

PROGRESS REPORT 1979

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Foreword

A fundamental element of CATIE's Charter states that its work should contribute to improving the standard of living of small-scale farmers, in particular by boosting agricultural, animal and forest production and productivity in the American tropics.

This position is not without foundation. It is based on the potential of low-income farmers to take part in increasing their production volumes, and on the technological possibilities which can increase productivity of land currently used for agricultural and forest production.

Since improving the standard of living of farmers is a very ambitious undertaking which includes political, socio-economic, cultural as well as agricultural components, CATIE has selected to focus on technological matters dealing with agricultural and forest production, especially on their biological aspects, on training and on transferring methods and research findings.

Thus, in 1979, production systems came under greater scrutiny, with limiting factors and those determining the adoption of technology being particularly emphasized. CATIE's research programs were strengthened, as much at CATIE headquarters, as in the countries and the farmers' fields. Simultaneously, greater emphasis was placed on training programs for the technical staff at national institutions, on designing in-service training methods, field-level interactions between farmers and specialists, and on handling information. These elements have been incorporated into models for local application, enabling national specialists to participate directly in transferring research findings to farmers.

One of CATIE's most significant contributions in 1979 was in consolidating the research methodology in agricultural production systems being developed over several years, and which recognizes that agricultural development is not only nurtured by new technological alternatives, but also by the social and economic conditions of the farmers. This has proven to be CATIE's most important contribution in its interaction with national institutions, international agricultural research centers and human resource training and development programs.

This methodology, whose general principles and most important results are described in the following pages, has been a fundamental element of exchange with national institutions and has contributed significantly to guiding CATIE's relationships with agricultural scientists of the

region, in establishing a network of agricultural and forestry research which will promote further technological development and overall improved production.

Improved mechanisms for inter-institutional cooperation in technical assistance and technology transfer have also been evolved, contributing to specific projects and agreements with national institutions, as well as in the exchange of information. During the year covered by this report, CATIE has been participating in a network of international cooperation with over 30 national institutions and approximately 40 international research, technical and financial assistance agencies.

In this way the consolidation of CATIE as a mechanism for channeling international technical and financial assistance to the countries and institutions with which it collaborates is being achieved, contributing thus to developing a regional model of cooperation. This experience may be useful to other regions with similar agricultural development problems and which need to unite efforts to face the urgent challenges of this new decade.

Within this spirit of cooperation and exchange, it is our pleasure to share the results of our most important actions in 1979 with the technical experts and researchers of the region, with the national institutions and the international scientific community.

A handwritten signature in black ink, appearing to read 'S. Fonseca', with a large, stylized flourish extending to the right.

Santiago Fonseca Martínez
Director CATIE



Systems Approach

INTER-DISCIPLINARY AND PARTICIPATORY STRATEGY

Food production deficits in Central America can become a serious problem if adequate measures are not taken to combat some of the causes. Solutions should seek to increase the productivity of lands presently used for farming and forestry production, and lands with good agricultural potential in the region must be incorporated into production of food and other products.

In order to define appropriate strategies to attain these objectives, it must first be remembered that approximately 70 percent of the region's food is produced on farms of less than 35 acres in size, with corn and beans a large proportion of what is produced on these units. Approximately 80 percent of these small holdings raise cattle for meat and milk; almost all have pigs and poultry, and most combine forest resources into their production schemes.

Low-income farmers with less than 7 hectares constitute more than 80 percent of the total farming population. Families are usually large, diets deficient, educational levels low; they have little access to credit facilities and even less capital. The farms are usually far from the main markets, have poor or marginal soils, and are located in high-risk areas for purposes of production. All these facts discourage the use of costly technologies which, in any case, may be less advisable under such circumstances, than those presently used that are characterized by low capital investments and a high dependency on family labor. Production systems make extensive use of radiant energy and are conservative in the use of costly practices.

The working conditions of these farmers and their production systems are beginning to be evaluated by agricultural researchers. The systems involve a series of complex relationships which make them difficult to comprehend, and their study frequently requires special methods. Once understood, it will be possible to improve existing management systems and to develop new more satisfactory ones.

Appropriate technologies adapted to the conditions of low-income farmers need to be developed, in order to facilitate a more efficient use of available resources. In this way, their income and levels of well-being can be improved without inconveniently increasing production costs and risks. For this reason, research at CATIE has been dedicated mostly to the development of production systems and other appropriate technologies for low-income farmers.

To study production systems, CATIE has adopted an interdisciplinary approach on research projects of regional scope which includes the active participation of staff from cooperating national agencies. All the research endeavors, ultimately, are oriented toward generating recommendations on production systems for small-scale farmers. To this end, it is essential to have detailed knowledge of the environment, the farmers and their systems. This means working in areas with a high concentration of small-scale farmers, enlisting their participation in the phases of regional diagnostic studies, problem prioritization, the design of alternatives, conducting the research itself, and validating results. Thus, part of the research is done at CATIE, in Turrialba, and part at the experiment stations of collaborating institutions in the different countries.

The direct involvement and participation of farmers accelerates the process of developing improved systems and the probability that generated recommendations be adopted. Besides, this method assures that real farming problems are noted, and that results obtained are relevant to their environment.

The participation of national technical teams in this work also accelerates the research process and facilitates the adaptation of methodologies to the specific conditions of each country or region. It also ensures a better understanding of the philosophy, approach and analytical methods as concern the development of production systems.

To help strengthen the research capability of national institutions, a continuous exchange is maintained with their technical experts, contributing, in this manner, to frank inter-communication of experiences and knowledge. Similarly, the interchange with international and regional centers has been stepped up, as more information on the components of the systems or the testing of genetic material with specific characteristics is required.

One of CATIE's principal concerns has been to develop a method to study agricultural and forest production systems, within this research orientation. The method has been devised, studied and improved, based on the experience acquired through its application. Thus, the method has evolved considerably in the process of consolidation. Efforts are being made at CATIE to establish a flexible methodology which can be useful in orienting research into the different aspects of systems and which, at the same time, can be adapted and used by either agricultural or forestry research institutions in the Central American countries.

The methodology is based on integrating the different processes of compiling and analyzing data within a general, overall research process. It emphasizes an in-depth knowledge of the environment in which with agricultural systems are found, and appropriately detailed knowledge of the structure and performance of those systems, and the study of alternatives for improving them, taking into due consideration such restrictions as may be imposed by the socioeconomic and physio-biological elements of the environment.

Thus, research endeavors are oriented toward satisfying both short-term goals, that is, developing technological alternatives for farmers, and medium-term goals, such as the development of research methodologies with the farmer being a part as well as a basis for them.



Research Highlights

ALTERNATIVES FOR THE SMALL-SCALE FARMER

PRODUCTION SYSTEMS FOR ANNUAL CROPS

Research at CATIE is in support of the efforts being made in the countries to generate alternatives in specific areas of interest. Research efforts are organized to focus on the systems, and to study the components of these systems. One of these is the multi-cropping system with corn and beans grown in association, which is commonly used by small-scale farmers through Central America. A considerable proportion of the bean production is grown in association, alternation or rotation with corn, with most problems primarily associated with beans. Beans are frequently grown in lowland areas unsuited for this product, or in excessively humid or dry areas, and are subject to a number of pest and disease problems. The corn-bean association, however, is one that makes the best possible use of the land. In 1979, the effects of different soil management practices on yield, and other factors of this association, were analyzed.

The corn-cassava association is another system used by small-scale farmers in lowland areas. It has good possibilities due, in part, to the robust nature of both crops and to their adaptability to different environments, as well as to the recuperation capacity of cassava and the plasticity of corn. In 1979, research was undertaken to determine the system's relative response to different planting seasons and corn population densities.

The sweet corn-string bean association is a variant of the corn-bean system, but one that may have significantly different requirements. For zones under 600 meters above sea level, the cowpea, *Vigna unguiculata*, is more advantageous from an agronomic point of view. However, there is little reliable experimental information on the corn-cowpea association. Viruses, usually transmitted by the Chrysomelidae, are a serious problem in cowpea production. In 1979, the relationship between the virus and its principal vectors, and the response of this crop to the attacks of the most common viruses in the area, were studied.

Tiquisque, or malanga, *Xanthosoma sagittifolium*, is cultivated on the Atlantic coastal plain of Costa Rica and is a potentially good starch food for the humid tropics. Last year, experiments were carried out on this crop in these areas, but it was found necessary to do further testing under more controlled condi-

tions in Turrialba: a preliminary study has been completed and several others have been initiated.

Corn-based Systems

Studies on the corn-bean system have been carried out for the past three years, in order to assess the effect of minimum tilling, conventional tilling, minimum tilling-2, and no tilling soil management methods. Results indicate that bean plant loss was greater when grown in association than as a monoculture; also, the effect of association on the number of plants was more important than the effect of soil treatments. With conventional tilling, the bean yield, when grown in association, was nearer its respective monoculture yield than in the other treatments.

For two years, the lowest bean yield occurred when grown in association with corn, without tilling; in the third year, the yield was slightly better, but still among the lowest. However, bean yields increased over time in all tests. It is not known whether this effect is due to a general improvement of soil conditions, or to a better adjustment of fertilizers.

In two of the three years, the overall number of corn plants produced was less than when this crop is grown as a monoculture. During the first planting season, from November to March, soil treatment affected corn yield significantly. On an average, response to conventional tilling was inferior to that obtained with the other treatments, which included the addition of organic residues. In general, corn yield was less affected by competition than bean yields.

Between April and October (second planting, rainy season), corn yield was affected significantly by the different soils treatments, with consistently lower yields in cases of no tilling. The highest yields were obtained on soils receiving conventional tilling, contrary to the results obtained during the first planting season where conventional tilling produced the smallest yield in terms of dry grain per unit area.

Different fungi attacking the corn ear is one of the greatest problems in producing this crop under high rainfall conditions. In Turrialba, *Diplodia macrospora* is one of the principal fungi which attack the ear; it particularly affects the 'Tuxpeño' variety, a short plant, during the rainy season; less so in the dry season.

The results of the research on this fungus, in relation to land preparation systems, would indicate that the system of minimum preparation offers advantages over conventional methods, because it maintains a more uniformly humid environment. On the other hand, when the same system is used for any length of time, and a stable supply of macronutrients is present in the soil, the fungus population tends to stabilize.

Results also suggest that only drastic changes in the management system, or the substantial modification of some inputs, could produce an appreciable change in the microbial population of the soil. Some possibilities are: liming, the addition of organic fertilizers, the use of green fertilizer, and the prolonged application of chemical products, such as herbicides, fungicides and insecticides.

In general, the above plus the advantages derived from soil and water conservation and the energy saved during land preparation, would mean that limited tilling could be considered favorably for use by low-income farmers.



Corn and beans grown in association is the cropping system most commonly used by the small-scale farmer of the Central American Isthmus.

RESEARCH HIGHLIGHTS

Another important aspect of the corn-bean system studied was the effect of different levels of phosphorus (P_2O_5) on the chemical properties of the soil and on crop yields. In untilled plots, the yield of corn was significantly high, while that of beans was lower, although the phosphorus applications did not produce significant yield differences in the overall system. In conventional tilling, the aluminum phosphate and iron phosphate fractions were higher than on untilled land.

Economic analysis at the conclusion of the experiment, showed that no tilling resulted in greater benefits than conventional land preparation. The highest estimated net profit was obtained with the fertilized, untilled treatment. Higher profits on conventionally tilled plots were obtained only when 300 kg/ha of phosphorus were applied.

These results clearly indicate the advantages of untilled land and the need for higher levels of fertilizers when conventional tilling is used instead of minimum tilling, as a form of land preparation.

Sweet corn – String bean. The use of green pods and young ears has probably paralleled the domestication of beans and corn. In beans, specific lines for the consumption of pods have only been developed in this century. Previously, there were some double-purpose cultivars which were considered better adapted for pod consumption, such as the green or string bean.

Different types of corn have long been recognized as specially suitable for unripe consumption, such as the sweet corn or 'choclo'. Nevertheless, only specific zones of Mexico, Guatemala and the Andes have traditionally consumed corn this way. In many zones, the same varieties are planted for grain, the only difference being the harvest time.

When string beans are grown alone, the commercial and total yield of 'Extender' and 'Tendergreen' lines of determined growth habits was greater than the 'Kentucky Wonder' of undetermined habit, during the rainiest part of the season. 'Tendergreen' production was similar during the very rainy as well as the very dry seasons.

In the system where grain corn or commercial sweet corn was grown in association with string beans of determined growth habits, yield varied considerably

over the three different planting periods: bean yield reduction was considerable, especially in the third planting due to competition with corn, and in the first planting because of fungus diseases in the pods. The relatively good yield obtained in the second planting can be attributed partially to an improved space arrangement and to the 12-day interval between planting the corn and the string beans. However, the string beans of undetermined growth habits suffered larger yield decreases than the bush plants, and fresh weight of the corn was lower when grown in association with the 'Kentucky Wonder' line.

The effect of the driest season on the competitive relationship between the two crops is noteworthy, as string bean yield was considerably reduced between seasons, which would seem to indicate that corn makes better use of available water than the beans, when there is a negative atmospheric water balance.

In terms of planting space and chronological arrangements between corn and string beans, it was found that it is better to plant string beans from 8 to 12 days after the corn. Planting arrangements must be accommodated to the growing habits of the string bean. In this case, the best results were obtained with the 'Kentucky Wonder' climbing bean.

The economic analysis of the string bean – corn system indicates that the net income of the bush string bean planted alone was greater only during the rainiest and driest part of the season. Its association with sweet corn produced higher net incomes during the intermediate season.

Income was low when the climbing string bean was grown in association with sweet corn and negative when associated with grain corn.

Net income for grain corn was US\$100 per hectare, with yields of approximately three tons and production costs of about US\$470 per hectare.

These results suggest that the association of sweet corn with string beans of determined growth habits,



Planting season and densities were among the factors studied in relation to the yields of corn and cowpea when grown in association.

is a biologically and economically viable system for testing in the field.

Corn—Cowpea. Bean production is deficient throughout the Central American area, a problem which is becoming increasingly serious in view of present day population growth rates. Yields per unit area are meager, especially in lowland areas where other pulses of similar nutritional value can be grown advantageously, particularly in those areas which are totally inadequate for the cultivation of the common bean.

The *Vigna sinensis*, known as coastal bean or cowpea, could be a good alternative for the common bean in regions where corn is frequently grown in association with beans. Corn is often considered the basic crop and beans are grown with it in such a manner so as not to reduce the corn yield, even in those cases where the beans could well be considered the association's main crop.

In the work with cowpeas grown in association with corn, efforts are being made to produce the cowpea without considerably reducing corn yield. For this

purpose, a study was carried out to determine the effect of planting season and space distribution of the bean in relation to corn, on the yield of both crops.

Bean yield, when grown in association with corn, was low; when the beans were planted alone, yield was three and a half times greater than the highest associated yield obtained. It must be noted that planting season is a critical factor in bean yield: the later the bean is planted in relation to corn, the lower the yield produced. As to corn, no significant effect on yield was observed with reference to planting season or methods used for beans. Higher corn yields were observed when two rows of cowpea were planted between the corn, perhaps because the corn was able to use more of the fertilizer applied to the now closer bean rows. The information obtained suggests that the beans be planted before the corn, in two rows of beans between each corn row.

Another experiment was to determine the effects of the density and spacial arrangement of cowpeas grown in association with corn, on the system's yield, and of corn population density on its yield and on the yield of the cowpeas grown with it. It was found that the latter's yield, when grown in association with corn was low in all cases. When cultivated alone, it yielded three times more than the best crop treatments in association. The density of the beans did not influence yield; however, planting density of corn was an important factor.

The yield of corn was very high when cultivated alone, with a population of about 50,000 plants per hectare. Similar yields were obtained when corn was grown in association with beans, with the same plant density. As could be expected, corn population significantly affects yield. Within the limits of the study, production was found to increase in line with corn population increases. Corn height was not affected by either the bean or corn population densities.

Results of the two tests indicate that the bush cowpea, *Vigna 44*, when planted in association with corn, produces approximately half a ton without reducing the corn yield.

RESEARCH HIGHLIGHTS

Corn-cassava. The corn-cassava association is one of the cropping systems most commonly used in the hot, humid tropical regions. In Turrialba, various aspects of this association have been studied, but little is known about ideal planting densities for producing economically profitable yields, in view of marketing conditions.

