dried cassava chips are relatively low. As a consequence, cassava chips or pellets are imported as a low-cost substitute for feed-grains, particularly barley. Further growth in world trade in cassava chips may be expected as Germany increases the use of prepared livestock feed mixes. If the United Kingdom and Denmark enter the European Common Market, as seems likely at present, they might also be expected to import dried cassava, given the importance of their livestock industries. These two factors might result in a doubling or trebling of the quantities of cassava traded internationally.

This market must, however, be examined carefully before concluding that it offers a significant long term market for new producers. Although this market has recently shown phenomenal growth rates, it represents only a small fraction of the total feedstuff ingredients for the EEC taken as a whole. Consequently, its downward pressure on feed-grain prices inside the EEC may be expected to be slight. If it achieved a substantial size, it would be expected to affect strongly feed-grain prices. This, in turn, would be likely to induce feed-grain producing regions in both France and Germany to look for higher levels of tariff protection against cassava. Some small tariff increases have already been put into effect. These higher tariffs (or perhaps import quotas) would have the effect of reducing international cassava trade.

Cassava starches and tapioca have been facing a stagnant market in the EEC countries and a declining market in the U. S. A., which is the world's largest cassava starch and tapioca importer. This appears to result from strong competition, in most areas, from corn and/or potato starch. This strong competition may be expected to continue as world supplies of rice and wheat increase. Both will tend to exert a strong downward pressure on world grain prices and hence on starch prices.

Although some limited markets for cassava starch may be maintained or developed because of its special qualities, the prospect of large increases in demand is both limited and uncertain.

Penetration of these markets, if it is to be achieved at all, may be expected to be based almost exclusively on low cost production and efficient marketing of cassava and its derivatives. In any event, these markets appear to be too limited and uncertain to serve as the prime focus of CIAT's cassava program.

Cassava as a human food is of great importance throughout Latin America and parts of Africa, although it is of lesser importance in most Far Eastern countries. Two needs are apparent in most tropical lowland diets—a shortage of good quality protein and a deficiency in total caloric intake. Cassava can be instrumental in solving these problems in two ways. Both require that cassava yields be increased in order to reduce prices and hence permit greater consumption. The one method would involve an increase in the quantity and quality of cassava protein for direct human consumption. The other would be the development of economically viable cassava-swine production systems based on this crop and other plant protein.

Attaining the goal of either program would require a reduction in the cost of cassava to the user. This can only be achieved by developing more efficient production systems which implies increasing yields to reduce costs for cassava. For example, cassava is still more expensive than corn as a source of energy in animal rations, at present prices in Colombia.

An overall direction or focus for CIAT's cassava program is to increase yields and to reduce costs. This is essential whether increased exports or increased human consumption, or the development of a cassava-swine belt comparable to the corn belt in the U.S., is to be one of the aims of CIAT's cassava program.

Literature Evaluation and Collection

CIAT is beginning a comprehensive evaluation and collection of the world's cassava literature. This project will obtain the most important materials pertinent to the improvement program. Preference will be given to the purchase of materials in microform, since, by using a reader-printer, the high cost of purchasing materials in hard copy is greatly reduced.

Production Agronomy (Production Systems)

This general area of activities includes the research that must be conducted by the various professional groups that directly contribute to the integration of practical recommendations for achieving a rapid increase in yields of cassava.

The professional groups whose action will be discussed here are: Agronomy and soils, plant protection, and agricultural engineering.

Agronomy and Soils. Cassava is widely grown in subsistence level "back yard" types of agriculture and as a plantation crop but available data do not permit an assessment of the relative importance of these. Both methods of production suffer from a lack of applied research directed toward increased yields per unit of time and per unit of area.

To increase productivity on small holdings designed for local consumption, as well as on plantations for feed and industrial production, work with the improved clones developed by efforts of the plant breeder-crop physiologist team will be conducted on: planting distances, fertilizer levels and timing on a wide range of soils, weed control methods, and planting and harvesting scheduling.

The multi-cropping nature of tropical agriculture demands applied research to improve the efficiency of different crop combinations, both in time as well as space. Data from a preliminary multiple cropping study started in 1969 at CIAT, in which cassava, corn and soybeans were interplanted, indicated that cassava may be economically included in certain multiple cropping combinations.

