# PRINCIPAL ACCOMPLISHMENTS OF THE PLANT PRODUCTION DEPARTMENT OF CATIE UNDER IFAD TA 38 A-D GRANT 1980-1985

## INTRODUCTION

The IFAD grant provided for activities in five different lines of action: prototype teams in specific areas; support research for three different ecological zones; training for scientists, extensionists, and farmers of the CATIE region; outreach to form linkages between the activities in specific areas and ecological zones and other areas in Central America and the Caribbean; and support for CATIE activities in the region.

The IFAD project was implemented in three representative ecological zones of Central America: the lowland humid tropics, with a dry period of less than three months; the wet-dry tropics with a dry period of 3-6 months, and the semiarid tropics with a dry period of more than 6 months. The Lowland Humid Tropics (LHT) covers more than half of the area of Central America but contains less than 40% of the population. It is therefore the area with the most potential for relieving population stress in the Central highlands and Pacific slopes. Major constraints are excessive rainfall, low soil fertility, high incidence of pests, and poor infrastructure; the Semiarid Tropics (SAT); where maize and sorghum production systems predominate, contains more than one third of the population of Central America in less than twenty percent of the area. Population stress is thus high while production potential is limited by irregular rainfall, steep and shallow soils, and inequable land distribution and 3) the Wet Dry Tropics (WDT), is not as extensive or as highly populated as the other ecological zones. The potential of this zone is less limited by the problems which pose constraints in the lowland humid and semiarid tropics. Better management of existing resources if often the key to development of this ecological zone.

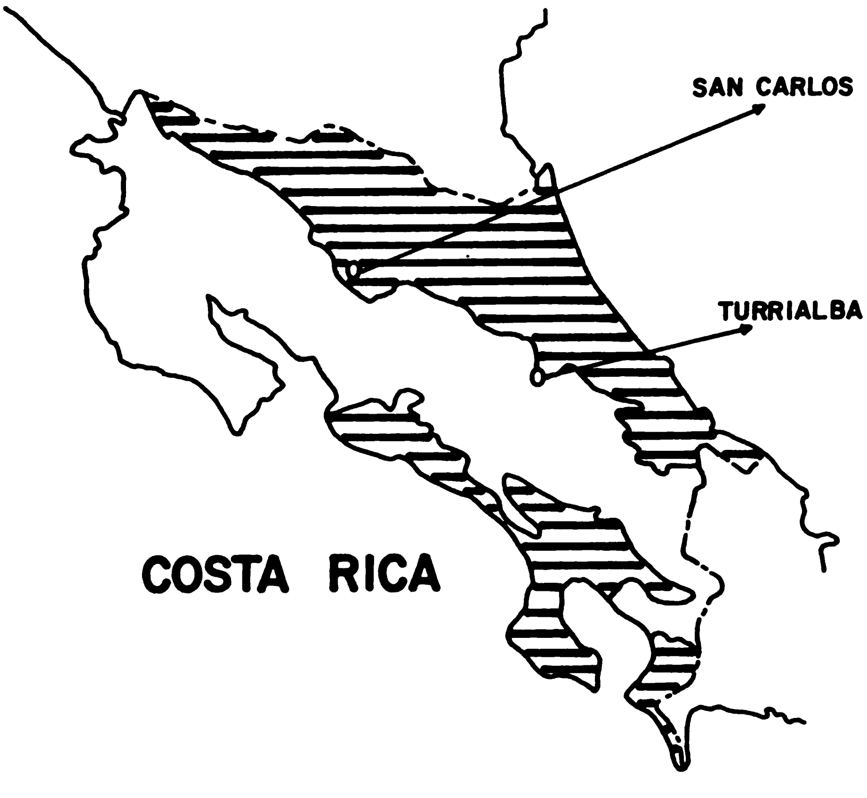
Achievements in research are summarized for each of the above mentioned ecological zones, followed by the most important accomplishments on the areas of training, outreach and institutional support.