The effect of corn density and the respective interaction in a corn-cassava association, at two levels of fertilizer, were studied. It was found that total yields of both grain corn and cassava roots were significantly effected, and that density tended to increase corn yield and to decrease cassava yield. However, no significant differences were noted for the two levels of fertilizer.

Corn yield increases progressively declined as population density increased. This tendency is more notable at the lower levels of fertilization, suggesting that a maximum yield can be expected from higher population densities when high levels of fertilizer are used, according to the anticipated effect of the competition for nutrients.

Response tendencies of total cassava yields to variable corn populations were lineal, when average fertilizer levels were used. Higher production was obtained with low fertilizer levels when cassava was grown in association with corn, although it tended to level off on increasing corn plant density. It was also found that the weight of non-commercial cassava roots was consistently lower for each population density, at the low fertilizer treatment levels.

In corn, the effect of fertilizers is significant, especially with regard to the percentage of healthy ears, although planting density and fertilizer levels did not affect their length of average weight.

In multi-cropping systems, the time for planting one crop in relation to another can exercise considerable influence on the results of the association. Under Turrialba conditions, it was found that when corn is planted a month after cassava, grain corn yield was reduced by 69 percent and cassava yield by 8 percent, as compared to their respective single crop yields. When corn and cassava were planted at the same time,



Cassava planted in association with other food crops, like corn, has proven to be a good alternative for improving cropping systems.

corn yield was only reduced by 8 percent, but cassava yields decreased by 51 percent.

Cassava and corn are both dominant crops and their foliage competes at about the same level. Thus, a change in the row layout can significantly affect the growth of both crops. Although the effect of the double row used in corn cultivation in association with other crops has already been studied, this effect has scarcely been evaluated in its association with cassava. With this in mind, tests were conducted to determine the effects of differences in corn and cassava planting schedules on the system's behavior, and to establish the effect of changes in row layout for both crops. The treatment basically consisted of three systems: corn planted alone in single rows and corn planted in double rows; corn in association with cassava in single rows and corn associated with cassava in double rows; cassava in single rows and cassava in double rows.

A comparison of the effect of relative planting dates on corn-cassava yields and corn yields when grown

alone, resulted in higher average yields for the unassociated corn, under all planting situations. The average yield of unassociated corn is higher than the corresponding average results of corn grown in association with cassava in single rows; these, in turn, surpass the double row corn-cassava association yields.

Based on the results obtained, it may be concluded that yield differences between monoculture corn and multi-cropping in association with cassava, in single rows, is lower in the latter case when planting dates for corn were delayed in relation to cassava. This kind of comparison eliminates the effect of corn planting dates, but not the effect of their interaction with cassava planting dates.

The spacial arrangement of the systems caused some morphological change in the plants. Associated corn was shorter and of smaller diameter, and produced shorter ears. The yield of cassava reserve roots was similar in both single and multi-cropping systems. Yields showed no major response differences to the applications of fertilizer.

Nitrogen-potassium fertilization of cassava and corn grown in association was studied in order to determine the influence, if any, of different levels of nitrogen and potassium applied in bands on both sides of the two crops.

Results indicate that 240, 120 and 115 kg/ha of nitrogen, phosphorus and potassium respectively, is recommended when soil conditions are a limiting factor. The addition of 80, 120 and 115 kg/ha is another option for capital-scarce farmers, which produces similar results. Data also indicated that even more economical results for the corn-cassava association can be obtained with 48, 120 and 60 kg/ha levels of nitrogen, phosphorus and potassium, respectively.

Corn and Beans, Followed by Sweet Potatoes. The ecological risks of grain production decrease when short dry periods coincide with the harvest. A dry period of approximately two months usually occurs in Turrialba, with monthly average precipitation of less than 100 mm. Low-risk corn production is thus possible. Production of the common bean is also feasible, although in this case the altitude of only

602 meters above sea level increases the possibility of ecological risks, especially in the form of diseases. The cultivation of roots is a good production alternative during the rainy period, before and after this brief dry spell.

In Turrialba, the sweet potato, *Ipomoea batatas*, has shown little or no response in terms of root production to the more commonly used fertilizer levels. An inverse relationship has been established between the quantity of fertilizer and root yield, but not always for total biomass. It has also been observed that low fertilizer levels increase harvesting indices. Moreover, the positive response of sweet potatoes to the application of potassium is a well known fact in many countries. Thus, an experiment was designed to determine the optimum levels of NPK for producing the best biological and economically profitable yields in corn-bean associations, and then to evaluate the effect of the residues of these fertilizers on the sweet potato planted sequentially, as well as this crop's need for a potassium supplement.

It was found that the highest yield was obtained with 168 kg/ha of potassium, and the lowest with 336 kg/ha. When no additional potassium was applied to the sweet potato, it was observed that increased fertilization of the corn-bean association actually reduced the sweet potato yield by approximately 6 tons per hectare, between highest and lowest yields. This is a good estimate of the effect of fertilizers applied to corn and beans, on the successive cultivation of sweet potatoes.

Considering that no significant yield differences were found for the corn-bean association and that, with small additional quantities of potassium it is possible to obtain adequate sweet potato yields, it would seem that this particular crop association, in succession, is more successful with low levels of fertilizer. The high potassium content of the soil in the experimental area would seem to indicate that this nutrient is already available for sweet potatoes, in adequate quantities.

Corn and Tiquisque. The specific objective of this study was the tuber production of tiquisque, *Xanthosoma sagittifolium*, also known as malanga, when the plant is subjected to different periods of shading by corn plants. For the study, corn was planted at two-week intervals. The tiquisque was planted at the same time, on all the experimental plots.

RESEARCH HIGHLIGHTS

Data indicate that the best planting dates for corn, if tiquisque is to be transplanted in August, are May 23 and June 6. Later planting dates resulted in over a 30 percent reduction in yield.

Tiquisque tuber yield for the five different shade experiments, showed a slight tendency to increase after growing for at least 8 weeks in the shade.

During the two months following planting, the tiquisque was heavily attacked by the 'picudo', *Derolomus palmarum*; after three months, all trial plots were infested. The incidence of attack seems to be more closely related to the season—in this case a moderately dry period—and to other climatic conditions, than to the treatments themselves.

For the corn-tiquisque association, consideration must be given to a space arrangement which ensures a better use of the fertilizer applied to the corn, such as replanting the seedlings closer to the corn plant stalks. Tiquisque has proven to be very tolerant of corn shade.

Corn system. Previous experiments clearly indicate that, prior to planting, there is a marked relationship between the different types of plant management and insect populations.

One experiment compared the effects of conventionally tilled and untilled soil as well as the control of soil and foliage insects. In addition, the effectiveness of Carbofuran and Aldrin were tested and compared.

Significant differences showed up as a result of soil preparation and insecticide use. The average yield in untilled soils was found to be significantly higher than in tilled soils and lowest yields were obtained when there was no insect control of any kind. Yields with Carbofuran were significantly higher than with Aldrin. This may be due to better insect control or to the stimulating effect of Carbofuran on crop growth. Results, verified in other studies, indicate that soil preparation has a considerable impact on crop performance. When the soil is tilled, insecticides must be used to ensure a good harvest.

Another study was made of the effect of weeds and crops on the incidence of "Gallina Ciega", *Phyllophaga menetriesi* and its damage to corn. Results indicate that manual cleaning and the use of herbi-



The interaction between the type of vegetation management system used, like "no tillage" and the insect population, prior to planting, significantly affects crop yields.

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cides are equally effective for reducing the incidence of *Phyllophaga* attacks. The presence of cassava or other tall plants, which serve as hosts for adult insects, significantly increase nearby larvae populations. Harmful larvae populations gradually disappear towards the end of August. It is important to note that coffee plantations are sources of adult populations, although it has been found that a barrier of plantain trees can restrict their access to the food crops planted nearby.

Another study compared the effect of several insecticides on the "Gallina Ciega" in corn, as well as on other soil pests. Corn was planted in holes by means of the spike or pointed stick method. The following substances were then applied to the seeds in each hole, after planting: Aldrin, Carbofuran and Phoxim, in three dosages. Pirimiphos-ethyl was applied to the soil at the base of the plant with hand pumps without spray heads.

Although significant differences were noted in amounts of damage in response to the different treatments, corn yields did not vary significantly. Moreover, no significant differences were established between insecticides; only between these and the controls for each index used as a measure of the damage.

Again, granulated Carbofuran and Pirimiphos-ethyl provided the best protection against *Phyllophaga*. The other insecticides ensured better crop results than the control plot, but the high dosages of Phoxim proved to be toxic on contact with the plants.

In Birrisito, near Turrialba, corn was planted using the pointed stick method, and different amounts of the same products were applied to the seeds in each hole: Aldrin, Carbofuran, Phoxim, Chlorpyrifos, Pirimiphos-ethyl and Methamidophos. The effectiveness of the different insecticides was judged solely by the survival of the small plants or seedlings.

In addition to *Phyllophaga*, there are a number of other pests which also destroy plants, including *Agrotis* spp., *Spodoptera frugiperda* and *Elasmopalpus lignosellus*. Damage caused by these other pests was not included in the evaluation of the experiment to control *Phyllophaga*, though it was taken into account in a general comparison of the effectiveness of the insecticides against pests as a whole.

The control plot suffered more damage than those with insecticide applications. Chlorpyrifos, Carbofuran and Pirimiphos-ethyl gave the best protection against the "Gallina Ciega"; Chlorpyrifos and Methamidophos gave better control of other pests like *Agrotis* and *Elasmopalpus*. The survival of plants up to 50 days after planting was better with Carbofuran; this product offers better protection to the plants from germination, and reduces plant loss during this early stage. Treatments with Phoxim again proved to be toxic to some of the seedlings.

An experiment was carried out on the effect of damage by *Diabrotica* spp., in order to quantify the effects of soil pests on corn yield. This was a preliminary experiment in which different modifications of the scale of damage to the roots were tested, to serve as a means for predicting final corn yield.

The data, by plot, of damage rate and yield per harvested plant, indicate that no lineal relationship exists between yield and root damage, although there is evidence of some decrease in yield with increased damage. It appears that a technique could be evolved on the basis of these damage rates for use in the field for evaluating corn root damage and relating this information to final yield.

Evaluation of corn varieties. For over six years, the 'Tuxpeño-1' variety of corn has been considered best for cultivation in the Turrialba experiments. It is used for mono as well as multi-cropping systems. In 1977, 37 corn varieties were cultivated at CATIE during the rainy season, for purposes of evaluation. It was found that 'Tuxpeño-1' was among the five varieties with the highest yields; the others were 'Hybrid B-666', 'Tico V-1', 'ICTA B-1' and 'ICTA T-101'. Results also indicated, however, that 'ICTA-101' adapts well to Turrialba conditions, and that it can yield as much or more than 'Tuxpeño-1', while 'Tico-VI' and 'Hybrid B-666' matched 'Tuxpeño-1' yields fairly consistently.

RESEARCH HIGHLIGHTS

Cassava-based Systems

Because cassava plays such an important role in the production systems used by small-scale farmers and because of other advantages already reported in relation to its association with corn, it was decided to study and evaluate the agro-ecosystems based on this crop.

The cassava root constitutes the food base for approximately 300 million people in the tropical regions of the world; its leaves and shoots are also edible. Although cassava provides large amounts of food energy, it occupies the land for a long time – approximately one year. This is much longer than for other food crops. Other factors to take into account include the problems that the root is low in protein content and that labor is highly concentrated at the beginning when the crop is planted, and at harvest time.

Although the association of cassava with other food crops such as corn and pulses has proven to be a good alternative for improving production systems, little information exists on the biological and economic aspects of these cropping systems.

An evaluation was therefore made, in Turrialba, of the biological productivity (biomass, nutritional energy and yield) of cassava associated systems, with corn, lima beans and string beans as the complementary crops. The economic returns from these systems were also evaluated.

Results indicate that the total root yield of unassociated cassava is higher than that of cassava grown in association with corn. The production of marketable roots was the same for cassava grown alone or in association with corn. However, the inclusion of lima and string beans in the system reduces the production of marketable cassava roots. In general, multiple cropping systems made efficient use of photosynthetic energy. The systems that invested more radiant energy in the production of food in proportion to their total biomass, were the single-cropped cassava and the cassava-corn systems; they also produced the greatest amount of nutritional energy.

From an economic point of view, better options for the farmer trying to increase his net income are the cassava-corn and string bean system, and the cassava-corn system. If a farmer wants to maximize his net family income, he can select between the cassava-corn and string bean system, and the cassava-corn, lima and string bean system. In addition, tests were made to evaluate the growth, production and quality of the cassava, corn and climbing string bean under different land arrangement systems, focusing on soil preparation, pruning and weed control.

It was found that excessive pruning diminished total root production as well as that of marketable roots. The simultaneous planting of the corn-cassava association reduced total root production; this reduction in yield, due to the association, remained constant with the three pruning intensities. Mixed cropping and pruning also decreased the percentage of starch in marketable roots. Severe pruning of the cassava increased the total production of string bean pods, though the number of top quality pods was reduced. Flat field planting favored cassava and string bean yields, but did not affect the yield of corn. Finally, net incomes based on farm or wholesale prices tended to favor the cassava-string bean system over those which also include corn.

Cassava system. Fertilizer break-down was studied with 'Valencia' cassava, in order to evaluate the agronomic and economic advantages of a fertilizer program for this crop, to supply necessary nutrients in adequate quantities during each stage of growth.

Results indicate that fertilizers increase the growth of the plants; fresh root weight, per plant, was heavier in fertilized plots, and fertilizer break-down made no difference in plant response to fertilization. Furthermore, it was found that fertilizer application for the cassava single-cropping system should be at a level of 65, 100 and 30 kg/ha, respectively, of NPK, under the soil conditions where the experiment was carried out.

Mung bean. The mung bean, *Vigna radiata*, is practically unknown to Central American housewives, in spite of the fact that bean sprouts are sold in supermarkets in all the capitals of the countries. Some stores also sell the dry grain.

As the mung bean could complement the use of common beans as a source of vegetable protein,

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Cassava is the food base for approximately 300 million people living in the tropical regions of the world. Planted alone or in association with other crops, it produces high quantities of food energy.

high-yield varieties are being sought, especially for lowland and marginal areas unsuited to common bean production.

In collaboration with a number of national institutions, the Center has been testing 10 mung bean varieties obtained from the Asian Vegetable Research and Development Center (AVRDC) in Taiwan. The samples were first multiplied at CATIE, in 1978, and then distributed to researchers in Honduras and Costa Rica. Mung beans have been planted in Costa Rica on CATIE property and at the Enrique Jiménez Núñez Experiment Station, 50 meters above sea level. In Honduras, they are being grown at the Pan-American School of Agriculture (EAP), El Zamorano.

On an average, the highest yielding varieties produced over 1,300 kg/ha, with top yields from cultivar CES-55, grouped among the precocious varieties and which attains good height and produces large grain. The 'EG MG-1743' variety was found to be vigorous in growth, has good grain weight, and adapts well to the conditions at the Enrique Jiménez Núñez Experiment Station. This same variety produced the highest yield at El Zamorano, 700 meters above sea level.

A combined analysis of yields obtained at CATIE and El Zamorano indicates that, on the average, yields for the varieties studied and production levels between one place and the other, did not differ significantly.

In order to evaluate the yield capacity of 14 mung bean lines, a test was carried out on seed obtained from several sources, after first being multiplied at CATIE. In this case, the yield of dry grain varied from 644 to 1099 kg/ha.

The highest producing varieties were found to be 'EAP' and 'CES-IF-5'. The 'EAP' variety had the highest yield, bore late fruit, attained good height and was tolerant to *Oidium* spp. The earliest variety of the group was H-70-17, a much smaller plant which is susceptible to *Oidium*.

Work with the mung bean sought information on planting densities which could be used as a basis for subsequent research, and which could be recommended to farmers. The yellow variety 'CES-IK-eTY' was used in this case, with 20 kg/ha of 10-30-10 fertilizer. The highest yield obtained was 3,600 kg/ha with a 30 cm distance between rows, and 40 plants per meter of row.

RESEARCH HIGHLIGHTS

Results suggest that the highest plant population densities tested are most suited for conditions similar to those in Turrialba, during the rainy season, that is, approximately 90 kg of seed per hectare.