Although cassava yields were reduced in proportion to the competition offered by the companion crop, the total economic yield may be more advantageous to the farmer. These results indicate the need to determine the best crop combinations, timing and other variables so as to maximize the income for the cassava grower.

Cassava is considered a potentially important food crop for swine to convert carbohydrates into a highly acceptable form of protein. As the roots cannot be harvested and stored fresh for more than a few days, and as drying requires vast quantities of power, production systems scientists, in cooperation with swine nutritionists will investigate the possibility of continuous planting and harvesting. This work will include the cooperation of agricultural engineers and plant breeders in developing plants with roots more suited to either mechanized or manual harvesting.

Another important use of cassava is in commercial starch production. Processing plants in Bolivia and Brazil have been constructed and later abandoned because local farmers were unable to provide an adequate continuous supply of cassava. Production schemes are needed which will provide adequate root volumes throughout the year and solve problems related to efficient harvesting and transporting to processing plants.

Large scale cassava production for swine feeding or starch processing will benefit from applied research on planting methods and spacing, fertilizers, weed control, water requirements, harvesting techniques, handling and related areas.

Plant Protection. The lack of attention to cassava disease is illustrated by the observation that in 1966 The Review of Applied Mycology had only two references to cassava diseases. In general, the literature implies that diseases and pests are not important in cassava production although information on disease and pest losses is scarce. Mosaic, one of the three or four known virus diseases of cassava, was estimated in 1956 to have resulted in an 11 per cent loss in the British African colonies where fields with 100 per cent mosaic infection yielded one ton or less per hectare. This suggests that major losses resulting from diseases and pests are occurring. The importance of pathogens and insects will probably increase as areas of cassava production are expanded and yield levels raised.

An objective evaluation of available information on cassava diseases and pests indicates that, with the possible exception of cassava mosaic in certain countries, little is known about the economically important disease organisms and their distribution, variability, transmission and control. Consequently, pathologists and entomologists will initially define the distribution of major diseases and pests. Work at CIAT in this area has already begun.

DISEASES The literature on diseases of cassava has been reviewed. A high percentage of the references merely mention the existence of the pathogen and a few are studies of pathogenicity and identification. Few refer to economic importance or control methods.

A survey in Colombia has revealed that cassava diseases caused by representatives of the general Cercospora, Rosellinea, Rhizoctonia and Oidium are prevalent. However, to date no disease caused by virus or mycoplasm (including common mosaic, vein mosaic, and witches' broom) has been identified in the more than 2,500 Colombian collections under observation.

The most important disease encountered so far is caused by a bacterium which attacks the leaves, stems, petioles and roots, often resulting in complete destruction of the plant. Many cultivars are completely susceptible, while a few show resistance. This bacterium may be an unidentified species of the genus Pseudomonas. A recent finding indicates that this is the same disease which is classified in Brazil as being caused by Xanthomonas.

The bacterial disease found in Colombia seems to be controlled by treating the plant cuttings in hot water at 52°C for 20 minutes. Presently all materials collected are treated, planted and observed in a greenhouse in a non-cassava growing area (Tibaitata, 8600 ft. elevation), before being moved to Palmira for field planting in the introduction nursery. The economic importance of the disease is not yet known.

INSECTS Work on the identification of cassava insects is just beginning. A preliminary review of the literature on cassava insect pests and an initial survey in Colombia indicate that there are three important cassava pests: horn worm (Erinnys ello Man.); shoot fly (Carpolonchaea chalibea Widem) and spider mite (Mononychus planki). In addition, there is a group of potentially important pests. Activities will continue to define the potential insect problems of cassava.

Cultivars from the Colombian collection are being screened for resistance to horn worm and to shoot fly. This screening will be extended to CIAT's international collection.

An important area for study is to determine the insect population levels that may result in economic damage in cassava-growing areas. In areas where insect damage is below the level of economic importance, it has been found that parasites, predators and fungi-damaging insects are effective in reducing damage to cassava plants. Identification and biological studies of these insects will be included in the work.

The program will try to find cultural practices that require minimum investments for insect control and attempt to apply integrated pest control concepts.