## LOWLAND HUMID TROPICS

For the humid tropics site, the Canton of San Carlos, Costa Rica ($10^{o}19'-35'$ N and $44^{o}$ $18'-80'$ W) was chosen, occupying 3371 $km^2$ in the northeast part of the country. Most of the canton is below 500 meters above sea level and receives 2500 to 6000 mm of annual precipitation. The area is classified as having no dry season but in February, March, and April, as little as 100 mm of rainfall per month may be recorded. Like much of Central America, the soils have received a certain input of volcanic ash but as this amount varies from site to site, Paleudults, Dystropepts, and Tropudalfs are found in the area as well as the expected Dystrandepts.

Zones with no volcanic influence (Paleudults) can be found in association with soils with varying amounts of volcanic influences (Dystropepts, Humitropepts, Dystrandepts and Tropudalts).

All of the farmers who participated in the project had obtained 10 ha parcels through various land reform schemes. No work was done with the extensive cattle producers who occupy more than 75% of the area of the Canton. The most important crops produced by the 5000 small holders in the Canton are maize, cassava, beans, rice, papaya, pineapple, cacao, and edible aroids. With the exception of maize and rice, most of these products are sold off the farm as there is an extensive, if poorly maintained, road system in the area.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# FOOD GRAIN PRODUCTION SYSTEMS

## Legume - Maize Associations

A low cost and simple method was developed to identify species and varieties adapted to the association with maize of different growth habits through the use of screens of dissimilar light transmission capacities. The method also permits the separation of the effect of above and below ground competition. Different crops were identified which could be used as biological indicators of degrees of above and below ground competition for scarce resources.

Both maize and associated crops (soybean and cowpea) were found to have altered growth rates when associated; the nature of the alteration depends upon the crop phenotype (both maize and legume) and the relative planting dates. Maize growth rates were affected most by indeterminate cowpeas, less by determinate cowpeas, and least by soybeans, later planting of the legumes reduced these effects. Growth rates of associated crops was principally affected by the reduction of photosynthetically active radiation by the maize -hence growth habit of the maize and time of association affected the growth rates of the associated legumes; soybeans being less affected than cowpeas. Soybeans would therefore be more suitable for association with maize than cowpeas.

## Maize Monoculture

Monoculture maize responded markedly to phosphorus fertilization on a soil quite extensive in the humid tropics of Central America, a Typic Humitropept, fine, halloystic, isohyperthermic, with the following chemical characteristics: pH 5.6, P (Olsen) 14.8 ug/ml; exchangeable K, 0.17 $(p^+)$ cmol $L^{-1}$, exchangeable Ca, 1.67 $(p^+)$ cmol $L^{-1}$, exchangeable Mg, 0.55 $(p^+)$ cmol $L^{-1}$, aluminium saturation, 35.2%, organic matter, 5,5%. Maize yields increased from 2765 to 5642 kg ha$^{-1}$ when 250 kg ha$^{-1}$ of $P_2O_5$ and 75 kg ha$^{-1}$ of $K_2O$ were applied. There was no response to zinc but an application of 461 kg ha$^{-1}$ of $MgSO_4$ $7H_2O$, the only form of magnesium locally available, increased maize yields by 700 kg ha$^{-1}$, although this increase was not statistically significant. Increased fertilization with phosphorus, potassium and perhaps magnesium and sulfur would contribute significantly to increased maize yields in the humid tropics of Central America; if pricing structure made these materials more readily available, then a better option to production is open to low income farmers.

Of 40 genotypes evaluated, five (Ferke (1) 8128, Across 7728, Poza Rica 8121, Across 8042 and Ferke (1) 8129) were selected with yield production of 4 to 6 ton/ha and recommended for farmers' use.

In 1985 the cultivars previously selected (Guaymas (1) 8022, 2.6 ton/ha; Ferke (1) 8129, 2.3 ton/ha and Across 7929, 2.4 ton/ha) outyielded local varieties under low management conditions by as much as 150% (local cv. yielded 1.0 ton/ha). The same varieties, using technology recommended by government agencies, outyielded local check variety by 80% (local cv. yielded 1.6 ton/ha).