Common beans. A study was made of the effect of several densities of caged Chrysomelidae *Ceratoma ruficornis rogersi* and *Diabrotica balteata* on the yield of common beans, with a level of more than 2 per plant established for *Diabrotica* and 2 per plant for *Ceratoma*, in the first experiment. In the second experiment, yields were lower with similar though not as well defined levels. Only *Ceratoma ruficornis rogersi* was tested in this case.

Even when there was a clear relationship between the number of insects and yield, variability was high due to the presence of a rarely seen corrugated mosaic virus which is transmitted by the Chrysomelidae. In some plants, the virus reduced yields to zero. However, it was possible to determine a yield curve in response to the density of the Chrysomelidae for both exposure periods, establishing more serious damage from the early attacks. Yields were also considerably reduced with a population density of only one *Ceratoma* per plant, probably due to the effect of the virus.

Cowpea. An experiment was carried out between December 1978 and March 1979 to determine the distribution of the cowpea mosaic virus (CPMV) in mono and multiple cropping systems with corn, as to date only unreliable data are available. Nine plots of cowpea variety 'V-5 Moh' were planted as a monoculture and 9 in association with 'Tuxpeño' corn. Management procedures used were the same for all the plots, except during the second fertilizer application when the associated crops received 60 kg/ha more of the 18-10-6-5 formula.

The incidence of cowpea mosaic virus (CPMV) and bean yellow stipple virus (BYSV) was measured 30 days after planting. Plants were individually examined and data taken every two days, indicating the date and type of symptoms. The incidence of CPMV increased rapidly, reaching 100 percent approximately 68 days after planting, in both the single and associated crop systems.

The number of plants affected per unit time was found to be higher in the single crop than in the associated crop system. This situation showed up



Ceratoma ruficornis rogersi is the most efficient vector of the cowpea mosaic virus (CPMV), a disease which significantly affects the yields of both single cropped cowpea and cowpea grown in association with corn.

repeatedly, although the opposite has also shown to be true.

Of all the plants observed with BYSV symptoms, only 60 percent reacted positively to antiserum prepared for this virus. This may be due to the disintegration of the virus's outer protein layer in the older leaves, a low concentration of the virus in the leaves, or the presence of some yet unidentified variety of BYSV. In any case, the incidence of BYSV at the end of the experiment, was estimated to be between 3 and 5 percent: between 4 and 6 percent in the single crop system, and between 1.5 and 3 percent with the two crops grown in association.

An analysis of the relationship between apparent plant age at infection, the weight and number of pods, and the weight of the dry seed, established that the total weight of the pods and the number of green pods tends to increase with greater time lapses between planting and the appearance of the first symptoms. For other viruses, particularly those affecting the common bean, it was noted that the infection affects the number of green pods on the plant.

No relationship was observed between grain weight and the age at which symptoms appeared. Nevertheless, in previous research, and also with artificial inoculation, a relationship was established between the age of infection and crop yield.

Single crop yield was 0.89 tons per hectare, while cowpea yield, when grown in association with corn, was only 0.17 tons; planting density of the cowpea was approximately 60 percent less, however, in the latter experiment.

In order to identify a relationship between the number of diseased plants serving as a substratum, and their efficiency as insect vectors, *C. ruficornis* and *D. balteata* individuals were collected on the plants under study; these were later tested in healthy cowpea plants.

The number of effective transmissions in the greenhouse increased in direct proportion to the number of plants infested in the field. Fifty-five days after planting, when over 80 percent of the field plants were already infected, transmission efficiency dropped, principally due to the advanced age of most of the leaves exposed. It is known that the Chrysomelidae prefer young leaves. Transmission efficiency again increased when new cowpea shoots appeared, as often occurs with this crop.

As verified in other experiments, *D. balteata* proved to be inefficient as a vector in this experiment. The artificial transmission of BYSV also did not occur. *C. ruficornis* was found to be the most efficient vector of CPMV, and its efficiency increases as the age of the host plant increases. The efficiency of *D. balteata* decreased as the efficiency of *C. ruficornis* increased.

The effect of area location of the experiments, within the experiment station, is an important factor with

regard to the levels of disease transmitted by insects, and must be taken into account so that results are not altered unknowingly by this variable.

The cowpea tends to resprout in the field if it is not buried after harvest. In spite of weed growth, voluntary cowpea plants always survive; these are probably good inoculation sources for experimentation on other aspects of this plant.

The study of the effect of a constant inoculation source for monoculture cowpeas, or when grown in association with corn or among old corn stalks, demonstrated that when the inoculation source is nearby, the percentage of plants affected by virus is greater during the first days of the epidemic, although no major differences were observed during the final period. This tendency was constant for the three cultivation systems tested. It was also possible to confirm that mixed cropping with corn inhibits infection, found to be more prevalent in the single cropping system.

It was felt that one of the principal problems affecting successful cowpea production is virus disease. In order to identify early varieties suitable for future experiments with these diseases, a number of cowpea varieties from the collection of the International Institute of Tropical Agriculture, IITA, have been tested. Varieties from the International Diseased Cowpea Nursery (IDCN) were also tested to determine their reaction to the viruses found in Turrialba.

A definite relationship was established between the percentage of diseased plants and vector populations, though no definite relationship was found between dry grain yield and the percentage of plants affected by CPMV. Because of the size of the plots, the effect of competition was sometimes greater than the effect of the virus.

RESEARCH HIGHLIGHTS

Evaluation of ñame Varieties

The ñame, *Dioscorea* spp., is a crop typical to various tropical regions. It provides a cheap source of nourishment in many parts of Africa and Asia as well as in the Caribbean. However, it is relatively unknown on the Central American Isthmus, except in some regions along the Atlantic coast.

CATIE has made considerable progress in identifying genetic material of this crop: high yield, of acceptable quality for the region, and resistant to pests and diseases. Research is also being done on identifying material with morphological characteristics suited to multi-cropping associations.

A first test in 1979 evaluated 11 ñame varieties in CATIE's Genetic Resource Unit's germplasm collection. Of these, only three produced close to or over 5 kg/plant, that is, a yield of approximately 33 MT/ha.

Research Support

As previously indicated, research at CATIE is in support of scientific endeavours in the countries. It is usually applied research, frequently with the aim of clarifying certain aspects of experimental methodologies or techniques.

As a part of this activity, specific work may be required by some research project to improve or verify the value of a method or a management procedure.

The CATIE Soil Laboratory ran several chemical and physical analyses of soil samples, and chemical analyses of plant tissues for a number of purposes. One of these was to evaluate soil fertility in fields to be used by researchers, in order to identify and rectify any possible adverse conditions prior to beginning experimentation. Another was to find explanations for the behavior of plants under different soil conditions or field treatments, at least partially, based on soil analyses. Still another was to characterize soil profiles of experimental plots. Foliage analyses were effected primarily as a part of the research endeavors into cropping systems used by small-scale farmers.

Ten greenhouse tests were conducted with soil from seven different regions of Costa Rica, in order to obtain further information on the soil fertility of different areas of the country, as well as to add to the information needed for studies to correlate soil analyses and plant yields. Similarly, 242 soil samples were taken from the experimental fields at La Montaña, where different research has been done on cropping systems, to evaluate their soil fertility.

Exploratory work was done to determine the chemical composition of both broad-leaf and grass-like weeds, with samples from the experimental area at CATIE where work on weed management is underway. Identified weeds were classed as either broad-leaf or grasses: *Bidens pilosa* L., *Richardia scabra* L., *Emilia sonchifolia* L. and *Connelina difusa* Burn, among the broad-leaves; *Paspalum fasciculatum*, *Cynodon nlemfuensis* and *Digitaria sanguinalis* L., among the grasses, amongst others.

In general, broad-leaf weeds extract more nitrogen, phosphorus, potassium, calcium and aluminum per unit of biomass, while grasses extract greater quantities of magnesium and sulphur. The average dry weight of grass biomass harvested was 556 kg/ha, while that for broad-leaf weeds was 1418 kg/ha.

It was found, however, that the elements most used by the weeds under the conditions of the previously mentioned experiment, were potassium, nitrogen and calcium; other elements were extracted at much lower rates.

An analysis of the effect of two insecticides applied to corn at time of planting, shows that corn yield may be directly affected by 5 percent granulated Carbofuran due to the effect of the insecticide on plant growth. In addition, germination was found to be poor and plants were deformed when a 0.2 percent solution of Chlorpyrifos in water was applied to the corn seed, at planting.

In a preliminary study of the effects of *Diabrotica* larvae in corn, a method was evolved for quantifying insect populations in the field, since other, more commonly known methods were felt to be too time consuming and good mainly for clay soils.

Earlier studies on the relative effectiveness of the transmission of VMFC by Chrysomelidae species ran into difficulties due to wide variation in the

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The incidence in food crops, of weeds like "Tabaquillo" *Richardia scabra* and parasites like *Diabrotica balteata* is being studied as part of the support efforts done at CATIE.

populations of each species. Thus, insect populations of these species and of other plant pests have been reared in the laboratories to study ways of overcoming this problem. It is hoped that more information on the life cycle, taxonomy, larvae identification as well as susceptibility to insecticides will be successfully obtained. For instance, specimens of the *Diabrotica balteata* and *D. adelpha* larvae were collected, and it has been possible to raise them successfully through an entire life cycle.

Part of CATIE's pest collection is being reorganized on the basis of a taxonomic study of the Chrysomelidae. Some of the previous identifications may be erroneous, due to the tendency of this group to adopt different forms and coloring within the same species. Efforts are being made to verify results and to better identify these forms, in order to ensure the collection's use as a reliable source of reference.

Research in the Countries

Costa Rica

Corn production is one of the principal agricultural activities of low income farmers in the Pococí County, Atlantic region, Costa Rica, they usually plant the crop in January-February and in July-August. Most of the farmers use the spike or pointed stick method for planting, and "criollo" varieties, but control weeds with herbicides and use fertilizers. In general, yield is low, which suggests that other technological alternatives must be developed. CATIE has started a cooperative project with the Ministry of Agriculture and Livestock in an effort to satisfy this need.

In 1979, specific efforts were directed towards the evaluation, at the small-scale farmer level, of the most promising technological components for upgrading the yield of crops being studied within the Annual Crops Program.

In this respect, weeds and pests are important limitations to improved productivity, as is the incidence of some diseases associated with high rainfall and temperatures. It has been found that soil preparation and weed control preceding planting interact with the incidence of disease and the response of crops to fertilizer.

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In general, the farmers in this region do not own machinery for preparing the land, although some hire such services. Soil preparation, however, may be unnecessary, excessive or even counter-productive. Research has been done on soil and weed management aspects to more thoroughly understand this problem.

Information was gathered for recommending fertilizer levels for corn-corn successions; in addition, some corn varieties of the area were evaluated. The importance of corn, bean, cassava and rice pests was also assessed, as was the effect of soil and foliage pest control for certain cropping systems.

Fertilization of corn, as practiced by the farmers of this region, is about 40 kg/ha of nitrogen, 20 of phosphorus and 10 of potassium, to obtain an average yield of 2 MT/ha in the first cycle, and 1.4 MT/ha in the second. These yields can be improved with certain changes in crop management practices. An evaluation of the effect of nitrogen and phosphorus was considered necessary, because of the lack of information on this subject. These experiments were carried out on two farms in the Pococí County, and on a farm in Guácimo County, Guápiles, Limón Province.

Corn yield for the first harvest of the two experiments responded significantly to nitrogen. In a third test, no positive response to nitrogen was noted. This could be attributed to other limiting factors which had not been corrected, such as extreme soil acidity. Only in one case, at La Esperanza, was any response to phosphorus noted.

The average yield for the second crop was higher than the first, although yield analysis did not reveal any significant effect to treatments, nor were residues detected from fertilizers used for the first crop. The average yield of the experiment with nitrogen was relatively high (4555 kg/ha). Nitrogen levels of over 50 kg/ha for the second crop did not significantly improve yields, regardless of the level applied to the first crop.

Average corn yields with or without phosphorus, suggest that it is unnecessary to add this element to these soils for the second crop, as the soil's supply in the test areas appears to be adequate.



Corn is still a major basic food crop of small-scale farmers. Research into corn production systems includes studies on fertilization, weed and pest incidence, the evaluation of varieties and variations in management technologies.

Another experiment in Costa Rica was to evaluate 5 corn varieties under two types of management technology, on three different farms in Pococí County, Limón Province, at an altitude of approximately 90 m above sea level. Two of these farms are in Cariari and the third at La Esperanza, 10 km farther north. The varieties studied were 'Tico-1', 'La Máquina 7422', 'Tlatizapan 7322', 'Tuxpeño' and 'Maicenón'.

Variations in management technology refer to differences in soil preparation, planting distances, fertilization systems, and the control of weeds and diseases. One of the technology levels tested is that normally used by the farmers, except with regard to fertilizers. Both tests used minimum land preparation or tilling.

All varieties gave equally poor yields and no differences were noted as a result of the different types of management technology used. This may be attributed to plant loss that occurred during the growth cycle, and the high incidence of rotten ears, most notable in the 'Tico-1' and 'Máquina 7422' varieties.

The combined effect of several of these factors reduced possible yields of tested varieties by approximately 50 percent. Thus, it is necessary to determine the reasons for plant loss and ways to reduce ear rot. Resistance to soil pests and ear rot are essential factors sought when testing varieties.

The effect of soil management techniques on yield, and other factors, were also studied, including the effect of the following weed control methods on corn diseases: 1) ground-level weed cutting plus Glifosato; 2) high cutting plus Glifosato; 3) ground-level cutting plus a mixture of MSMA, Paraquat and Atrazina; 4) ground-level cutting plus MSMA, and weed-specific Paraquat; 5) ploughing and harrowing plus Esteron and weed-specific Paraquat; 6) ground-level cutting with manual weeding. Other experiments compared soil and fertilizer treatments in plots with corn grown in association with cassava and beans.

Results previously obtained indicate that under Atlantic Zone conditions in Costa Rica, more efficient use of inorganic fertilizers is possible when land is not ploughed before planting. Yields of unfertilized plots were two or three times higher on no tilled land than on ploughed land. No tilled land responded more to low levels of fertilizers than fertilized land; with higher amounts, results were similar.

In 1979, an experiment studying the response of a corn-cassava association to four fertilizer levels and four plant management systems on the land prior to planting, was carried out. Corn yield indicated response to fertilizer level but not to the different forms of management. The lowest yield obtained was with mechanical preparation and no fertilizers. Thus, although response to fertilizers was evident, higher amounts must be added to mechanically prepared soils in order to obtain results similar to those obtained without any soil preparation.

General entomological information was gathered on the cropping systems to be recommended for use on the Atlantic zone of Costa Rica, in order to better understand the interaction of pests under the four different systems normally used in the area. Production losses caused by pests were evaluated, and priorities established for future research on specific pests which limit production.

Highest production yields were observed in corn grown alone, with pest control. In all plots, *Diplodia* caused considerable ear rot. Rice plant populations in test plots without pest control were reduced by an average 28 percent. In cassava, pest control assured higher yields.

A study on pests affecting cassava in the Atlantic zone was continued in order to determine the season in which they appear. Most frequently found pests were: *Thrypidae*, *Lonchaeidae*, *Anastrepha manihoti*, *Erinnys ello* and *Aleyrodidae*.

Guatemala

CATIE work in Guatemala is centered around the municipalities of Santiago Sacatepequez, Chimaltenango, Zaragoza, Patzún, Tecpán and San José Poaquil, in the Departments of Chimaltenango and Sacatepequez.

The principal agricultural activity in this region is corn grown in association with climbing beans in the Department of Chimaltenango, and with lima beans and pilay beans, *P. coccineus*, all subsistence crops, in areas above 2200 m above sea level.

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Variations of this association based on subsistence corn, known as milpa, involve four crops: bush beans, potatoes, peas and guicoy, or tender squash. The farmers thus produce some commercial products in areas dedicated to subsistence crop cultivation.

Since the program focuses on low-income farmers, emphasis has been given to improving the possibilities of farmers with land for producing corn and beans for subsistence, to grow another crop for marketing.

Some work was also done on single-cropped vegetables, for incorporating them into multicropping systems.

In 1979, there were two main aspects of the research activities in Guatemala: work with systems including corn and beans for consumption, and work on the individual crops which are components of the different systems.