WEEDS Weed control takes on special importance in cassava because of the long period between planting and the time when plants form a complete shade or cover. No data exist at present on losses from weed competition; however, they can be assumed to be at least 20 per cent, which is the observed yield loss on most tropical crops with current control methods.

Varieties will be tested for their competitive ability with weeds, and herbicide trials are needed to determine safe and effective chemicals and application times and rates. Emphasis will be given to integrating weed control into cassava production systems.

Agricultural Engineering. Agricultural production is most economical at present in areas where agricultural engineers have collaborated in the development of agricultural systems. Examples include cotton, corn, wheat, sugar cane, pineapple, bananas, rubber, soybeans and grain sorghums. The major engineering contribution has usually been in the consideration of the entire production system with special emphasis on harvesting and processing.

Agricultural engineering efforts in cassava will concentrate on systems for low-cost production, harvesting, handling and processing of fresh roots for human food or animal feed. Attention will also be given to the harvesting and utilization of leaves for animal feed.

In addition, agricultural engineering is required to supplement breeding-crop physiology efforts toward identification or development of plant types best suited for production involving more efficient use of labor and machinery. Root distribution in row beds, effect of poor drainage on root rot, leaf harvest potential, etc. are important considerations.

Ways to improve land preparation, planting, pest control methods and other agronomic practices are additional agricultural engineering areas that will contribute to the development of cassava production systems at costs equal to or lower than existing feeds in the tropics.

One of the major obstacles to the utilization of cassava is the high water and relatively high starch content which cause the root to begin fermentation within several hours after harvest. Suitable procedures and equipment for economical and rapid harvesting and drying are not available.

Breeding - Physiology

Collection, Introduction and Quarantine of Germ Plasm. A representative collection of existing genetic variability in the cultivated species is basic to any improvement program. To date, CIAT has collected more than 3,000 cultivars —2,500 from Colombia and 500 from other Latin American countries. CIAT has been cautious in collecting from other countries and continents until a suitable system is arranged to receive and check materials for viruses and other pathogens. CIAT is collaborating with ICA in a cassava plant quarantine program and will attempt to obtain samples from the collections available in other countries as soon as disease transmittal precautions are clarified.

This collection will constitute the basic material needed for the research program, will serve as a world center for study by visiting scientists, and is being made available to all nations and individuals requesting cassava germ plasm for experimental purposes.

Plant Improvement. Varieties differ greatly in length of growing cycle (6 to 18 months or longer), dry matter content (30 to 40 per cent), content of toxic glucosides related to HCN (from less than 50 to well over 100 mg/kg), harvest index (root weight divided by total weight), stem and leaf morphology, and yielding ability.

Cassava, as many other largely unimproved species, has evolved and perpetuated an interrelated series of morphological and physiological characters in response to primitive selection pressure and cultural conditions. These traits afford maximum adaptability to existing unimproved environments (poor soil preparation, wide spacing, weed competition, infertile soils, water stress, etc.), and thus maximum productivity may not be feasible with currently available plant types.

A greatly increased yield potential will be obtained only by deliberate designing of plant types responsive to improved agronomic practices. The first step, therefore, is to understand the basic physiology of this crop in order to design the ideal plant type, and to attempt to construct it through breeding if it cannot be identified within the range of present variability in the germ plasm collection.

This will be done through cooperative efforts of the plant breeder and the crop physiologist. Essential steps will be to (1) select varieties that represent the range of morphological and maturity variability; (2) derive rapid methods of propagating these types; (3) plant them under simple nitrogen level and spacing variables; (4) observe leaf and stem traits in relation to the rate of development of leaf area—the optimum or critical leaf area index for dry matter production and relation to leaf arrangement and light penetration, the relationship between photosynthesis, and the efficiency of translocation of carbohydrates to the root.

Research will also be undertaken to investigate the stimuli affecting root initiation (photoperiod, thermoperiod, water stress, etc.) and their relation to time of root formation and differences in days from planting to harvest.

Once an understanding of the most efficient and productive plant type is reached, the breeder will attempt to create this ideal type through clonal selection, as cassava is highly heterozygous, and intra-specific hybridization.

Despite reports of sterility barriers, a hybridization program should not be difficult. Immediate testing of hybrid materials through clonal propagations will permit rapid identification of superior types.