## Maize - Beans

It was determined that the proposed alternative (planting beans 20 days before physiological maize maturity) reduced possibility of drought stress during bean flowering, leading to increase bean yields.

Economic analysis identified the proposed alternative as the best crop arrangement, especially when low leafiness maize type (such as Compuesto Blanco 2 and ETO Blanco) are used. Yield increase of beans were 20-25% above the traditional system which is to plant beans at physiological maturity of maize.

In none of the experiments significant interactions between maize and beans genotypes were detected, indicating that in the maize-beans relay cropping systems selection of maize and beans can be done independently.

Investigations with maize of different plant heights associated with climbing beans, determined that maize phenotypes shorter than 2.5 m with strong stalks led to a highest yield of beans. The best bean lines in the system were V7920, V7919 and V7918 with production of grain above one ton/ha.

## Maize - Cucurbits

Yield of Central American cucurbits (*Cucurbita mixta* and *Cucurbita moschata*) in the systems maize-cucurbita can be increased 60% by association with double rows rather than single rows of maize. Maize yield is reduced 47% in this planting pattern.

## Maize - Cassava System

Maize yields were not increased by hand-weeding or by use of preemergence herbicides in a well-fertilized soil, tilled previous to planting.

Cassava yields were increased over those obtained by hand weeding with metolachlor at 2.5 kg $ha^{-1}$, alachlor at 2.6 kg $ha^{-1}$ and a combination of linuron at 1.5 kg $ha^{-1}$ and alachlor at 0.89 kg $ha^{-1}$. A combination of 1.5 kg $ha^{-1}$ of linuron with 0.25 kg $ha^{-1}$ of oxyfluorfen caused severe toxicity to both maize and cassava. Atrazine at 1.25, 1.63 or 2.0 kg $ha^{-1}$ caused light phytotoxic symptoms to cassava which soon disappeared, indicating that further work might be done with this product in the system.

Cassava and maize phenotypes were identified for the cassava + maize intercropping pattern. The most desirable cassava plant type is one of intermediate height (1.7 m), medium to low leafiness (like M Col 22 or CM -342-180) and first branching at approximately 1.3 m above ground. The best maize phenotype would be one of intermediate height (2.2 - 2.3 m) and leafiness (50-55 $dm^2$) and good husk cover.

The presence of significant genotype-by-system interaction, emphasized the importance of considering the cropping system before making selection of both maize and cassava.

The best maize cultivars recommended for the intercropping system are Guaymas (1) 8022 and Ferke (1) 8129, with yields of 1.2 to 1.4 $ha^{-1}$ even under conditions of low fertility and plant population (18000 plants/ha) in which local materials only produced 0.4 $ha^{-1}$.

For the maize+cassava system, the most economical fertilization was 37 kg $ha^{-1}$ of N, 40 kg $ha^{-1}$ of $P_2O_5$, and 37 kg $ha^{-1}$ of $K_2O$ applied only to the maize. Higher fertilization rates did not bring about sufficiently higher yields of either maize or cassava to compensate for higher costs of fertilizer. Both maize and cassava showed a greater response to fertilization as well as higher overall yields in La Fortuna than in Pital, due principally to differences in soil types. The experiments in La Fortuna were run on Tropudalfs of high base status while the experiments in Pital were located on Paleudults with high levels of aluminium saturation.

## Cassava - Bean System

The Talamanca bean cultivar (local) did not respond to hand weeding or to the application of various preeemergence herbicides when the soil was tilled prior to planting. A factor in this finding may be the rapid maturity of this cultivar, which takes less than 70 days from planting to harvest.