Fourteen experiments were carried out on the different systems in collaboration with ICTA's Technology Testing Program for Region V, with headquarters in Chimaltenango. These experiments were of two types. In the first, the region's traditional arrangement of corn was maintained, varying fertilization and the type of associated crops (potatoes, guicoy and bush beans). The objective was to identify those crops which could be associated with corn for consumption, without reducing corn yield.

In the other type of experiment, the crops to be grown with the corn were selected by the cooperating farmers, and changes in planting arrangement and variety of corn were introduced. The corn program made available a new variety, 'Chanin-3', whose growth cycle and size are shorter than of other varieties in the region. These characteristics should reduce competition of corn with the other associated crops. The main objective was to determine whether modifications in spacial arrangement of the traditional corn field (milpa) could increase production in the associated crops, without reducing corn production.

In the experiments on four systems commonly used, production increases were noted in four different areas, for corn grown in association with potatoes, after fertilization by the farmers. In all cases, guicoy

caused considerable reduction in corn production, even when both were heavily fertilized. Chimaltenango was the only place where this was not observed; here, two crops were planted in the same row. In general, it was found that the effect of potatoes cannot be compensated for by heavy fertilization of corn.

'Chanin' corn yields were significantly lower than that of criollo corn, but conditions were better for growing broccoli and cauliflower. In the case of potatoes and carrots, the competition from criollo corn was less critical.

Whenever climbing beans were not included into a system, corn production was found to increase significantly, indicating the advisability of replacing climbing beans with higher yielding bush beans, which are more easily grown in association with corn. Economic analysis indicates the superiority of 1.8 m row arrangements, despite the fact that it appears more economical for farmers in the highlands to produce only vegetables, and to buy their corn for consumption. It was observed that the associations allowed the farmers to take a loss on 'Chanin' corn, and still make some money, even when they had to buy corn for consumption.

In the fertilizer experiments with several corn-based systems, great variations in yield were noted from one farm to another. Guicoy almost always adversely affected the yield of other crops, though. The only exception was in the Chimaltenango Valley, where guicoy and corn were sown on the same day.

The ground bean never significantly affected corn production. Potatoes, however, significantly reduced corn production in one place, and significantly increased it in two others. In these two cases, potato production was under 10,000 kg/ha. Where potatoes negatively affected corn production, the potato yield was very good, with over 20,000 kg/ha. On the three sites where climbing beans were used, it was noted that their association with potatoes seems to slightly though not significantly, increase bean production. Higher amounts of fertilizer applied to the corn reduced the yield of the climbing bean.

Studies on cauliflower planted alone, indicate significantly higher yields when planting densities were increased.

'Green Boy', 'Globe 62M', 'Superette', and 'King Cole' proved to be the most successful of the hybrid varieties of cabbage being tested, both with regard to yield as well as endurance in the field, until harvest time. Yield responded favorably to higher planting densities but with currently used levels of fertilization, changes are not recommended. According to the economic analysis, benefits compensate for the high seed cost.

The beet varieties 'Crosby Egyptium' and 'Asgro Wonder' proved to be slightly better than 'Early Wonder', and statistically superior to 'Detroit Douls Red', which developed germination problems under high-land conditions.

Work to date on lentils indicates that good nodulation occurs without artificial inoculation. It appears that the *Rhizobium* content in the soil is adequate for lentils, because of the widespread cultivation of lima beans, peas and *Lathyrus nigrovalis* in the region.

Nicaragua

In line with the Project's research guidelines for this country, it was decided to focus attention on beans, as they are being cultivated, as a single crop, by 73.8 percent of Nicaraguan farmers on about 56.5 percent of the nation's cultivated land. Furthermore, an additional 6.2 percent of the farmers plant beans in association with corn and sorghum, on 7.4 and 2.5 percent of the arable land, respectively.

The alternative of planting sorghum in association with beans in alternate belts, based on the technology used by farmers growing beans as a monoculture was introduced, with the following modifications: the incorporation of sorghum, higher planting density for beans, the use of complete formula fertilizers on the entire system; two applications of urea to the sorghum; and increased use of pesticides for controlling insects. The procedure considered most appropriate for purposes of validation was to test this alternative system on semi-commercial plots, with farmers located in different areas of the subregion.

Results obtained indicate that the sorghum-bean association increased the use of labor in comparison to monoculture beans, by 83 percent. This is clearly an advantage, as it improves rural employment and productivity, usually under-utilized. The greatest increase in labor was during harvest and for crop handling, due to the increase in number of working days associated with this type of work, as a consequence of the added component: sorghum.

In general, it is evident that the associated sorghum-bean alternative both increases and makes better use of labor, over time, by creating a new employment season.

Different technologies were tested for growing single-cropped beans and for beans in association with sorghum in alternate bands, partly because of the need for additional labor but also because of greater use of inputs for the sorghum-bean combination, including improved sorghum seed, fertilizers and pesticides.

Production and yield results in sown and harvested areas indicate that yields were higher in the sorghum-bean alternative, planted in alternate bands. Furthermore, the sorghum-bean alternative included 25 per-



The principal agricultural activity in Chimaltenango and Sacatepequez, Guatemala, is the production of corn, grown in association with beans and other subsistence crops.

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cent of the same amount of land used for bean monoculture for sorghum, thus ensuring higher productivity with high average yields for both crops.

Increases in total cost between the activities for the alternative and those of the farmers' traditional system, were primarily due to the use and application of inputs. Both situations registered similar negative net incomes for the amount of area planted, although family income from the sorghum-bean association was higher due to better use being made of the labor input. Single-cropped beans do not produce significant income differences for the areas planted, while the sorghum-bean alternative does.

In general, results recommend changing the single-cropped bean for a sorghum-bean association, as sorghum is an additional component easily handled by farmers, the association promotes a better use of labor, bean yields improve and a new crop, sorghum, is produced. Thus, better use is made of land resources and two products and one subproduct are obtained. Production is consequently diversified and the risk of total loss is reduced.

El Salvador

The Annual Crops Program in El Salvador expanded activities by starting up a research project on cropping systems in semi-arid zones, and an integrated project for small farms.

In one case, the corn-sorghum alternative was tested and compared with the system currently used by farmers. Recommended technology, includes arranging crop residue in level curves instead of burning it, and controlling soil insects with granulated "Volatón", resulted in a 366 kg/ha increase in corn and a 243 kg/ha increase in sorghum, as compared to yields obtained by the farmers. This difference compensates for the extra fertilizer costs, provides a small margin of profit, and can therefore be recommended for use, although pertinent technology must still be adjusted to further reduce fertilizer costs and to remove or control other factors limiting sorghum production levels.

As part of the study on variations in system components, several varieties of sorghum, corn and combinations of the two were compared, as were fertilizer

dosages and times of application for the corn-sorghum system. It was found that sorghum planted with 'maicito' corn, produced significantly higher yields than expected from the yield-trend of other combinations. This illustrates a competitive characteristic of this type of corn which grows favorably with sorghum, making it a good alternative, particularly for not very favorable environments. Based on market prices, the incomes from systems using 'H-11', 'Maicito' and 'CENTA M1-B', exceeded the net income obtained with the 'Corn H-3' – Sorghum system which was used as a control.

In Jorocó, the 'Hybrid H-11' also surpassed other varieties tested. Sorghum produced higher yields when grown in association with the corn variety 'CENTA M1-B', which gave much lower yields than the other varieties tested. In this case, the greater yield of sorghum could have resulted from less competition from the corn. Sorghum yield when planted with 'H-11' was higher than anticipated in view of the negative correlation between the yield of both crops attributed to competition. This would indicate the relative superiority of the 'H-11'-criollo sorghum system over the other combinations, within the limits of this experiment.

In Tejutla, another experiment compared 5 varieties of sorghum planted in association with 'H-3' corn. The 'Criollo de Leche' sorghum variety surpassed other varieties tested, with the highest yield obtained when associated with 'M1-B' corn, confirming the advantage of this particular association between 'Criollo de Leche' sorghum and 'M1-B' corn, attributable to certain specific characteristics of both crops that diminish the rate of competition between the corn and sorghum.

In general, the 'M1-B' variety gave the highest yield of all corn varieties tested, while sorghum associated with the 'H-3' variety produced the lowest yields. These effects can also be attributed to the specific characteristics of the varieties, to be considered when designing associated or multiple cropping systems. The highest corn and sorghum yields were obtained when criollo sorghum was used.

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The control of soil insects and residue management, instead of burning fields, increase the yields of corn-sorghum systems.

Honduras

In this country, CATIE has been working closely with the Agricultural Research Program of the Natural Resources Secretariat, on a research project on farming systems for small-scale farmers, in the Comayagua Valley and in the La Esperanza region. A resident staff member has also been working on implementing the research component of the Integral Development Plan for the Western Region of the country.

This region encompasses Copán, Ocotepeque and Lempira Departments, bordering on El Salvador and Guatemala. It is one of the poorest regions in the country, characterized by little or no state services, low agricultural production levels, poor soil, unfavorable climatic conditions and other factors which have a negative effect on the development potential of the zone. A large part of this area lies between 200 and 400 m above sea level. The most populated center of the region is Santa Rosa de Copán, but the area with

most inhabitants is in the La Entrada zone, point of convergence of the migratory flow from the frontier or border areas towards San Pedro Sula.

In 1979, considerable attention was given to testing sorghum, corn and bean varieties as these are the crops most frequently grown by small-scale farmers. Examples of some of the principal results to date, are: in La Entrada (Copán) at 420 m above sea level, and in San Marcos (Ocotepeque) at 880 m above sea level, 14 experimental and commercial varieties of corn were tested and evaluated. At La Entrada, the variety 'Teoltizapan 7443' gave the highest yield among the later-bearing plants, but demonstrated a high incidence of ear rot, judged to be related to deficient coverage. The yields of the other varieties were equivalent to or less than those obtained with local varieties. In San Marcos, the local variety was found to produce the lowest yield, was among the tallest growth and latest bearing plants, had the highest ears and was most subject to flattening. The 'Tuxpeño C-17' variety produced the highest yield, was among the most early, low-growing plants, with lower ears, and was little affected by flattening.

At the Copán ruins (540 m above sea level), 14 bean varieties were evaluated during the May-August growth cycle. Beans are seldom grown during this season because of excessive humidity which fosters disease. However, no significant statistical differences were detected in the number of plants harvested, the number of pods per plant or the commercial yield. The 'Porrillo' variety produced 29 percent more than the 'Criolla' variety, while the commercial 'Zamorano' variety produced only 32 percent of the 'Criolla' yield.

Also at Copán ruins, 10 varieties of early and intermediate corn were evaluated when harvested in May and September, in order to select material that adapts well to low rainfall conditions. Noted for their yield were the 'ICTA B-5', 'Synthetic Florida', 'La Lujosa 7701' and 'Composit Dominican Republic' varieties. The lowest yield was produced by the 'Maicito' variety, while 'La Lujosa 7701' was found to be the earliest.

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At Jigua (360 m above sea level) 6 experimental varieties of corn were evaluated, including early, intermediate and late-developing types. Yields were generally low, mainly because of flooding, but it was possible to observe the superiority of 'Hondureño Planta Baja', 'ICTA B-5' and 'La Lujosa 7701'.

In Chalmecca, Copán (450 m above sea level) 7 varieties of red beans were evaluated, between October 1979 and January 1980. The varieties 'Acacias 25', 'Acacias 4' and 'Desarrural' produced the highest yields, exceeding even the 'Zamorano' variety, though not surpassing the 'Criolla' variety, statistically.

In Vivistorio, Copán, 10 lines of climbing bean, relay planted between corn rows were also evaluated. Some proved to be excellent, with production up to 1350 kg/ha despite poor germination in some cases. No incidence of "mancha angular" (angular stain) or antracnosis was observed, both of which are common to the bush bean in that region.

In order to identify and evaluate the relative importance of some of the technological components on corn yield, various treatments in two locations in the Department of Copán were compared. The study revolved around a supposedly "better" or more recommendable basic treatment technology. Variables were obtained by separately modifying planting density, varieties, fertilization and the control of foliage insects.

The difference in yield between the two locations was marked: La Entrada yielded more than twice what was obtained in Chalmecca. This indicates, to some extent, the effect of environment and general management procedures on the crops, regardless of other factors under study. In both locations, fertilization proved to be the most important factor. Yields were reduced by 39 percent in Chalmecca and by 30 percent in La Entrada, when no fertilizers were used. The most important difference among the factors studied was the effect of the application of insecticide, which could be attributed to the greater insect problem in Chalmecca. A comparison was made between three types of technology and the technology normally used by the farmers, represented mainly by different cost levels. Averages taken in 15 locations indicate the net superiority in terms of yield, of intermediary and high cost technologies over minimum technology and the type of technology used by the farmer. Economic analysis indicated that the intermediary technology is superior.



A mixed perennial plant system of plantains, 'laurel' and cacao contributes to improve land use and higher incomes for the farmers.

PERENNIAL PLANTS: A RESOURCE FOR CONTINUOUS, ECONOMIC PRODUCTION

The aim at CATIE is to have an in-depth knowledge, to study and improve the perennial crops used by the low-income farmer in Central America, and to contribute to increased productivity and to stabilize production to ensure an ongoing and relatively inexpensive process in order to upgrade the socioeconomic conditions of the farmers. Thus, research on perennial crops is oriented towards establishing useful agricultural technologies to help resolve low yield harvest problems.

Last year, research at the regional level was not undertaken. However, collaboration and advisory services were provided to national research and development programs, especially in terms of cacao and coffee research for the Central American region and Panama.

Most of the program's efforts concentrated on cacao projects in Turrialba, and on a coffee project in close cooperation with the Regional Cooperative Program for the Protection and Modernization of Coffee Cultivation (PROMECAFE) in Mexico, Central America and Panama.

The program has been working on establishing cacao clone gardens in Costa Rica, Nicaragua and Honduras, as well as starting up similar gardens in Panama.

Last year a large amount of certified cacao seed was produced and then distributed, principally throughout the Central American region. Seed from coffee and other perennials was also collected, prepared and distributed throughout the PROMECAFE region.

Mixed Perennial Systems

In 1979, coffee and cacao harvests began, providing an idea of the precocity of the 'Timor' hybrid and of selected cacao hybrids.

Data is being collected as usual for all the other crops, both annual and perennial. The development of laurel trees *Cordia alliodora* was promising, especially when grown in plots with cacao and coffee, where it appears to take advantage of the fertilizers applied to these two crops.

In the study on the effect of four intensities of plantain shade on corn, common beans, wing beans and cowpea, it was found that cowpea responded well to shade, with total annual yields of 1747 kg/ha of dry beans under one plantain shade. Under two, yield came to 847.4 kg/ha, a significant difference with the first treatment.

The response of the common bean to light was also marked. During the dry season, which is the best time for this crop, treatment under one plant shade produced 776.6 kg/ha, while production under full sun conditions was 1025 kg/ha.

Yield under two plants shade was less by 50 percent than for the first treatment, with a significant difference. The other treatments produced very low yields, especially the one under the fourth plantains of shade, demonstrating marked differences in response to the first two. The yields in August (rainy season) were very low, as was to be expected, and very different from those planted in full sunlight.

Treatments with 2, 3 and 4 plantain's shade produced low yields of beans. Differences between them were not significant, but were considered not uneconomical. The total annual harvest with one plant shade is about 50 percent of the total crop yield when planted alone. Even so, it is economical when the additional income from the plantains is considered: about 800 stalks a year. Other treatments produced low yields when compared to commercial crops, but with the economy of the small-scale farmer in mind, and considering that the association saves money which would otherwise be spent on weed control in the plantain plantation, it would seem a good practice to harvest once during the dry season, though not two. As is customary in that zone.

Corn cultivation proved to be extremely sensitive to the influence of shade. Some plots produced nothing at all during the rainy season (October), which accounts for the very low average in yield.

The differences are very marked if these yields are compared to those from fully exposed plots: 5926 and 1719 kg/ha with full exposure and one plantain for shade, respectively.

RESEARCH HIGHLIGHTS

The wing bean, as an annual crop, was also very sensitive to the amount of light received. The difference between cultivation with full exposure and with one plantain shade is almost 60 percent. The difference in the shade level of two plants is much greater; that is, about 30 percent of what was obtained under one plant. The other two treatments have even lower average yields, and therefore are not recommendable.