Laboratory determinations of starch, protein quantity and quality, as well as HCN content, are being made for all materials now available. Strong selection pressure will be exerted when wide variation in these factors is encountered in new germ plasm accessions or in materials derived from hybridization.

Breeding for resistance will be initiated as specific pathogen-disease interactions are clearly identified and their economic importance determined. Some of the diseases reported are suspected to be physiological in nature and are probably reactions to minor element deficiences. These will be investigated. Basic studies on heritability, genetics, cytogenetics, and inheritance patterns will be undertaken only if needed to solve problems related to breeding methodology.

Local and International Testing. Local and international testing are important. At present it is not known whether individual clones are widely adaptable to the broad areas and various soil types and climates of the tropics. Furthermore, it is not known whether the best available varieties have a photoperiodic response.

CIAT will participate with ICA in the evaluation within Colombia of improved cassava varieties that may be developed or introduced. However, it is recognized that this task is one which should be basically carried out by the Tuberous and Root Crops Program of ICA in all areas of Colombia where cassava is currently cultivated, and also in those areas where the crop may have a potential for production. CIAT will support this activity in order to gain knowledge about the behavior of new cultivars under different environmental stresses.

International testing will evaluate in various environments the package of highly productive varieties and improved cultural practices developed from the research efforts discussed above. This program will be conducted at a number of the national experiment stations presently interested in cassava. Significant findings directly related to increased productivity will be disseminated from this network of experiment stations to farms in the respective areas.

Biometrics

One of the important areas for study with a crop that has not been intensively studied is to document the variability in the various plant characteristics so as to increase the efficiency and accuracy of the research efforts. With appropriate statistical studies in connection with the biological research, the biometrician becomes able to advise on size of samples, number of replicates needed, and overall research design.

Related activities of the biometrician and his staff include analysis of data, providing instruction for trainees in research and statistical procedures, and counseling on the overall systems engineering aspects of production systems.

Utilization Research

Research on utilization of cassava needs to be oriented to defining the potential of the root as a food for humans or in industrially processed products. At the same time, work must continue in connection with developing efficient swine feeding systems in which cassava is a major component in the diet. The potential of cassava in beef feeding rations might also be explored.

While no specific CIAT research will be aimed at developing new industrial uses for cassava, the nutrition biochemist will try to stimulate a participation of other international, national and private entities in research programs which will complement and extend CIAT's efforts. New industrial products research might include the possibility of developing economically feasible systems for enriching cassava protein content by means of fermentation by single cell micro-organisms.

Similarly, CIAT expects to continue present working relationships with the Metabolic Unit of the University of Valle to facilitate human nutrition studies to evaluate the digestibility and the possible effects of differential levels of HCN in cassava roots and products.

Basic research is being conducted in several institutions, both private and public throughout the world, and CIAT will be alert to any developments that may be utilized in an economical manner.

Training

The lack of qualified cassava research specialists is one of the reasons for the scarcity of knowledge about varietal improvement, agronomy, crop protection, and other aspects of this important crop. Meaningful progress in increasing yields of cassava cannot be made if a strong research thrust is not directly associated with training.

CIAT is identifying outstanding young workers from a number of important cassava-producing nations and will invite them for practical research training with emphasis on production. Each young man will be assigned to work directly with a senior scientist in his area of interest. Training will emphasize the field aspects of production research and, in exceptional cases, will be combined with an academic program leading to a graduate degree. Past experience has shown that six months is the minimum training period and that a one-year program is more desirable. These trainees, upon returning to their countries, will remain in continued contact with CIAT staff through reciprocal visits, provision of new materials and techniques, international conferences, and published information.

Further, persons enrolled in CIAT's crop production specialist training program will receive training and experience in applying new cultural practices and managing existing and new varieties for optimum economic yields. These men, in turn, will organize and carry out similar training programs in their countries.

<u>International Center: Resources, Germ Plasm, Information</u>

One of the dynamic aspects of an international institute or center, such as CIAT, is that the research, training, and development activities serve to complement each other. In addition, the institution focuses attention worldwide on the specific crop, its problems, and the efforts being made throughout the world to improve its productivity and production. It attracts visitors who come to discuss problems and progress; and its staff, as it travels to the various countries, not only becomes acquainted with national problems and programs, but is able to offer counsel on research and training methodologies, and to serve as a direct, informal communication link among cassava specialists in many countries.