The best alternatives for weed control in the cassava bean system were chloramben at 2-6 kg $ha^{-1}$, alachlor at 1.5 kg $ha^{-1}$, or linuron at 1.5 kg $ha^{-1}$ which did not cause phytotoxicity to either crop and resulted in a yield of over 30 t $ha^{-1}$ of cassava. Similar yields could be obtained with hand weeding but this alternative depends on labor availability. Certain herbicides (oxyfluorfen 0.4-0.8 kg $ha^{-1}$ and alachlor at 2.9 kg $ha^{-1}$) were phytotoxic to beans.

Bean varieties differ in their adaptability to this cropping pattern. Best recommended varieties for this system are PK-675, ICTA Tamazulapa and ICTA 8164 with yields between 0.9 and 1.0 t $ha^{-1}$, 52% higher than local cultivars.

When beans were associated with cassava, bean yields were reduced proportionally as bean populations were reduced while cassava yields were not significantly affected by association with beans at any population. It would seem best to use the higher plant population, 150.000 pl $ha^{-1}$ when beans are associated with cassava as this produced the highest L.E.R. (Land Equivalent Ratio) independent of soil type.

Neither beans nor cassava responded to increases in fertilization from 0 to 6 qq $ha^{-1}$ of 12-24-12 fertilizer (55 kg $ha^{-1}$ of N, 110 kg $ha^{-1}$ of $P_2O_5$ and 55 kg $ha^{-1}$ of $K_2O$), indicating that such a level of fertilization of the bean-cassava system constitutes an uneconomical practice.

## Plantain - Maize

Association of maize with plantain was shown to be a beneficial alternative for small farmers. Maize yields were reduced by less than 25% in comparison with monoculture maize. Plantain yields only decreased significantly in the association in the first year when the traditional planting pattern was used. An economic analysis of the results for the first year of the association showed that the association in the hexagonal planting pattern would produce 75% more income per hectare than if the hectares were equally divided between maize and plantain monocultures. In the second year, there were also no detrimental effects to plantain production, with the association in the traditional planting pattern producing sufficiently more to compensate for its poor performance in the first year. It was shown that this association could help low income farmers offset the cost of plantain establishment.

## Bean Monoculture

Five elite cultivars were selected, multiplied and reevaluated in on-farm trials. Yields above 1.5 t $ha^{-1}$ were obtained with ICTA 8164, Negro Huasteco, Compuesto 1, ICTA Tamazulapa and Brunca.

Moderate applications (2 t $ha^{-1}$) of lime soils to with levels of aluminium saturation of 15-50%, increased bean yields by more than 80% (from 600 to over 1000 kg $ha^{-1}$), producing a greater economic return than fertilization with phosphorus, nitrogen, or potassium, or than inoculation with selected strains of rhizobium. Bean yield was more significantly correlated with levels of aluminium saturation than any other soil factor, including levels of exchangeable water soluble or readily reducible manganese, indicating the importance of correcting this factor before applying other amendments.

Massive applications of phosphorus (200 $kg^{-1}$ of $P_2O_5$) increased bean nodulation in the field but brought about smaller yield increases than liming in a soil with moderate levels (30%) of aluminium saturation. The high cost of phosphorus fertilizer in Central America is the major constraint to using this method as opposed to liming to overcome soil deficiencies which limit crop production. However, in soils with low levels of phosphorus and exchangeable aluminium, liming did not improve phosphorus availability.

In a greenhouse study, using a soil with high levels of aluminium saturation, nodulation and total nitrogen recovery was improved more by high levels of liming than by applications of lower levels of lime with phosphorus and molybdenum, There was an interaction of rhizobium strain with treatments, indicating that certain strains are more effective than others when soil deficiencies were not corrected.

## Sorghum Monoculture

A sorghum genotype ICRISAT M 91057 was selected for tolerance to conditions of high soil moisture and high levels of soluble Manganese as often occur in the lowland humid tropics.

## Alley Cropping

Application of mulch of leguminous trees or alley cropping with *Erythrina poeppigiana* was able to maintain maize and bean yields at 2.6 and 1.0 t $ha^{-1}$ over three years. There was less acidification of the soil and less destruction of soil organic matter with the leguminous tress than with mineral nitrogen.