If an appropriate variety of the wing bean is cultivated as a perennial plant, the production of fresh string beans for consumption, picked before the seed is ripened, and that of the tuber-root, would amply compensate for low dry grain productivity. This species is known to have been developed and cultivated successfully in shade, in association with other crops.

“Achiote”, *Bixa orellana*, is a shrublike plant that has been cultivated throughout the Americas since pre-colombian times. Its use is extensive, for both human and animal nutrition, for the coloring and cosmetic industries, and for some medicinal uses. Market prices are quite good for achiote, and therefore it is considered a good alternative for small-scale farmers who can grow it in fences or other places where it will not compete with other crops.

Thirteen varieties from different locations were compared and studied, in order to better understand the adaptability and other desirable characteristics of this crop.

Of these, ‘Oriente-1’ responded best during 1979, with a yield of 2544 kg/ha. Next in productivity was ‘Oriente-2’.

These two varieties differ significantly from the other lines; ‘Santo Domingo’, the least adaptable line, only produced 211 kg/ha.

Testing for adaptability of the winged bean was carried out within the international cooperation system, using some of the local varieties as controls. The primary objective of the test was to adapt genetic material of this perennial plant, which has much future potential as an alternative for the gardens of poor farmers or for family vegetable plots. It is



The cultivation of beans under plantain shade produces lower yields than in commercial farms, but provides cost benefits for small-scale farmers by restraining weed growth between the plantain rows.

a climbing plant that has been used successfully in association with other crops by the poorest farmers of the South Pacific and Australia.

The ‘LBN-C1’ variety proved to be the highest producer, followed by line ‘6307-A’, which has been successfully cultivated locally for 6 years and appears to be well adapted. In third place is line ‘LBN-C3’.

These experiments for adapting lines fulfilling different needs will be continued. It is well known that some lines have excellent nutritive and culinary characteristics and can be used as vegetables, but the tuber can also be used as a food because of its high protein content.

Cacao Production Systems

Since no other institution in Central America does cacao research, it has been necessary to continue and expand the test trials on existing outstanding genetic material in order to increase levels of resistance to pests and diseases of the hybrids currently recommended to farmers.

PROGRESS REPORT 1979

All cacao research has been carried out at Turrialba and at the La Lola Experimental Farm. In Turrialba, the hybrids resulting from crossing the 'Catongo' from Brazil with native stock, were tested.

Of note among the results obtained in 1979 is the fact that the production of individual plants has increased considerably, with average tree yields significantly higher than the averages of previous years. The 'Catongo' X 'AS SB Hulera' cross produced the highest yield. In 1979, the treatment with highest yields corresponded to the 'SGU 84' X 'Catongo' cross, making it a promising hybrid.

The yield-test of clones of 'Nacional' origin was made in order to determine their resistance in the field to the attack of cacao pests and diseases, and to study the qualitative characteristics of the product obtained from the experimental plots.

The general yield level of the clones was high. 'EET 95' was the most productive clone, followed by 'CC 260' and 'CC 261', although the clone with the highest average was 'EET 400'. Despite the fact that its production performance in 1979 was poor, it heads the list because of extremely high production during its first productive years.

When the quantitative heritage of various components of cacao yield were studied, and the yield averages of the parent material were analyzed, 'SCA 6' proved to be an excellent parent, as had already been noted in earlier tests.

It is interesting to note that the cross of 'SCA 6' with 'CC 42' produced excellent results. As the latter generally performs poorly, it can be classified as having specific combining ability. This clone is reported to be resistant to *Phytophthora*, as well as having good agronomic characteristics. It needs to be tested with other parent clones in order to determine its influence in progeny, and for its use as a hybrid. Clone 'UF 29' continues to be an excellent parent, as observed earlier, and is still being recommended as a result of its many attributes.

To date, the crosses have demonstrated a certain level of resistance to "Mal de Machete", indicating that



This is the unrenowned cacao flower. Cacao is one of the perennial crops being studied for top quality genetic materials and resistance to pests and diseases.

resistant parents are stamping progeny with this character, although not in the case of crosses between two susceptibles. Clone 'CC 42' has shown itself to be most susceptible when combined with other susceptible parents, but its general performance when crossed with 'Pound 7' and 'Catongo' clones is quite good.

Experimental results at La Lola indicate that clones 'Pound 7' and 'SCA 6' are the best parents for imprinting high-yield characters in progeny, although the 'SCA 6' X 'Pound 7' cross itself is of notoriously low yield; in past years, however, its yield has increased slightly. Yield performance in this cross has usually been good in Turrialba.

The yield behavior and resistance to *Ceratocystis fimbriata*, a disease also known as "Mal de Machete", was also studied in the cacao hybrids. The 'ICS 1' X 'SCA 6' cross was the most productive, and 'UF 613' X 'SPA 9' placed first for total average yield. The best parents for resistance to disease were 'SPA 9' and 'IMC 67', making their use in the field attractive, since one of the most critical problems faced by small-scale farmers is the high percentage of tree deaths caused by this disease.

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The behavior of 31 new and 5 high-yield clones was also evaluated. Many of these clones, including 'CC 9' and 'CC 99' have high yields of over 2700 kg/ha of dry cacao. Another group of clones, including 'CC.137' and 'EET 64', rated 'very high', with 'EET 48' and 'EET 62', both originally from Ecuador and of 'Nacional' origin, product more than 4000 kg/ha.

Work in horticultural and plant physiology aspects included studying the effect of thinning on four 10 year-old hybrids and of several different fertilizer treatments. Regarding fertilizer application, no response to higher quantities added to the soil was noted, although it is assumed that these results are still somewhat premature.

Short inter-plant distances are being recommended, to be followed by thinning as needed, after a few years. Results to date demonstrate that even after 11 years of age, the plants are still not competing too strongly; thus, high density populations are possible even after over 10 years of plant life.

Plots that produced the least shoots were those that were thinned the most. These same plots also demonstrated the largest increases in trunk size, the greatest average number of healthy pods per tree and the least number of pods affected by black pod disease, *Phytophthora palmivora*.

The study of early selection of hybrid cacao plants indicated that those with thick stalks produced only slightly more than the thin selections, but these produced much more than unselected plants. The result of this experiment indicate the need for selecting and separating the plants according to their vigor within each cross, in order to provide them with a better competitive environment, so they can develop to their maximum competitive ability.

Resistance to the "Mal de Machete" was studied in the fight against cacao diseases. Among the most important results was the fact that the artificial inoculation procedure commonly used to detect resistance to the disease does not always correlate with field data. The response of some clones in the field is very good; that is, they naturally resist or escape from the disease, while in the laboratory they succumb to the artificial inoculations. Exactly the opposite occurs with other clones.

On the other hand, the inoculation of dry cacao husk matter into the cultivation medium altered responses



In 1979, more than two million improved cacao seeds were distributed to 12 countries.

in the clone resistance tests. Population behavior was more or less similar, however, although at different levels; that is, some clones were found to be resistant while others were susceptible.

It appears that perhaps both methods test some phase of, though not the complete, resistance or tolerance process of the plant, since data from the two tests did

not correlate well with field data on deaths by natural infection.

It can be concluded from genetic studies that more than one pair of genes intervene in the inheritance of disease resistance from clone parents. This complicates the genetic system somewhat, since laboratory tests frequently do not correlate with field data, as mentioned previously. The genetic system appears to be additive as well as dominant, and significantly influenced by the environment, according to the analysis of a diallel that has been in the field for four years.

Most of the clones and crosses have some dead trees after the fifth year, though most of the deaths begin in the seventh year, confirming earlier observations on this feature of tree resistance or susceptibility.

With the appearance of the Monilia disease *Monilia rozeri*, in Costa Rica, efforts have been made in the Cahuita zone of Limón Province to detect plant material resistant to the disease. No evidence of resistance nor a test good enough to satisfy expectations were found, however, after the first inoculations were made with green or ripening pods which were harvested or had dropped off the trees. Throughout, CATIE has collaborated with the Ministry of Agriculture and Livestock of Costa Rica in developing plans for eradicating the disease and later, when this proved impossible, for co-existence.

With the assistance of the American Cocoa Research Institute (ACRI), and by means of a contract signed with CABSHA S. A. of Costa Rica, clone gardens are being established for providing seed, not only in Costa Rica, but for other countries in Central America also interested in planting cacao. To date, close to 80 percent of the gardens have been established on a total of 10.5 ha. Some plants are still missing, as some of the clones do not have sufficient material for purposes of reproduction. Some of these plants have already been pollinated, but their number is still very low.

In 1979, 2,350,235 seeds from genetically improved material were distributed to 12 countries. Costa Rica, Panama, Honduras, Nicaragua and Guatemala bought most of the seed, although others also purchased smaller amounts, such as Belize, Ecuador, Singapore, Cuba, some of the West Indian islands and the United States of America.



Studies on coffee seed storage will help determine their viability and their use in germplasm conservation and distribution programs.

Coffee Production Systems

Coffee, a main source of income for many farmers in Mexico, Central America and Panama, is being seriously threatened by the berry borer and coffee rusts. A program (PROMECAFE) has been set up by IICA in collaboration with the countries of the region, CATIE and the Regional International Organization of Plant Protection and Animal Health (OIRSA), for improving coffee cultivation and controlling these diseases so as to increase crop production and thus raise the income levels of coffee farmers.

A series of activities has been programmed to achieve these objectives, with CATIE playing an important role because of its Coffee Germplasm Bank which has varieties that are highly resistant to rust as well as others with excellent productivity records. In 1978, 16 of the most promising varieties of coffee were selected from the Germplasm Bank for their resistance to coffee rust and high productivity. These 16 varieties have been sent to the countries in the PROMECAFE region, where nurseries are being

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established to provide material for experiments on their adaptability to the different conditions of each country. A model practical guide or manual was prepared for this purpose, containing information on planting and management systems to be used in all the countries.

From September to December 1979, the most promising varieties of coffee of interest to the countries were harvested, selecting the best plants according to phenotype, productivity and bean characteristics. These seeds have been distributed to the countries, upon request. To date, approximately 46 kilos of seed have been delivered, not counting an additional 50 kilos of 'Caturra' sent to Argentina. This seed will be used to establish basic lots for further seed production. 'Catuai' and 'Catimor' are among the most frequently requested varieties, both 'Caturra' hybrids. 'Catimor' shows resistance to all the types of fungi identified to date.

For some time now, CATIE has been producing hybrids, although the productivity capability, adaptability and resistance to disease of large quantities of material is as yet unknown. Four experiments have subsequently been established at the Center and one at CATIE's La Lola farm, to test the adaptability of the different varieties to the conditions of very humid tropical forests at 100 m above sea level. In 1979, seed was also collected from several plants of the 'Catimor' variety which has been sent to Brazil for rust-resistance studies.

Genetic Resources

The Genetic Resource Unit has established as its primary objective to collect, permanently maintain, and distribute germplasm of native crops principally, and of exotic crops of basic importance to CATIE's areas of action. The germplasm entries will be maintained in live collections, and as seed, and research into the most effective means for conserving and distributing seed will be conducted.

In 1979, 280 seed samples were prepared for medium and long-term storage. Two hundred of these samples were prepared for short-term storage for later

reproduction. In the storage of coffee seed, viability was best maintained in open storage at a relative humidity of 70 to 90 percent. Results were most unfavorable with 50 percent relative humidity, since losses were greater than if the seed had been stored under normal environmental conditions. Hermetic storage did not produce expected favorable results because of the complete absence of oxygen.

Methods of tetrazolium testing in coffee seeds were also improved, making it possible to determine viability within a maximum of 4 or 5 days. Germination of *Passiflora* seed was best after a week of cold stratification (+5°C); the best sub-stratum for germinating papaya seeds was found to be sand. Dioscorea seed kept well under long-term storage conditions and germination was most uniform when carried out in layers between paper towels. In cacao, wet storage was unfavorable when micro-organisms were not controlled. When the seeds were kept under aseptic conditions, seed viability was notably prolonged.

Three hundred and ten introductions were planted out in living collections, mainly of coffee *Coffea* spp., peach palm *Bactris gasipaes*, several *Araceae* and *Sapotaceae*. A guide was also prepared for the 'Cabiaria-1' miscellaneous collection.

Field trips have been taken to seek germplasm material by species and by region, and to obtain information on their cultivation and use. Thus, in Costa Rica, chile, corn, and mixtures of various beans and zapote crops were collected from indian communities in the Talamanca mountain ranges. Native cacao was also collected. In Colombia, 114 samples of pejobaye (peach palm) were collected, and in Guatemala, a miscellaneous collections of *cucurbita* spp., beans and some fruits were also made.

In order to collect, store and retrieve basic information on the germplasm collections, and to describe them systematically, a documentation system is currently being computerized, principally for data originating from the descriptions. The system's usefulness was verified with a test on the original data describing 153 cassava clones. Moreover, a descriptive list was prepared for pejobaye, and a first evaluation was initiated. The analysis of 200 clones and 153 miscellaneous entries was also completed. In addition, data on 32 clones was used in a pilot project seeking to calculate the discriminative value of a quantitative characteristic.

ANIMAL PRODUCTION ON SMALL FARMS

In Central America, a high proportion of total livestock production comes from low-income farming operations which are often quite inefficient due, in part, to the farmer's lack of access to adequate technology to ensure a more efficient use of their resources.

Since domestic animals are an important source of protein for human nutrition and animal production — dairy and beef cattle, poultry and hogs — is a component of almost all rural holdings in tropical countries, regardless of size, CATIE's Animal Production Program has sought to develop production systems adapted to small farm conditions. The strategy involves research for developing production models based on biological experimentation and the socio-economic conditions in the areas of work.

In line with this orientation, the Animal Production Program has expanded its actions to encompass the entire region; by 1979, activities were being carried out in all the countries of the Central American Isthmus. To begin with, a diagnostic study of existing agricultural conditions was conducted. To this end, two areas were selected in each country, and between 200 and 300 farms in each were first described, then the typical farming systems for the areas were identified and follow-up studies were set up.

The information obtained demonstrated the great variety existing between countries and between areas, and emphasized the importance of livestock production in all of them, particularly in Monte Verde and Nicoya in Costa Rica, Los Santos in Panama, and Nueva Concepción in Guatemala. There are only two areas, in Panama —Santiago and Chiriquí— with less than 30 percent of all farms engaged in cattle production; in Tactic, Guatemala only 11 percent of the total land area is used for pastures. This is largely due to the extremely rough terrain which limits productive land use to 50 percent of the land surface.

The Potential of Pastures as Animal Feed

Studies for improving the use and determining the productive potential of pastures have been continued because of their importance for livestock feeding in the tropics.



Animal production is a component of almost all tropical farms, regardless of their size.



Pastures are the food base for tropical livestock. The quality of the pastures depends largely on the success obtained in eliminating competition from weeds.

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Grass Forage species. The genera *Cynodon* and *Digitaria* are among those that have adapted well to the conditions of the humid tropics (Bermuda grass and Pangola grass, respectively). The 'African Star Grass', *Cynodon nlemfuensis* var. *mlenfuensis*, has proved to be one of the most successful pastures and has served as the basis for CATIE's intensive dairy cattle feed systems. Other species such as 'Bermuda Cross 1', *Cynodon dactylon* and *Digitaria decumbens* 'Transvaala' cultivar, have also shown promising results. When determining the yield of these species, marked differences were noted in their response to nitrogen. The 'Transvaala' had the lowest yield amongst the crops studies, with or without nitrogen.

The success of 'King grass', *Pennisetum purpureum* as cut fodder during periods of shortage, and the interest of farmers along the Pacific Coast of Costa Rica, has stimulated the distribution of vegetative material provided by CATIE for establishing fodder pastures, to date, on approximately 25 hectares.

Legumes Utilization. The shortages, and increased cost, of nitrogen fertilizers have been determining factors in increasing efforts to improve tropical legume management procedures. During the period covered by this report, a manner for improving the establishment of some of the promising legumes provided by the International Tropical Agriculture Center, CIAT, was studied. The rapid growth of a species will help it avoid competing with weeds; this figures as an important factor in determining the successful establishment of a pasture. Thus, the effect of various kinds of seed scarification prior to planting was taken up. After comparing three species submitted to mechanical treatment and different concentrations of sulphuric acid, it was found that it is necessary to identify the best seed scarification process for each species, prior to planting.