Other activities of the center directly support the research, development and training activities in the various countries—the Germ Plasm Bank by collecting, evaluating, multiplying, and distributing plant materials to assist national breeding and introducing programs, and the Library by collecting, evaluating, and making available background information on cassava as well as current data on research activities.

Schedule of Activities and Scientific and Support Personnel Required

Agricultural Economics

Limited economic analyses of significance have been made of cassava, with the exception of a study of the market prospects for cassava in the EEC. Studies are needed and will be conducted in the following areas:

1. Economics of cassava production to determine how costs can be reduced. The cost-reducing effects of increases in yields and modified production systems for both small and large farms will be emphasized.
2. Economic disease and insect control.
3. Present and future demand, domestic and international for cassava and derivatives.
4. Employment and earning potentials of an expanded cassava production.
5. Problems of marketing fresh and processed cassava.
6. Competitive position of large and small producers of cassava under various production systems.
7. Competitive position of cassava and substitute products.
8. Economic consequence of the adoption of improved varieties and technology.

These areas of activity will provide valuable information for orienting and providing priorities for other research activities in the cassava improvement program. This effort will require the full attention of an economist with at least two research associates beginning with the first year. It is possible that a major thrust will be required during the first three years, after which probably only half a man/year of an agricultural economist will be needed, as long as the supporting personnel is continued.

Library

The task of reviewing, selecting and collecting the world literature on cassava occupies a high priority and is already underway. Some initial efforts are being carried out by the Canadian International Development Agency and by the Univiersities of Georgia and Colorado. These constitute a sound basis for an exhaustive review of the literature; next, a discriminate collection of the relevant work will be incorporated in the CIAT library to support the research efforts and to function as a resource and information center.

This effort will require the continued service of at least two research associates during the first five years of the project.

Production Systems

Agronomy. An agronomist at the level of one man/year will play an important and continuous role in the program, requiring his services not only for the five years anticipated in the program, but for an indefinite period thereafter. His specific activities can be projected as follows:

First year: Study existing production systems; select and multiply varieties for study; design new agronomic systems for testing; work with agricultural engineers for mechanization systems.

Second and third years: Test the new systems in several locations.

Fourth year: Refine systems and incorporate new and improved varieties in the testing schemes; help initiate international tests.

Fifth year: Continue tests of new varieties and systems; continue international tests.

The agronomist needs the support of one research assistant.

Soils. The production systems development will require the input from a soil scientist at the level of one-half man/year, during the five years of the program, together with one research assistant.

Agricultural Engineering. The inputs from agricultural engineering are important for the development of efficient production systems and will be closely coordinated with the work of the agronomist, soil scientist and plant protection specialist.

The program will require one-half man/year during the first year and will increase to the full time of an agricultural engineer for the second and third years, when major emphasis will be placed in the development of low-cost production systems, including planting, application of protective chemicals, methods of harvesting roots and foliage, and drying.

After the third year, the emphasis probably can be reduced to the level of one-half man/year, if a research assistant is provided from the beginning of the program and continued through the fifth year.

Plant Protection. Needed work in pathology, entomology, and weed control is outlined in the following paragraphs:

PATHOLOGY. Research will be started or strengthened in the following areas, as of the first year of the program and continued during the anticipated five years duration:

1. Survey, identification and economic evaluation of cassava diseases.
2. Definition of plant quarantine treatments for planting stocks for international programs and exchange.
3. Control methods of economic diseases.
4. Screen for specific-disease resistance, in collaboration with the crop improvement scientists.

The contribution of one man/year, starting the first year, will be required and it is expected that this scientist will devote his full time to the program for its duration. He will require a research assistant.

ENTOMOLOGY. The entomologist will conduct research in the following areas:

1. Survey, identification and economic evaluation of insect pests.
2. Screen for specific-insect resistance in close collaboration with the crop improvement scientists.

3. Define control methods for the economically important insect pests.

One-half man/year will be an adequate input in this area, starting the first year and continuing through the fifth year, with one research assistant.