Application of mulch of *Gliricidia sepium* to maize and beans in a farmers field in the lowland humid tropical zone increased yields of both crops by 25%. Thus, a low cost alternative to nitrogen fertilization exists.

Cassava yields could not be maintained over three years even with alley cropping or heavy applications of organic and mineral fertilizers. This crop is more affected than maize or bean, by soil physical characteristics which deteriorate under continuous cropping without tillage.

## Living Mulches

Use of velvetbean (*Mucuna pruriens*) to control weeds in maize was highly successful, if velvetbean was seeded 40 days before maize planting and cut back or killed with herbicide following maize planting. Later use of herbicide as a growth regulator of the velvetbean in this system was less successful because of unfavorable effects on the maize.

## Growth Analysis of *Paspalum fasciculatum*

Growth analysis of *Paspalum fasciculatum*, a particularly problematic weed in the lowland humid tropics of Central America showed that it has to be controlled within the first 8-9 weeks because at later stages, stolon production makes its control more difficult.

## Rice Monoculture

In a minimum tillage system, two products (oxadiazon or oxyfluorfen) provided satisfactory weed control. Oxadiazinon at 1.13 kg $ha^{-1}$ produced 3038 kg $ha^{-1}$ of rice and only 278 kg $ha^{-1}$ of weeds while the lower priced oxyfluorfen at 0.24 kg $ha^{-1}$ produced 2652 kg $ha^{-1}$ of rice. Oxadiazinon at 0.88 kg $ha^{-1}$ produced 2436 kg $ha^{-1}$ of rice. Non-weeded rice produced 1100 and the hand weeded check produced 2267 kg $ha^{-1}$.

## Rural Credit and Grain Storage

It was found that in the San Carlos area of Costa Rica, banks were the most important source of credit because they offered the lowest nominal interest rates. Although when additional costs were considered, real costs of credit was frequently higher for banks than for other sources of credit (friends, relatives and private lenders). Predictive curves for the demand of credit in the area could be determined from the relationship between the amount loaned and the real cost of credit and between the amount loaned and the extra cost of credit. Additional costs affected the total cost of small loans more than of large loans because they tended to independent of the amount of capital.

A study of grain storage practices was realized in the San Carlos area. Sixty-four farmers were interviewed with the following results:

1. Ninety seven per cent of the farmers store beans, 31.3% store maize, and 7.2% store rice

2. Farmers store an average of 230 kg of beans, 240 kg maize, and 80 kg of rice

3. All of the rice and maize and 94% of beans stored are consumed by the farmers

4. Eight percent of the farmers who store beans, sell part of the production (156 kg, average) either to neighboring farmers or middlemen

5. Twenty-nine percent of the farmers who store beans use some of their production (21 kg as average) for seed

Most farmers (67%) use oil drums for storage, 39% use cloth bags, while 11% use plastic bags inside cloth bags.

Twenty-eight percent of the farmers reported having losses in storage. The average maize loss was 14.0%, while the average bean loss was 6.0%. No farmers reported losses of rice in storage. Fourteen percent of the farmers attributed the losses to insects, 7-8% to unfavorable climate, 3% to disease and 3% to rats.

## TROPICAL ROOTS, CORMS AND TUBERS

### Cassava Monoculture

From thirty-eight local and improved cassava varieties, thirteen were selected based on superior agronomic qualities for further evaluation according to sensory testing and quality demanded by export markets.

This work, started by the Project in 1982, resulted in the recommendation of the following varieties: Tilaran-1, Brasil 14-47-70, Mex-59 and P 77-14. All of them yielded above 27 t $ha^{-1}$ of commercial roots of equal or superior quality to the local cultivar "Valencia" which yielded 18.8 t $ha^{-1}$. The variety P 77-14 (27.2 t $ha^{-1}$) and Tilaran-1 (37.8 t $ha^{-1}$) are (in this order) the best in appearance, color, shape and root flavor for export market according to farmers testing study.