One of the advantages of using legumes in pastures is the greater depth of their roots which allows them to obtain nutrients from deeper soil levels, and improve the likelihood of resistance to drought. A study was carried out in Turrialba on the depth reached by the roots of different legumes, 20 weeks after planting. It was found that root depth depends greatly on the type of soil as well as other additional factors such as the presence of a water table, the availability of nutrients, and rain schedules. At 20 weeks, all species except 'Kudzu' had the same root depth.

Leucaena leucocephala is increasingly important in a number of different tropical regions. As a forage, it stands out for its high protein content and adaptability to not very acid tropical soils. The data collected on 6 of 90 lines under study, shows that some reach a height of 1.5 meters in less than 6 months, and require adequate weed and ant control during the establishment period.

Management of Mixed Pastures. Tropical grass-legume mixes should constitute a basis for livestock feed; for this reason, studies of the effect of some management factors on the productivity of mixed 'Kudzu-Ruzi' grass pastures were continued. Findings indicate that in order to maintain adequate botanical composition of a mixed pasture, adequate attention should be paid to grazing frequency as well as to the rate of defoliation. The effect of the treatments on several pasture parameters differs, and its importance depends on food production and grazing pressure capabilities. To enhance the content of a 'Kudzu' pasture, the grazing load should vary between 1.2 to 2.5 animals/ha/day, depending on the type of management system being used.

Since native or naturalized pastures are an important component of small-scale farms, a study was begun to measure the response of native pastures to different grazing pressures, duration of rest periods, and fertilization with phosphorus. No effects were registered with regard to the use of phosphorus fertilizers on the different parameters during the first nine months of the study. Pasture growth rate was slow, but it increased as the foliar area left by animals increased. Actual forage availability increased with longer rest periods, but this was of little effect at low levels of forage availability; this can be related to the appearance of short-growth varieties which adapt well to high grazing pressures, even with short rest periods. Consumption per unit of weight increased in direct relation to increases in rest period, reaching a maximum value at 51 days. Species such as those described above are preferred by the animals over *Axonopus compressus* (Imperial grass) and *Hemilepsis aturensis*. Grazing load values were slightly higher than those obtained in Turrialba on improved pastures, which is especially important, given the conditions of the pastures under study.

Food Crops as Animal Feed. Cassava, *Manihot esculenta*, is a high quality forage for animal feeds, hence the importance of studying the effect of variables such as planting density and frequency of defoliation on traditional agronomic management practices.

Among other results obtained in 1979, it was found that greater planting density increased the per hectare yields of forage and roots, although per plant yield tendencies demonstrated that high planting densities had a negative effect on the amount and quality of marketable roots.

The poorest forage yields were obtained when cassava plants were not defoliated during the growth period; this could be due to the loss of leaves throughout the entire growing season. It is to be expected that more frequent defoliation produces lower quality forage, judging from higher leaf/stalk relationships. It is estimated that a possible 1,500 to 2,100 kg of raw protein per hectare can be obtained from cassava foliage, when high planting densities are used and plants are defoliated every three months.



The residues of banana and plantain pseudo-stalks and leaves have proven to be promising alternative components of new food subsystems for ruminants.

The production of forage and grain from Adlay wheat, *Coix lacrima* Jobi, planted at different distances and with different levels of nitrogen, phosphorus and potassium, indicates that a series of problems must be resolved before Adlay can be considered a commercial crop. In the first place, it should be noted that sufficient seed with good germination is lacking, since the only suppliers have not selected their seed and have not been concerned about seed storage aspects. There is also little or no uniformity as to plant size and rate of grain maturation, factors that can be improved through selection. This crop does not respond to NPK fertilizers, and yields appear not to be affected by planting distance, and thus, in theory, it would make an excellent potential feeder. Distance between plant did have some effect on persistence rate, that is, the greater the distance between plants, the less plant loss between the first and second cuttings, as a consequence of reduced competition.

Some of the products used on small farms, like the pseudo-stalk and leaves of the banana and plantain, *Musa* spp., commonly grown on small farms throughout Costa Rica, were submitted to basic nutritional evaluation. Pseudo-stalks are commonly used as animal feed, while the leaves are usually left as mulch in the field. For purposes of the evaluation, samples of pseudo-stalks and leaves were collected from three varieties of *Musa acuminata*, one from *Musa balbisiana*, and four from hybrid varieties of these species. The potential of the pseudo-stalk is high for the development of feeding sub-systems for ruminants, judging from the content of the cell wall and its high rate of digestibility. However, the high moisture and low raw protein content can restrict its use, particularly because of the effects they exercise on consumption.

Although the protein content of leaves is comparable to that of good quality tropical forages, their use is limited because of their low digestibility. Since the leaves play an important role in crop agronomic management processes as a means for controlling weeds, they are not recommended for animal feed.

The evaluation of an *in situ* method for determining the digestibility and digestion rates of tropical forages, with an eye to their later use in studies on the effect of supplementation on the digestion of tropical forages, was carried out using dacron bag digestion technique. Worth mentioning among the

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more relevant findings is that ruminal material entering, and ground forage leaving the walls of the dacron bag, affected digestibility determination of dry matter to only 0.67 and 0.40 percentage units, respectively. No differences were detected between animals in determining the digestibility of dry matter, though differences did show up in the digestibility of the constituents of the cell wall.

When *in situ* digestibility was compared with *in vitro* digestibility, it was noted that the latter underestimated the value of dry matter digestibility regardless of the length of the incubation period.

Studies on the dynamics of fermentation of 'King grass' silage (*Pennisetum purpureum*) have been continued, since there has been little research effort on the kinetics of tropical forage fermentation. Most of the work has involved the evaluation of only the final products of the silage process. Results, corroborated by those from other research conducted previously at CATIE and by experience acquired elsewhere, lead to the belief that lactic acid should not be considered a basic quality criteria of tropical forage silage, as it is in temperate zone forages.

Studies were made of the silage of the shoots of corn, *Zea mays*, with different levels of poultry litter. Results indicate that the addition of poultry litter at the time of silage produces a lineal increase in the content of dry matter of the final product. This is due to the addition of material with a lower degree of humidity than the shoots, and has no effect on dry matter losses, which indicates that there was no problem due to poor compacting.

Upon analyzing the data of the IDRC project's statistical diagnostic study of small-scale farming milk and meat production systems using harvest waste, it was found that 33 percent of the small-scale farmers use the banana pseudo-stalk as feed for milking cows. Thus, aside from identifying the chemical and *in vitro* digestibility of different banana and plantain varieties, two experiments were conducted to measure rates of consumption. Both experiments allow free consumption of the pseudo-stalks, although the energetic composition and energy level of the supplement varied. It was found that the energy composition (relation of molasses to cassava starch) had no major effect on the parameters studied, although the energy level (level of supplement) exercised an important influence.



A day's feeding on colostrum, at 10 percent of the live weight, is enough to ensure the transmission of passive immunity to calves.

It was also observed that the energy level caused increases in the total consumption of dry matter, although the level of consumption of the pseudo-stalks decreased. Based on these results, and in view of the fact that the pseudo-stalk is roughly 80 percent water, it was concluded that although the pseudo-stalk is highly digestible, its consumption is low in the absence of a supplement. However, when a supplement with 80 percent estimated digestibility is added, this causes an improvement, albeit slight, in digestibility rates. The probable explanation is that the positive influence of the energetic supplement is not due to its digestibility (or energy contribution), but rather to its low water content. Thus, although the pseudo-stalk is of excellent quality and is over 70 percent digestible, its use is limited by its high water content. This should not prevent its rational use, as long as necessary measures are taken to avoid an imbalance between the consumption of water and of dry matter.

Milk Production Systems

In 1979, research activities on the improved rearing of dairy calves under tropical conditions were taken up again. Thus, a rearing system was set up, characterized by early grazing, limited milk intake (only 160 l/calf) and using supplements made out of tropical by-products. This sub-system has been incorporated into CATIE's milk production modules and is being used in the countries where CATIE is working. However, the length of time during which colostrum should be administered to ensure the passive transmission of immunities to the calf, had yet to be defined. To this end, research was conducted with two-week old calves, limiting their milk intake and using supplements.

It is quite evident that colostrum is essential, a fact readily accepted by scientists and farmers alike; however, present research has found that it is unnecessary to feed colostrum to calves for the traditional length of time. One day's feeding with colostrum at 10 percent of the animal's live weight seems sufficient, as long as the first ingestion of colostrum does not occur later than 6 hours after the calf's birth.

One of the problems usually encountered when beginning experiments with dairy cows is their heterogeneity due to physiological (genetics, age, state of lactation) and environmental (feeding, climate, management) factors which prevent a homogeneous distribution of animals among treatments. In order to establish mathematical relations to better evaluate homogenization, production data gathered since 1972 on three breeds (Criollo, Criollo X Jersey and Jersey X Ayrshire) were examined for studying the correlation between partial production and total production. It was found that it is possible to predict a highly accurate total production based on monthly production figures, particularly during the first half of the milking period, the fifth month being best suited for this purpose. Differences showed up between breeds in terms of the relationship between partial and total production, favoring the Criollo. This can be explained by the fact that the lactation period of the Criollo is shorter than for other groups.

Some zootechnical and economic characteristics of several breeds were measured on a commercial, irrigated farm in El Salvador. The profitability analysis for 1979 indicated that fixed costs (interests and depreciation) accounted for 48 percent, feed for 24

percent, and manpower for 18 percent of the total costs. One quarter of the gross income came from cattle sales. The price of milk and daily production per cow strongly influenced the total variation of the gross monthly income for milk sales.

The behavior of several breeds was studied on another dairy farm in El Salvador. It was found that productive performance does not vary significantly from season to season, and that the best production and reproductive performance was obtained with Holstein and Brown Swiss crosses, adopting a cross-breeding system involving three breeds, in order to maximize the advantages of heterosis. Selections may be made on the basis of the first period of lactation since the values of the milk production constancy rates are sufficiently reliable. More attention should be given to raising and managing young replacement heifers, since the age for first calving increased somewhat during the years of the study. Furthermore, previous results were confirmed concerning the superiority of rotational crosses over purebred animals.

Meat Production Systems

In a former study carried out at CATIE, functions were developed for predicting weight gain and the nutritional efficiency of rations based on poultry litter as a substitute for natural protein (meat meal), and bananas as an energy source, as partial substitute for molasses. Waste cane bagasse (source of fiber), bone meal and common salt were also used.

In a previous study, it was calculated that bananas provide 40 percent of the useable energy and that poultry litter can replace natural protein in different proportions. In addition, the effect of trace mineral supplements was also studied, as well as the effect of sex and weight of the animals at the beginning of the fattening period. Real as well as predictable values were obtained. The differences in weight gain between breeds was significant, although nutritional efficiency did not vary. The initial weight of the animals was the only variable studied that significantly affected final weight gain. Moreover, animals weighing 300 kg resulted in economic losses, regardless of the level of poultry litter used.

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The study for determining the needs of cattle in the tropics has continued, using new models. The evaluation and integration of data is underway; models for predicting the chemical composition of the animals are included. Research is also being done with simulated computer experiments, validating the results with actual production data generated in the field.

The study of the accumulation of potentially dangerous drugs in the tissues of animals fed on poultry litter concluded that even when drug concentrations are low, it is recommended that the viscera of animals fed on high levels of litter should not be used for human consumption. Meat and fats, however, can be safely consumed.

Double-purpose Production Systems

A total of 230 farms in four zones (Turrialba, San Carlos, Pérez Zeledón and Pococí—Guácimo) were surveyed in the study of small farm production systems in Costa Rica. The analysis of the information collected in the surveys indicates that small farms more commonly have mixed systems (livestock + agricultural endeavors), rather than livestock rearing as their only activity; only 26.1 percent of the farms had livestock as their only enterprise; 13.5 percent of the farms had livestock plus annual crops; 34.7 percent with livestock plus perennial crops; and 25.7 percent with all three: livestock, annual and perennial crops.

Milk production is the most important livestock activity on the small farms studied. Within this, the double-purpose system is the most widespread management system used, particularly when livestock is combined with agricultural endeavors.

Grazing is the common denominator for livestock production in the different farm systems studied. Approximately two-thirds of the farms have pasture divisions, though this does not necessarily imply pasture rotation. Pastures are not usually fertilized, though weed control and forage cutting is common. The use of agricultural by-products as animal feed is more common on farms with perennial crops; banana and plantain pseudo-stalks and sugar cane tips are those most frequently used.

According to the zootechnical indices used, the efficiency of livestock endeavors is greater on farms where livestock is the only enterprise, or on those combining livestock with perennial crops. These results indicate the use of higher levels of technology in animal production on both types of farm.

Analysis of the information obtained in the study of biological aspects of dairy production on small farms in Costa Rica, indicates that the most important livestock activity of 98 percent of these farms is milk production. Based on this information, it was considered advisable to further analyze the variables in double-purpose and specialized milk production systems. In the Central American Isthmus, double-purpose is understood to be a production system where the cow is milked once a day, and raises its calf until it is weaned. In the specialized dairy system, the cow is milked once or twice a day, and only the young female calves are raised artificially. In the double-purpose system, common practice is to leave about a quarter of its mother's milk for the calf and to leave any left-over milk. In the specialized dairy system, the calves are fed milk or serum from a bucket, or are given milk substitutes.

The breeds used in specialized systems are dairy breeds, or these crossed with Criollo or Cebú stock; in the double-purpose system, even pure Cebú cows are milked.

As is to be expected, the use of improved technologies such as improved pastures, pasture division, fertilizers, concentrates, etc., is more widespread among specialized dairy farmers.

During 1979, data for use in generating zootechnical and economic indices on CATIE's double-purpose module were still being collected. The botanical composition of the module's pastures were analyzed and it was found that the most abundant species is *Axonopus compressus*, as well as a large number of low-growing weeds. A comparative analysis was also made of the zootechnical indices generated during 1978 and 1979. Production accumulated during lactation was found to be greater in 1979, and varied less than in 1978. The lactation period was approximately 30 days shorter in 1979, and was also less variable than in 1978. Daily production during lactation was therefore higher in 1979.

Several indices were developed on reproductive performance, a factor that significantly affects the

economic situation of any livestock enterprise. In general, it may be said that reproductive performance improved in 1979, primarily with reference to the interval between conception and birth, which partially explains why lactation was shorter that year. Another factor that may have positively influenced reproduction was the inclusion of a male in the herd, thus eliminating the problem of not detecting when the cows come into heat. The average number of animals serviced satisfactorily is good; improvements noted over 1978 resulted from having previously had an animal that had reproductive problems. Conclusions drawn from these results suggest that the interval between birth and the period when the animal next comes into heat should be reduced, if low reproduction rate problems (16 month intervals between births) in double-purpose system animals are to be solved. Once the cow is in heat, she is extremely fertile, as indicated by the number of services per conception.

Small Animal Production Systems

Smaller animals are a permanent element on low-income farms. Although they are primarily used as a food source for the family, they also play a role in the farm's economy. According to statistics for the area, 98 percent of all hogs, 75 percent of the poultry population and 100 percent of the sheep and goats belong to family units. The very nature of this type of farm causes low yields and inefficient use of available food resources. The competition with humans for food and its general, overall scarcity, results in a stagnation in production in some countries, and a reduction of animal herds in others, as in the case of sheep in Guatemala. There is a great difference between the technology used for commercial poultry and hog production and that used by family farms.

Low-income farmers need technologies adapted specifically to their conditions with regard to smaller species, in order to improve the use of available resources and thus the amount of resources available for family consumption and marketing. It is worth noting that the indices for consumption of small animals in the countries of the Central American Isthmus are very low. This is one reason why research

into small animals has been and still is almost non-existent in the countries of the area.

A diagnostic study of hog production systems in the Central American area is part of the project's activities; studies into poultry production are progressing, as are those into the status and potential of the smaller ruminants.

It was found that hog production is closely tied to certain areas in the countries, as well as to the density of the human population, which determines the prevailing production systems. The annual slaughter rate is low, in fact, significantly lower than the biological potential of the species. The average weight of the animals at slaughter is very low, resulting in low carcass weights. Statistics indicate generally small populations per country, with low productive indices. Ninety-eight percent of the hog population is raised in the traditional or family system; only a very small percentage is raised intensively, a characteristic common to all the countries. There are marked differences in productivity between the two systems, caused principally by the combination of high annual rates of slaughter and carcass weights. Since pork production in the region is low, it plays only a limited role in the regional diet. Hog populations and pork production has experienced a limited expansion during the past three years. A high percentage of the hog population is owned by small-scale farmers.