WEED CONTROL The weed specialist of CIAT will survey and assess the importance of weeds in cassava production and will investigate the value of integrated methods of weed control to provide practical recommendations that will form part of the cassava production systems. A concentrated effort during the first two years of the program with a continued program at a reduced level will be adequate for this activity. One-half man/year during two years, with two-tenths man/year after the third year, will be required, plus one research assistant.

Plant Improvement

Collection and Introduction. The botanist assigned to plant collection will be needed for a minimum of four years, at which time the plant collection will be considered complete. This program has just completed two years and the activities proposed for the following two years is to explore, collect and introduce Manihot germ plasm, with particular emphasis in wild species, from the eastern ranges of Peru and Bolivia; Paraguay, Argentina, Central America and the Caribbean countries. Introduction from Brazil will not be pursued until a safe method or procedure is established to prevent the possibility of introducing into Colombia the coffee rust disease. Cooperation is being sought with programs in countries where coffee is not an economic crop.

Physiology. The activities of the plant physiologist will be directly related to the plant-breeding program. He will study such aspects as rapid methods of propagation, stimulation of rooting, photoperiodic responses, thermoperiod effects, starch synthesis, translocation and storage, water stress, and other phenomena pertaining to the basic understanding of the physiology of the cassava plant. The plant breeder will use this data in making selections and in attempts to design efficient phenotypes, if they are not available within the range of natural variability in the species.

The importance of the physiologist to the program will thus decline with time although possibly his full time activity will be required for the five years' anticipated duration of the program. However, on the basis of the progress developed by the fourth year, his input could be reduced to a lower level. As no experience exists to guide this decision, it is suggested that the physiologist be identified during the first year, to participate at full time during five years.

During the first year, the physiologist will study the effects of basic environmental variables on cassava; select and multiply distinctive types; become acquainted with normal growth cycles; will start laboratory and propagation studies.

During the second year, he will intensify laboratory and field studies of effects of water stress and the relation of yield to plant structure, and will terminate propagation studies.

The third year will be devoted to complete studies of environmental effects, with the design and initiation of any additional studies that may be felt necessary and will continue studies of effects of morphology on yield.

The fourth and fifth years will be devoted to terminating all major studies and to design and begin specific research projects that may require the backing of one research associate and one research assistant.

<u>Breeding</u>. The activities of the plant breeder will be closely related to those of the physiologist and the botanist involved with plant collection and the maintenance and evaluation of the germ plasm collected.

In the early phases, varieties will be selected from among the introductions and widely evaluated for possible release to national programs. Later, as desirable characters are identified among the introductions selected, cross-pollination, selfing and progeny testing will be initiated.

The work of the plant breeder will intensify and additional help may be required after the third year. It is anticipated that the full time of a breeder will be required and expected to continue several years beyond the five years planned here. The specific activities during the first five years would follow along these lines.

First year. Devise and conduct a screening system; learn crossing techniques of other aspects of flower biology; identify desirable characteristics and make preliminary selections to plant small scale field trials in varied environments.

Second and third years. Continue screening of all introductions and continue small scale evaluation trials; release selected varieties for intensive agronomic research; initiate crossing program among varieties, for genetics and breeding purposes; establish procedures for starting seedlings and study possibilities of botanical seed propagation methods; continue studies of floral biology.

Fourth and fifth years. Intensify hybridization and evaluation program for seedings; release second generation of selections.

The breeder will require the backing of a research associate and one research assistant.

Biometrics

One-half of a man/year will be required in the field of biometrics, as of the second year of the program, and this effort should continue during the remainder of the five year projection, at the same level described. One research assistant will be required.

Utilization Research

An accelerated program to screen cultivars for high protein content and quality, low HCN (based on rapid tests that must be developed by research) is justified for a period of the two initial years at the level of input of one-half man/year, with a reduction of scientific time input to a level of 0.25 man/year as of the third year. A research associate will be needed from the second year of this project. The specific activities during the following years will be to collaborate with the swine studies, and to study the possibility of utilization for beef feeding.

Training and Communication

The cassava program provides limited opportunities for in-service training activities during the first year and will rapidly increase its capability for this important area of the program from the beginning of the second year onward.

The areas in which in-service training for research and production specialists can be provided are: Production systems, pathology, entomology, agricultural economics, breeding, physiology and agricultural engineering. It is anticipated that, beginning with the second year, there will be capacity for up to 12 trainees each year in the cassava program.