Differences in management practices were evaluated according to whether cassava was the first crop planted following clearing (Class A) or whether another crop preceded the cassava (Class B). The following differences were observed:

1. Land preparation costs for cassava as a first crop were 50% higher than for cassava following other crops

2. Planting practice is similar for both systems (A and B): stakes planted horizontally, using 9000 to 9300 per hectare

3. None of the farmers using Class A system fertilized, while only 20% of those in Class B practiced fertilization

4. Farmers practiced more pest control in cassava planted immediately following clearing

5. Cassava yields in Class A produced 1.5 times yields than cassava followed by another crop

In an experiment with low levels of inputs (no fertilizer, disease or insect control), the highest yields of cassava (21.2 t $ha^{-1}$) were obtained when cassava was weeded 4, 8 and 10 weeks after planting. Beginning weeding after the 10th week significantly reduced yields. A single weeding four weeks after planting resulted in lower yields (15.5 kg $ha^{-1}$) although not significantly lower than the three weeding treatments. It was concluded that the period 4-10 weeks after planting is the most critical one for weed control in cassava.

Cassava - Yam

In an effort to combine a crop with export potential with a traditional food crop of the low elevation humid tropics, an association of true yam with cassava was tested at the Turrialba experiment station. It was shown that only by planting both crops in May and using supports for the yam, could acceptable production of both crops be obtained (13.000 kg $ha^{-1}$ of commercial quality cassava and 13972 kg $ha^{-1}$ of export quality yams).

Plantain - Cocoyam

Increases in productivity could be realized by associating cocoyam with plantains in the year of establishment as this practice did not affect plantain yield with respect to monoculture. The economics of the practice would depend on relative plantain and cocoyam prices with the critical ratios being 2.9:1* and 2.4:1 based on production data over the first two years. When relative prices are above 2.9:1, it is most economic to produce monoculture cocoyam; when relative prices are less than 2.4:1, the more economic practice would be monoculture plantain. When relative prices are between 2.9 and 2.4:1, the association is the most favorable practice.

## Ginger Production Systems

In a cassava-ginger production system, yields of export quality ginger were quite poor (4396 kg $ha^{-1}$) when no weed control was practiced. Yields were increased by 70% by hand weeding at monthly intervals and by 101 and 95% respectively with preemergence applications of diuron at 1.7 kg $ha^{-1}$ and oxyfluorfen at 0.97 kg $ha^{-1}$. However, disease incidence in ginger associated with cassava was greater than in monoculture ginger under high rainfall conditions (3200 mm $yr^{-1}$).

## Yam (Dioscorea) Monoculture

When yams are grown under high input conditions (fertilization, nematode and disease control, and use of stakes), loss in yields due to weed competition principally from grasses was 35% (yields were reduced from 44.8 to 29.2 t $ha^{-1}$). In the 9 months yam cycle, the most critical period for weed control was 4-10 weeks after planting when low growing grasses are the principal weeds.

Four preemergence herbicide treatments (linuron at 3 and 4 kg $ha^{-1}$, linuron at 3 kg $ha^{-1}$ with pendimethalin at 1 kg $ha^{-1}$, oxadiazon at 0.8 and 1.3 kg $ha^{-1}$, and linuron at 3 kg $ha^{-1}$ with alachlor at 1.4 kg $ha^{-1}$) were effective in controlling weeds in non-staked yams for

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* Ratio of price of 1 kg cocoyam: 1 fruit plantain.

five weeks after application, resulting in weed populations of less than 10% ground cover. However, the predominant species of weed, *Rottboelia exaltata*, which germinates over a longer period, subsequently offered serious competition to yam.

## Aroids

Use of large planting pieces produced higher yields of edible aroids Taro (*Colocasia esculenta*) and cocoyam (*Xanthosoma sagittifolium*) but was uneconomic because a high proportion of the production is thus used for seed. Removal of apical buds can regulate the size and number of cormels produced, enabling farmers to adjust production to market preference.