The analysis of secondary information, and the investigative visits and diagnostic studies conducted in the project area, indicate a prevalence of two production systems throughout the area. In 1979, data was compiled on the characteristics of the intensive or commercial systems, as well as on the family or traditional systems, in terms of the biological and socio-economic aspects of production of the two types of system. The data clearly indicate that research for commercial production should emphasize nutritional matters, aimed at making better use of non-traditional food sources to ensure balanced rations. The project can provide some information on this subject. The family production system takes two forms: breeding and fattening; both are found in all the areas studied. Principal variations dealt with the source and type of food used. As in the commercial operations, food is the primary limiting factor, which involves the almost complete lack of protein sources as a specially critical factor.

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RENEWABLE NATURAL RESOURCES: THE URGENT NEED FOR CONSERVATION AND MANAGEMENT

The six countries of the Central American Isthmus face increasingly severe problems resulting from the improper management of renewable natural resources. Forest land production is in crisis. Natural areas for multiple resource use have been considerably reduced, while the demand for wood and services increases. For example, in the Central American area, it is estimated that natural forests are reduced annually by between 300,000 and 350,000 hectares, while reforestation only replaces a few thousand, often with inappropriate species. The enormous reduction in natural forest area, both in broad-leaf as well as coniferous forests, directly affects small-scale farmers, who are closest to the lands bordering the native forests.

In the Central American Isthmus, the bulk of available wood is used for firewood and charcoal. With increasing rural populations, forests are disappearing rapidly and the demand for fuel is becoming more difficult to meet.

Relatively little information is available on the production and consumption of firewood and charcoal because these products rarely enter normal marketing channels where they could be recorded. The increases in the prices of petroleum-based fuels limits their large-scale use by the rural population. Currently, the vast majority of low-income rural dwellers use firewood and charcoal from trees in the forest and on the farms.

Although records indicate that mixed heterogeneous forests in the humid zones are difficult to manage for continuous yield, this is not so with some secondary forests. Likewise, some plantations, especially of pine, can produce between 10 and 20 times more useable timber per hectare and per year than natural forests, as has been proven in the Turrialba region of Costa Rica.

This justified conducting intensive research on identifying the species best suited for planting and, of these, the best varieties, based on different selection procedures.



In Central America between 300 and 350 thousand hectares of natural forest are eliminated every year, while only a few thousand hectares of land are being reforested annually.

There is urgent need for identifying more species suited to different ecological conditions. It is essential that varieties of promising species be available for the use of small and medium-scale farmers, to help supply their own energy needs. At this time, request for seed of this type of species have been received from numerous zones of the region, including several situations where trees are grown in association with crops or pastures (agro-forestry systems).

Throughout the Central American Isthmus, low-yield agriculture (marginal) and livestock usually occupy recently cleared lands. Many of the forests are located on very steep inclines, with fragile, poor soils, or other significant limitations. These areas are usually destroyed as a consequence of spontaneous processes and, less often, by human settlement. These areas are critical protective watersheds for bio-physical systems on which nearby or downstream agricultural and livestock enterprises depend entirely. They also supply the water, as well as other products and services, to cities and industries. Even fishing conditions in the rivers, lakes and coasts in a given watershed area can be affected. Appropriate watershed management, then, is critical for both rural and urban populations, especially for small and medium-scale farmers.

Agro-forestry Systems

During 1979, most of the research concentrated on measuring tree component characteristics, in terms of benefit and growth, campesino attitudes and other socio-economic factors, and production aspects, including traditional systems and controlled experiments.

Information obtained from the case study initiated a year ago in La Suiza, Turrialba, Costa Rica, on the management of traditional tree-crop associations and the empirical refining processes used by the farmers, was analyzed. Nine field tests were established to assess growth, pruning, yield and timber production, as well as the interaction between forest species and agricultural crops.

Data was also collected on the association of laurel, *Cordia alliodora*, and pastures, sugar cane and coffee, with regard to optimum densities and crop as well as tree yields. The first study was complemented with a comparison of cane yield in a laurel stand, and in an

adjacent covered area. Data was obtained on increases in the annual production volumes of forest species grown in association with crops, as well as on the influence of the trees on erosion and run-off, comparing pastures and coffee plots with and without tree components.

A possible disadvantage of very tall tree species is that they can be the cause of fruit, flower and even soil damage due to the impact of drops of water falling some distance from their foliage. For this reason, intermediary strata for intercepting and breaking the speed of these drops is an important part of the system. Furthermore, when coffee plantations are intermixed with poró, *Erythrina poeppigiana*, or laurel, choice of coffee variety and pruning method for the tree species can significantly affect the magnitude of this problem. Drastic pruning of poró drastically reduces the central stratum; moreover, this is usually done at the beginning of the dry season, when root competition for water is at its highest.

People, in general, are aware of the ecological benefits of mixed crops; for example, poró provides nitrogen and organic material for the soil of a coffee plantation. However, this awareness seldom extends to the possible economic benefits of timber-yielding species. The average annual per hectare yield of laurel in association with cacao, in the coastal Atlantic zone of Costa Rica, can exceed US\$1000. Estimates for laurel grown in association with coffee, in the Turrialba area, come to about US\$654 ha/year. Currently, timber is usually cut to meet family needs; thus it is fairly common to find that only three or four mature trees are felled at a time. This practically ensures sustained yield management, and means that once the higher stratum is well established, it can be maintained continuously.

Food production from trees grown in association with agricultural crops is limited by a wide variety of social and practical considerations. Field workers can be physically hurt by the thorns of the pejobaye, *Guilielma gasipaes*, (peach palm); this is why agro-forestry associations rarely contain this species. Some farmers grow fruit trees on their coffee plantations, and others make use of the flowers from the itabo,

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Yucca elephantipes, as a food; this species is also widely used as a living fence posts. Nevertheless, many farmers dislike having this type of product on their farms, because of the damage caused to the trees and fences when the fruit and flowers are harvested, often by unwelcome outsiders.

As mentioned previously, nine field trials have already been established. Perhaps one of the most important concerns growth control of laurel when grown in association with agricultural crops. It is most commonly combined with pastures (often mixed with other trees like poró), sugar cane, and most frequently, with coffee (again, usually in combination with poró).

The laurel-coffee association shows considerable potential for economic benefits from lumber. The leguminous species *Erythrina poeppigiana*, also used in coffee plantations, contributes significantly to the recirculation of bioelements, as verified through the measurement of biomass and soil nutrients.

Laurel forms a high stratum of up to 12 meters; poró forms the central stratum at 5 meters, and coffee the lower stratum, at about two meters. It should be mentioned that variations in coffee yield are more significantly related to unregistered factors such as the intensity and type of management used.

In June 1978, a test was initiated with the timber-producing species *Terminalia ivorensis*, a valuable African tree used in numerous reforestation programs, particularly in West Africa. The data on the yield of agricultural crops (corn, cowpea and beans) grown in association with *Terminalia* indicates that the association is very profitable. Economically, the cost of establishing *Terminalia* together with other crops was 73 percent less expensive than when planted alone. Furthermore, results indicate that forest cultivation, rather than having a detrimental effect on agricultural production, can be combined to produce significant benefits.

The combination of laurel with cacao plantations and with pastures is apparently widely practiced by farmers in the Atlantic zone of Costa Rica. Laurel grows well in combination with cacao, into tall trees of large trunk diameter. The biggest management problem seems to be the distribution of the trees as to space and time.

In a laurel-pasture association plot under study, with 200 trees per hectare, it was found that trunk diameter increases were small due to the density of the trees and that thinning was therefore required. It is calculated that with appropriate management, profits of from US\$600 to US\$800 can be obtained from timber-cutting alone. Data on the management of laurel grown in association with cacao indicated that larger trees that no longer increase in volume can be felled, in coordination with pruning schedules or the renewal of cacao plantations.

The association of *Cedrela odorata* with coffee was studied in San Carlos and Tabarcia, Costa Rica, on plots with trees averaging 16.5 and 17 years of age. The value of this Spanish cedar has been acknowledged since colonial days, and has been exploited traditionally in lowland forests, where it establishes itself in clearings. Attempts to start *Cedrela* plantations have met with repeated failure in Latin Amer-



Increased economic returns as a result of growing 'laurel' for timber in association with coffee are highly feasible.

ica, due in part to attacks by the mahogany borer, *Hypsipyla grandella*. Nevertheless, *Cedrela* is regularly cultivated in some areas by farmers who are aware of and obtain considerable benefit from the trees, either by using the wood which is very durable, or by selling the timber on the open market.

In Costa Rica, the Spanish cedar is frequently grown in association with coffee. The use of legumes as coffee shade is common; the cultivation of other valuable wood species not so common, though should be introduced as a means for diversifying and possibly increasing the productivity of land planted with coffee. Results indicate that average annual increases of wood are worth from US\$374–580/ha/year. Although data is unavailable on the effect of trees on coffee yield, it is clear that this type of association is a method for diversifying land use and perhaps permitting its more efficient use. Tree cultivation is a medium-term investment, and although the trees are susceptible to *Hypsipyla*, they seem to tolerate most of the attacks and rapidly pass through the most susceptible period.

Wood Production. Research, originally begun in 1960 and being continued in its present stage which was initiated in 1976, is being conducted in order to select a small number of good timber-producing forest species appropriate for intensive cultivation in the humid zones of Central America, and to select improved varieties and lines of these species for establishing local seed sources.

The Latin American Forest Seed Bank received seed from several international institutions as well as having collected a substantial amount of seed from seven species. Seed from these species has been sent to Central and other Latin American countries; Liberia, Ruanda and India. Furthermore, collaboration was provided in collecting seed from different species and sources for testing by international forestry centers such as the Commonwealth Forestry Institute in England and the Centre Technique Forestier in France.

New tests on species were begun with the *Acacia*, *Araucaria* and *Agathis*, and contacts have been made for obtaining seed of these genera; as a result, seed from 8 species was received during 1979. Germination has been rather poor, but a sufficient number of plants was obtained for establishing new test plots of

Araucaria bidwillii and *Acacia mangium* in each of CATIE's two arboreta.

Results of other tests were evaluated during 1978 and 1979, confirming the earlier identification of *Pinus caribaea*, *Eucalyptus deglupta* and *Cordia alliodora* as promising species for the Turrialba Valley and surrounding districts.

Provenance trials have resulted in the selection of six promising fast-growing species for timber plantations in the region's humid zones. Acceptable seed sources have already been identified for two of these species. The provenance test plots of *P. caribaea* have been measured twice; *Pinus*, *Leucaena* and *Eucalyptus* were germinated and seedlings taken to the field. Three new tests were set up for *P. oocarpa* and one



The appropriate exploitation of lumber contributes significantly to improving farmer incomes while conserving forest resources.

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for *Leucaena*, and another one for *Cordia alliodora*. These plots are all located in different areas of CATIE terrain, at cooperating institutions located elsewhere, and on private farms.

Progeny tests on *Pinus caribaea*, *Cupressus lusitanica* and *Cordia alliodora* were conducted throughout the year, and a new test was begun on 57 *P. caribaea* progenies from Queensland, Australia.

Experiments on the vegetative propagation of *Eucalyptus deglupta* and *Cordia alliodora* produced varying results: sufficient root growth developed, but methods must be further refined. Seventy percent of the *P. caribaea* trees grafted using the tip-cleft method were successful. Moreover, the forest nursery was completed in 1979.

Management of Primary and Secondary Forests. In Costa Rica, cativo, *Prioria copaifera*, provides the raw material for the laminated wood industry. Large stands of this species still exist in the humid tropical zone on the Atlantic.

To study the performance of this valuable species under forest conditions, two permanent growth plots were established in 1978, in the Tortuguero region of Costa Rica. Data was collected in 1979 on the frequency of the cativo on these plots, their average diameter, commercial volume, floristic composition and natural regeneration.

Exploitation of CATIE's experimental secondary forest at Florencia Sur was started for the first time in 1979. Information on production factors was also gathered at that time. The quantities of bioelements present in the soil are not significantly different from secondary tropical forests in other parts of the world, and no real differences were detected between the natural regeneration of the species and its regeneration on the experimental plots. Losses due to exploitation are low; natural regeneration is slow, so enrichment systems should be established. The forest, overall, proved to be a good source of income.

Silviculture of Rapid-growth Species

Four promising species were submitted to different types of thinning. Both the thinned and unthinned plots of *P. caribaea* var. *hondurensis* and *E. deglupta* showed relatively low increases in 1979. The positive effect of thinning noted in 1978 was probably not repeated the following year because of the rapid closing in of the canopy, hence the need for this species to be thinned heavily at an early age. For *Cordia alliodora* and *Gmelina arborea*, selective thinning proved better than a systematic approach, as much for later growth as for the overall quality of the stand. Different degrees of selective thinning produced trees which were larger and of better quality, though they did not increase the productivity of the stand. The type of thinning selected will depend entirely on the type of raw material wanted.

Forest Protection. In 1979, 150 insect species which damage forest plantations were collected in various parts of Costa Rica; samples of the species were then sent to the National Museum in the United States for identification.

Research was conducted on foliage flammability and the effect of fire on the germination and survival of three types of pine. Tests in Honduras were made on the calorific value, burning rates and the effect of burning on run-off as well as on the chemical properties of the soil. Some practices for reducing fire-risk and for using trees as fire breaks in *Pinus oocarpa* stands were evaluated. *Leucaena leucocephala* was found to be unsuccessful for this purpose in pine forest areas of Central Honduras. Control areas were selected in a number of forest plantations in the Turrialba valley, Costa Rica, for purposes of identifying pests and diseases.

Management of Watersheds and Forest Areas

Substantial progress has been made in processing the approval and funding of a CONICIT project on "Horizontal interpretation in a tropical montane forest and its hydrological importance." This project encompasses the management of several watersheds, and will be financed in part by five Costa Rican institutions as well as CATIE. Quantitative research into the erosion and sedimentation elements of different

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Different levels of selective thinning for pines and other rapid-growth species produces better quality trees.



The careful management and rational exploitation of forests is vitally important for purposes of watershed conservation.

land-use systems around Barú volcano in Panama is almost completed, and studies into water erosion and the incidence of weeds in coffee-*Erythrina poeppigiana* agro-forestry systems with a third stratum of *C. alliodora* are also nearing completion in Florencia Sur, Costa Rica.

Forest Areas. In this field, research activities are completely integrated with those of technical assistance and cooperation, in a single, multifaced relationship with national institutions. The first phase of projects in Costa Rica and Panama for designing, testing and refining shortterm operational planning methods for management institutions, forest area systems and individual forest areas was completed. The methods used are new to Latin America and the Caribbean.

In Honduras, the first phase of a project for designing, testing and refining long-term planning methods for new forest area categories in Latin America (Biosphere Reserve and Multi-use Areas) was also completed.

In Costa Rica, Panama, Guatemala and Nicaragua, projects were also initiated to test the design of long-term planning methods for other new forest area categories in Latin America (Resource Reserve, Forestry Reserve, Scientific Reserve and Wildlife Refuge).

Existing long-term management planning methods and plans for environmental education and interpretation were further refined, based on results of planning activities in seven forest areas of Panama, Costa Rica and Nicaragua. A study was also completed for developing a research method in Costa Rica.

In Honduras, a first phase of a study dealing with socio-economic and cultural aspects of indigenous groups and rural settlers in relation to the planning and implementation of a forest area in the Biosphere Reserve of Río Plátano, was finished. And finally, a study was begun into the attitudes of the rural population, in this case small-scale farmers and fishermen, on the management of a multiple-use area near Lake Yojoa, Honduras.



Training and Technical Assistance

ACTIONS FOR AN INTEGRATED DEVELOPMENT

Traditionally, higher education in Latin America has been oriented by a scientific method which reduces phenomena to their basic components, facilitating their analysis as separate units. Thus, education has traditionally approached the disciplines independently, with each area becoming increasingly specialized, resulting in a dissociation from the problems of the real world.