Necessary administration and follow-up support must be provided to facilitate training and to maximize this cooperation of the participating scientists. The input for this function will be initially at the level of a training associate during the five year period. In addition, and starting the second year, a one-half man/year input from a training and communication scientist will be added for the remainder of the project to provide the needed professional manpower for processing information preparing training materials, and organizing conferences and symposia.

The Proposed Budget

The proposed budget for this program is presented in the following section, showing scheduling of scientific and support personnel and funding required for operational and capital funds needed for equipment and development of facilities.

A 6 per cent increase per annum has been applied to the annual figures to cover inflation cost.

CASSAVA IMPROVEMENT PROGRAM: ALLOCATION OF SENIOR STAFF (MAN/YEARS)

	1st Year	2nd Year	3rd Year	4th Year	5th Year
Assistant Director	0.4	0.4	0.4	0.4	0.4
Crop Improvement	2.0	2.5	2.25	2.25	2.25
Crop Protection	1.5	2.0	1.7	1.7	1.7
Agronomy & Soils	1.5	1.5	1.5	1.5	1.5
Agricultural Economics	1.0	1.0	1.0	0.5	0.5
Agricultural Engineering	0.5	1.0	1.0	0.5	0.5
Biometrics	0.0	0.5	0.5	0.5	0.5
Training and Communication	0.0	0.5	0.5	0.5	0.5
Library	0.0	0.0	0.0	0.0	0.0
Total Man/Years	6.9	9.4	8.85	7.85	7.85

ALLOCATION OF RESEARCH ASSOCIATES AND ASSISTANTS (I) AND POST-GRADUATE INTERNS (II)

	1st Year		2nd Year		3rd Year		4th Year		5th Year	
	I	II	I	II	I	II	I	II	I	II
Assistant Director	--	--	--	--	--	--	--	--	--	--
Crop Improvement	3	2	5	4	5	4	5	4	5	4
Crop Protection	1	2	6	4	6	4	6	4	6	4
Agronomy & Soils	2	1	5	2	5	2	5	2	5	2
Agricultural Economics	2	0	2	1	2	1	2	1	2	1
Agricultural Engineering	1	0	1	1	1	1	1	1	1	1
Biometrics	--	--	1	--	1	--	1	--	1	--
Training & Communications	1	--	1	--	1	--	1	--	1	--
Library	2	--	2	--	2	--	2	--	2	--
Total	12	5	23	12	23	12	23	12	23	12

CASSAVA PROGRAM OPERATIONAL BUDGET AND ADDITIONAL CAPITAL REQUIREMENTS

a. Salaries	Man Years	First Year	Man Years	Second Year	Man Years	Third Year	Man Years	Forth Year	Man Years	Fifth Year
Assistant Director	(0.4)	12,720	(0.4)	13,483	(0.4)	14,292	(0.4)	15,150	(0.4)	16,059
Breeding-Physiology & Nutrition										
Plant Breeder	(0.5)	15,900	(1)	33,708	(1)	35,730	(1)	37,874	(1)	40,147
Research Associate	(1)	10,600	(1)	11,236	(1)	11,910	(1)	12,625	(1)	13,382
Crop Physiologist	(1)	31,800	(1)	33,708	(1)	35,730	(1)	37,874	(1)	40,147
Research Associate		---	(1)	11,236	(1)	11,910	(1)	12,625	(1)	13,382
Nutrition - Biochemist	(0.25)	5,430	(0.5)	11,512	(0.25)	6,101	(0.25)	6,467	(0.25)	6,855
Research Associate		---	(1)	11,236	(1)	11,910	(1)	12,625	(1)	13,382
Crop Protection										
Pathologist	(0.5)	15,900	(1)	33,708	(1)	35,730	(1)	37,874	(1)	40,147
Research Associate		---	(1)	11,236	(1)	11,910	(1)	12,625	(1)	13,382
Entomologist	(0.5)	15,900	(0.5)	16,854	(0.5)	17,865	(0.5)	18,937	(0.5)	20,074
Research Associate		---	(1)	11,236	(1)	11,910	(1)	12,625	(1)	13,382
Weed Specialist	(0.5)	15,900	(0.5)	16,854	(0.2)	7,146	(0.2)	7,575	(0.2)	8,029
Research Associate		---	(1)	11,236	(1)	11,910	(1)	12,625	(1)	13,382
Agronomy & Soils										
Agronomist	(1)	31,800	(1)	33,708	(1)	35,730	(1)	37,874	(1)	40,147
Research Associate		---	(1)	11,236	(1)	11,910	(1)	12,625	(1)	13,382
Soil Scientist	(0.5)	15,900	(0.5)	16,854	(0.5)	17,865	(0.5)	18,937	(0.5)	20,074
Research Associate		---	(1)	11,236	(1)	11,910	(1)	12,625	(1)	13,382
Agricultural Economics										
Economist	(1)	31,800	(1)	33,708	(1)	35,730	(1)	37,874	(1)	40,147
Research Associate	(1)	10,600	(1)	11,236	(1)	11,910	(1)	12,625	(1)	13,382
Agricultural Engineering										
Agricultural Engineer	(1)	31,800	(1)	33,708	(1)	35,730	(0.5)	18,937	(0.5)	20,073
Research Associate	(1)	10,600	(1)	11,236	(1)	11,910	(1)	12,625	(1)	13,382
Biometrics										
Biometrician		---	(0.5)	16,854	(0.5)	17,865	(0.5)	18,937	(0.5)	20,073
Research Associate	(0.5)	5,300	(1)	11,236	(1)	11,910	(1)	12,625	(1)	13,382

	Man Years	First Year	Man Years	Second Year	Man Years	Third Year	Man Years	Forth Year	Man Years	Fifth Year
Training & Communications										
Training & Communication Scientist		---	(0.5)	16,854	(0.5)	17,865	(0.5)	18,937	(0.5)	20,073
Training Associate	(1)	10,600	(1)	11,236	(1)	11,910	(1)	12,625	(1)	13,382
Library										
Research Associates	(2)	21,200	(2)	22,472	(2)	23,820	(2)	25,250	(2)	26,764
Support Personnel										
Research Assistants	(6)	27,077	(9)	43,052	(9)	45,635	(9)	48,374	(9)	51,276
Post-Graduate Interns	(3)	7,569	(12)	32,094	(12)	34,019	(12)	36,060	(12)	38,224
Technician I	(1)	3,282	(2)	6,958	(2)	7,376	(2)	7,819	(2)	8,287
Technician II	(1)	2,133	(4)	9,044	(4)	9,587	(4)	10,163	(4)	10,773
Technician III	(2)	2,133	(6)	6,786	(6)	7,193	(6)	7,621	(6)	8,079
Secretary I	(1)	3,914	(3)	12,445	(3)	13,192	(3)	13,983	(3)	14,822
Secretary II	(2)	5,217	(2)	5,531	(2)	5,862	(2)	6,215	(2)	6,588
Field Assistants	(3)	7,687	(6)	16,596	(6)	17,592	(6)	18,647	(6)	19,766
Laborers	(12)	10,434	(16)	14,747	(16)	15,632	(16)	16,574	(16)	17,568
Hourly Help and Overtime		2,000		3,000		3,500		4,000		5,000
Total Salaries		365,196		619,070		639,677		659,453		699,776
										(2,983,172)
Other Expenses										
b. Supplies		30,000		20,000		22,000		24,000		26,000
c. Transportation		8,280		12,135		12,148		11,362		12,044
d. Maintenance		8,280		12,135		12,148		11,362		12,044
e. Travel		13,800		30,337		30,371		28,406		30,110
Total Other Expenses		60,360		74,607		76,667		75,130		80,198
										(366,962)
f. Administration and General Expenses		101,128		159,546		164,759		168,954		179,394
										(773,781)
GRAND TOTAL		526,684		853,223		881,103		903,537		959,368
										(4,123,915)
Additional Capital Requirements										
g. Library		20,000		10,000		5,000		5,000		5,000
h. Office and Laboratory Equipment		45,000		30,000		20,000		20,000		20,000
i. Vehicles & Field Equipment		37,500		10,000		10,000		10,000		10,000
j. Greenhouse & Screenhouse Additional Space		45,000		15,000		---		---		---
Total Additional Capital Requirements		147,500		65,000		35,000		35,000		35,000
										(317,500)