It is now generally accepted that this orientation must change, and problems should be viewed as part of a system or systems interacting with their environment. Thus, CATIE's structure, philosophy and methods enable it to direct its educational efforts towards the development and implementation of integrated and multidisciplinary training models, to prepare professionals to be able to identify problems within the context of their real environment and to be able to assess the relative importance of each component, within the farm systems. The objective, then, is to ensure that professionals have a good academic background plus a practical and integrated approach to problems, and the capacity to formulate and implement solutions. Multidisciplinary training and field team work is emphasized, as a part of integrating the actions of the different technical experts. Human resources trained in this fashion will be able to interpret CATIE's philosophy, and to transfer its research methods and techniques for improving and upgrading agricultural, livestock and forestry production and productivity, to low-income farmers.

POST-GRADUATE STUDIES: INTERDISCIPLINARY TRAINING

The UCR/CATIE Post-Graduate Studies Program in Agricultural Sciences and Natural Resources was continued in 1979, based on the agreement between the two institutions. The University of Costa Rica (UCR) is responsible for the academic coordination and orientation of courses, certain basic courses and the awarding of Master's degrees, through the UCR Post-Graduate Studies Program. The specialized technical staff at CATIE give most of the more advanced courses, and serve as student counsellors and research advisors. CATIE provides the research facilities, classrooms and accommodations in Turrialba, and takes care of most of the financial administration aspects.

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CATIE provides different levels of training, all of which emphasize interdisciplinary studies and team work.

In 1979, progress was made in the Program's administrative organization for better defining admission and quota-allocation procedures, the presentation and publication of graduate theses and the program's economic consolidation.

Approval was obtained for presenting theses directly for publication; the studies programs were revised and updated, and mechanisms were established enabling some students to do their research in their countries of origin or at renowned research institutions. New admission procedures were proposed, emphasizing the value to be given to prior experience in the final analysis. Partly as a result of this, the program's image in Central America, as well as throughout the rest of Latin America, has been strengthened and the number of professionals arrived at CATIE from its principal area of influence for studies, has increased significantly.

During the period covered by this report, CATIE staff gave a total of 26 courses: 10 in Natural Renewable

Resources; 7 in Tropical Crops; 7 in Animal Production and 2 in general inter-disciplinary courses.

Scholarships last year were provided by a number of sources: 11 from the Government of Holland; 6 from the British Government (ODA); 2 from EMBRAPA, Brazil; others from IBM, the German Government, the International Center for Tropical Agriculture (CIAT), the Central Western University of Venezuela, and CONACYT, Mexico.

CATIE sponsored a meeting in Turrialba in October 1979, of the deans of the Schools of Agronomy and Veterinary Sciences of the Central American Isthmus countries. They met to examine the background and current status of training programs available in the region for professionals, and to exchange ideas on problems and needs, and on cooperation possibilities.

The role of the professional agriculturalist in society and development was stressed at this meeting. The subject of limited quota vs. free access universities was analyzed and the need to develop mechanisms for compiling and defining criteria and guidelines for maintaining and raising the quality and availability of higher education was stressed.

The deans extended a vote of support to CATIE for its Post-Graduate Program, and expressed their sincere interest that it be continued, adding that it is a necessary and important resource for training professional researchers and educators in Agronomy and Veterinary Sciences for the Central American Isthmus.

They also agreed to create a regional association to help coordinate the efforts of the Schools of Agronomy and Veterinary Sciences in the region, and to upgrade professional university and post-graduate training in the fields of communications and teaching methods.

INTERNATIONAL COOPERATION

NON-FORMAL TRAINING: AN EFFORT TO FILL DEMANDS AT OTHER LEVELS

CATIE endeavors in non-formal training during 1979 included short courses, specialized conferences, seminars, workshops and in-service training that sought to reach a broader audience. The program's aim is to contribute to updating knowledge and developing specific skills and abilities in national professionals involved in production, research and the transfer of technology.

As a result of these efforts, more than 800 technical experts from the Central American Isthmus participated in 56 different training events, including 24 short courses (one week duration, on average), 11 specialized seminars, one workshop and four technical seminars. The Center's professionals also attended 16 international meetings.

In addition, 115 technical experts received in-service training, of different duration and intensity, in line with the practical approach of training in the field and interaction between technical experts and trainees.

Another important result of the training programs, was the progress achieved in developing more appropriate training methods and models and the pertinent teaching and training aids, for specific, and multi-disciplinary courses, more particularly in the areas of Agro-ecosystems, Agro-forestry, and Milk and Cacao production systems.

TECHNICAL ASSISTANCE

This aspect of CATIE's work involves many activities, although they are focused mainly in two areas: one, the provision of professional advisory services—at the behest of the countries—for CATIE staff, on more or less individual though preferably an institutional basis, to help resolve given general or even more specific problems; the other, the provision of direct technical assistance to national research, and agricultural and forestry development programs and projects. The actions contribute significantly and positively to CATIE's image in the countries, and are still among the best means for maintaining and improving necessary linkages.



Direct exchange between experts, visiting scientists and technical specialists from national institutions continues to be one of CATIE's best ways for maintaining and strengthening the links with the countries.

Technical cooperation activities over this past year have focussed on transferring newly generated technology to national institutions, as well as that adopted from other regions and countries, as one way of upgrading institutions and supporting their development programs, throughout the Central American Isthmus. Progress has been made in developing models for accelerating the transfer of technology, in joint efforts with and in support of national technical experts who, finally, are the ones responsible for this work.

Thus, the **Annual Crops Program**, in addition to pursuing its cooperative efforts in supports of national institutions in the research and training activities

outlined above, provided technical assistance to CENTA in El Salvador on formulating research strategies on production systems, in annual programming, analyzing and determining socio-economic factors, and identifying harmful species of *Phyllophaga*. The Program also collaborated with the Caribbean Research and Development Institute (CARDI), in Jamaica, on collecting and analyzing basic information for defining areas. CARDI sponsored a Workshop on Farming Systems, with CATIE support, to study small farm research and to determine essential factors in the cropping systems used in the Antilles. CATIE is also collaborating with EMBRAPA, Brazil on a program of interest to several Central American countries. Here, the Center is advising EMBRAPA on appropriate types of research for resolving problems of low-income farmers. The **Perennial Plants Program** has continued helping countries in setting up a regional cacao research network for distributing improved seed and providing technical assistance on crop improvements. CATIE also continues to work with PROMECAFE on controlling coffee diseases, especially the rusts, and on the plant breeding program, and in training national technical experts.

The **Natural Renewable Resources Program** participated in planning and preparing a regional project on "Firewood and Charcoal Production, and the Development of Alternative Energy Sources", to be implemented over the next six years in collaboration with ICAITI, the Central American Institute for Research and Industrial Technology, in Guatemala, and with national institutions.

This program has also been providing technical assistance to the La Yeguada Forest Reserve in Panama, on managing pine plantations on degraded lands, and on determining the agro-forestry possibilities of the Tejutla Zone in El Salvador, for small-scale farmers. Advisory services were provided to two universities—in Guatemala and Nicaragua—on designing their curricula for natural renewable resource management. Technical consultants provided services on five occasions in Costa Rica and Colombia, on forestry aspects. A joint CATIE/Ministry of Agriculture mission conducted a diagnostic study in Costa Rica on the possibilities of bilateral assistance for managing forest and watershed areas and other natural resources, for the DDA of Switzerland.

Technical assistance was also provided to all the countries of the Central American Isthmus in pre-

paring integrated management plans and in developing corresponding operative plans; in preparing educational environmental interpretation plans, and requests for international funding and program implementation, covering a number of forest areas, including integrated watershed management, forest reserves, multi-use areas, scientific and natural reserves, archaeological monuments and international and national parks. CATIE has also been working with Colombia and Panama on the integrated management of the Darién region, and with Belize on establishing forest areas.

The **Animal Production Program** continued its three regional technical assistance projects involving direct farmer participation. This has facilitated an improved awareness of actual farm working conditions, ensuring the development of technology transfer methods appropriate to the conditions of each area. In Costa Rica, work with the Land and Settlements Institute (ITCO) was continued in Río Frío, and activities in the Institute's other areas of action were also expanded, specifically on milk production systems for small-scale farmers in newly settled zones.

One of the most important results of this project was the increased amount of land devoted to pastures and their more efficient use. By increasing the number of pasture divisions and intensifying grazing loads on a rotational system, it was also possible to increase milk production, raising the settlers' total incomes from sales, from Central American \$287 to \$918. Under the same project, efforts to develop profitable production alternatives for settlers in Birrisito, Costa Rica were started in November 1978, and similar endeavors in Parrúas, between San José and Turrialba, in April 1979. Based on the milk modules tested in Parrúas, it was found that calf rearing was not advisable because of the scarcity of land. Improved cost efficiency, the number of pasture divisions and changes in grazing loads improved milk production by 138 percent, raising the total gross annual income from Central American \$2,884 to \$8,975. In Río Frío, a storage center was established with a laboratory to periodically test the milk and assess its quality.



TRAINING AND TECHNICAL ASSISTANCE

Technical assistance teams participated directly in all marketing activities. It has been estimated that with the establishment of an additional 12 units (already being built), production will increase to 12,000 liters, making it more feasible to organize the settlers into a relatively inexpensive marketing channel. A cross-breeding system is being developed for producing dairy cows adapted to the humid, low and hot zones. CATIE's breeding center is working on developing young bulls of high genetic potential to upgrade dairy herds; to date, 48 animals of different breeds and crosses have been raised, 10 of which are being used on the farms in Río Frío and Parrúas.

The milk development project in Coto Brus, in conjunction with the Ministry of Agriculture and Livestock and the county agricultural center in Coto Brus, has been continued. By March 1979, it had reached 53 percent of the organized farmers in the county. Efforts were made to transfer 34 different types of technology. Of these, 9 were adopted by about 75 percent of the farmers; 12, dealing with sanitation, were adopted by 78 percent. Thus, an estimate of 22 technologies were adopted, with a 62 percent adoption rate. New farms incorporated into the program in 1979 as well as those that have been with the program since its first year of activity, have made considerable technical progress, with increases in milk production profits.

A random survey was made of 25 farmers to analyze milk marketing aspects. Results indicate that marketing channels vary considerably, and information obtained in only one location is not sufficient to provide reliable data.

The CATIE/Honduran Central Bank livestock production project studied the impact of work accomplished to date; results were quantified according to differences in the amount of time participating farmers have used the services. Farms have been incorporated gradually and, in many cases, not enough time has elapsed to detect change: total of 63 farms have been reached; 26 joined last year and 14 have been with the project for less than 6 months. The number of farmers with only scant knowledge of recommended techniques has changed significantly from a mere 23 percent with little or no knowledge, to 35–40 per-

cent with good knowledge of essential technology. Similarly, data gathered on the quantitative aspects of the project (degree of adoption), indicates that a positive and consistent change has occurred towards a better understanding and adoption of methods which affect livestock developments in a practical manner.

A socio-economic study carried out on farms in Caisán and Santiago, Panama, found that mixed agriculture-livestock systems produce the highest net incomes by family and by farm, although in both zones family incomes are low. Livestock exploitation in these areas is extensive and makes little or no use of technology. With these factors in mind, the Technical Assistance Project being carried out with the Agricultural Research Institute of Panama (IDIAP) continues testing grass-legume management techniques. Initial yields indicate that when nitrogen is applied to the soil and pastures are rotated, jaragua grass produces notable increases in meat production. Yields are also better than those from constantly grazed pastures. Positive results were attained in Kudzu and Desmodium forage production by adding lime. When Jaragua is grown in association with Kudzu and Centrosema, sustained pasture conditions are maintained for a longer time when forage collection is regulated and when 42 day rest periods are established. Increases in the weight of weaned calves contrast sharply with the results of the traditional extensive exploitation system, with calves gaining in two years what traditionally raised calves gained in four. Systems are now being designed for feeding dairy cows in the summer, based on 'King grass' silage tests.

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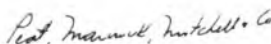
Financial Overview

E. GARNIER, CPA - V. MUÑOZ, CPA
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Consejo Directivo
 Centro Agronómico Tropical de Investigación y Enseñanza:

Hemos examinado el balance de situación del Centro Agronómico Tropical de Investigación y Enseñanza, Turrialba, Costa Rica al 31 de diciembre de 1979, y el estado conexo del resumen de ingresos y gastos por el año terminado en esa fecha. Nuestro examen se efectuó de acuerdo con las normas de auditoría generalmente aceptadas y, por consiguiente, incluyó aquellas pruebas de los registros de contabilidad y aquellos otros procedimientos de auditoría que consideramos necesarios según las circunstancias.

En nuestra opinión, los estados financieros antes mencionados presentan razonablemente la situación financiera del Centro Agronómico Tropical de Investigación y Enseñanza al 31 de diciembre de 1979 y el resumen de ingresos y gastos por el año terminado en esa fecha, de conformidad con los principios de contabilidad que se mencionan en la nota 1 (a) a los estados financieros, aplicados sobre una base consistente con la del año anterior.

14 de mayo de 1980

The Board of Governors Centro Agronómico Tropical de Investigación y Enseñanza

We have examined the balance sheet of Centro Agronómico Tropical de Investigación y Enseñanza, Turrialba, Costa Rica, as of December 31, 1979, and the related statements of revenue and expenditures for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the aforementioned financial statements present fairly the financial situation of Centro Agronómico Tropical de Investigación y Enseñanza at December 31, 1979, and the revenues and expenditures for the year then ended, in conformity with the accounting procedures described in note 1 (a) to the financial statements, on a basis consistent with that of the preceding year.

TROPICAL AGRICULTURAL RESEARCH AND TRAINING CENTER

TROPICAL AGRICULTURAL RESEARCH AND TRAINING CENTER

Summary of revenue and expenditures

Revenue

Members of the Center	US\$ 765,000
Agricultural products and services	632,952
Commercial operations	970,112
Administration of projects	235,655
Funds for execution of special agreements	2,314,275
Others*	1,358,506
	<u>US\$6,276,500</u>

Expenditures:

Directorate and coordination	US\$ 223,500
Technical activities*	4,740,800
Administration of services	611,200
Agricultural production	459,900
Infrastructure and general expenditures	241,100
	<u>US\$6,276,500</u>

* Includes 160 man/months of direct technical assistance given to CATIE, equipment and operative expenditures not administered by the Center, but by the donor.

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PROGRESS REPORT 1979

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Nicaraguan Agricultural Technology Institute	INTA
Natural Resources and Environment Institute, Nicaragua	IRENA
Peasant Programs, Nicaragua	PROCAMPO

International Institutions

ACRI	American Cocoa Research Institute
AVRDC	Asian Vegetable Research and Development Center
BMZ	Technical and Economic Cooperation Ministry, Federal Republic of Germany
CARDI	Caribbean Agricultural Research and Development Institute
CIAT	International Tropical Agriculture Center
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
DDA	Development Cooperation Program, Switzerland
DSE	International Development Foundation, Federal Republic of Germany
EEC	European Economic Community
FAO	Food and Agriculture Organization of the United Nations
GTZ	Technical Cooperation Society, Ltd., Federal Republic of Germany
GPB	The Netherlands Government
IBM	International Business Machines
IBPGR	International Board for Plant Genetics Resources
IBRD	International Bank for Reconstruction and Development (World Bank)
ICAITI	Central American Industrial Research and Technology Institute
IDB	Inter-American Development Bank
IDRC	International Development Research Centre, Canada
IFAD	International Fund for Agricultural Development
IICA	Inter-American Institute of Agricultural Sciences of the OAS
IPPC	International Plant Protection Center
IUCN	International Union for the Conservation of Nature and Natural Resources
KELLOGG	W. K. Kellogg Foundation
MAB	Man and his Biosphere Program, UNESCO
NSF	National Science Foundation
OAS	Organization of American States
ODA	Overseas Development Administration, England
OTS	Organization for Tropical Studies
PC	Peace Corps, USA
PNUMA	United Nations Environmental Program
RBF	Rockefeller Brothers Fund
UNU	The United Nations University
UNESCO	United Nations Education, Scientific and Cultural Organization
UPEB	Union of Banana Exporting Countries
USAID/ROCAP	U.S. Agency for International Development/Regional Office for Central American Programs
WWF	World Wildlife Fund.

Photographs

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G. Budowski: 42, 44, 45, 47 & cover upper right

J. Engels: 33

E. Locatelli: 21 above

M. Ruiz: 37 & 38

J. Saunders: 14 below, 18, 21 below & cover, upper center

M. Shenk: cover, extreme upper left & lower right

F. Solano: 12, 28, 30, 31, 32, 49, 50 & cover, upper center left

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