## Sweet Potato Monoculture

Two outstanding sweet potato clones (8523 and 8467) were selected and multiplied. Yields over 55 t $ha^{-1}$ with 82% marketable tubers were obtained with clone 8523 as compared to only 23% marketable tubers in local varieties. A relationship between skin color and commercial root production was established. Red skinned varieties had 94% marketable roots while dark and light skinned varieties had only 75% and 69% respectively marketable roots. Another clone 7170 was selected for animal feeding since it produced more than 50 t $ha^{-1}$ of above ground biomass.

## OTHER PROMISING CROPS FOR THE LOWLAND HUMID TROPICS

### Soybeans

Greenhouse and field studies showed that soybean genotypes differ in their ability to withstand unfavorable conditions associated with flooded soils.

The yield of several varieties increased when the soil was saturated rather than at field capacity.

Continuous flooding reduced yields of all varieties but this reduction was only 25% of yields at field capacity for the varieties SIATSA 194-A and Baru, with productions of 1.7 and 1.2 t $ha^{-1}$, respectively. The latter was also the best adapted to intermitent flooding (1.1 t $ha^{-1}$).

Under saturated soil conditions, the best varieties were Jupiter and PK 7394 with yields above 2.5 ton/$ha^{-1}$.

Four cultivars (Papillon, SIATSA 194-A, TEX 297-192C and TGX 536-100C) under normal (non-saturated) conditions, yield above 3.0 t $ha^{-1}$, showing good potential for LHT conditions.

A seed storage method for small farmers (sealed containers) was tested and identified as a viable alternative; it maintains seed viability up to 6 months, being equally efficient as cold room storage at 15$^{o}$C and 60% relative humidity.

Three genotypes with superior seed storage capacity were identified (TGX 307-047D, TGX 342-356D and TGX 742-02D), all with yields above 2.9 t $ha^{-1}$. Local varieties do not store well.

Interaction between soybean genotypes and storage methods was detected, indicating that finding of an easy screening technique for improving selection for storage capacity will be difficult.

### Winged Beans

Forty-eight lines of winged beans were tested for grain and root production; the best line was UPM-207 with a yield of 4.0 t $ha^{-1}$.

### Groundnuts

Thirty-two lines from ICRISAT with high potential for the LHT were introduced to be tested in soils with low pH; six lines where selected (ICGS (E)-2, -22, -8, 15, -5 and Robust 33-1) with experiment station yields above four t $ha^{-1}$.

### Flooded Soils

A study of adaptation of different crops to flooded soil conditions showed significant differences in performance. Only rice was completely unaffected by negative redox potentials associatied with flooding. Taro and soybean showed a moderate yield reduction due to negative redox potentials, confirming the need of Taro for high oxygen levels when grown under flooding. Liming, to offset Mn toxicity only improved tolerance to flooding in sorghum. Cocoyam showed no ability to tolerate even moderate levels of flooding.

## SEMIARID TROPICS

The area selected to represent the semiarid ecological zone was the department of Esteli, Nicaragua, located between 12°58' and 13°22' N latitude and 86°14' and 86°36' W longitude. The department includes the townships of San Juan de Limay, Pueblo Nuevo, Condega, Esteli, and


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La Trinidad, with a total area of 2173 $km^2$. There is considerable variation in climate and soils in the department; some areas receive less than 800 mm of annual rainfall, while others receive more than 1500. Six soil orders occur in the department, accounting for the following percentage of the total area: Mollisols (31%), Entisols (22%), Alfisols (19%), Inceptisols (13%), Ultisols (13%) and Vertisols (2%).

There are presently over 100.000 ha of farms in the department: there are 33.081 hectares of state-owned farms; 67.814 hectares of small farms, of which 80.6% are smaller than 35 hectares; and 5.042 hectares of privately-owned large farms. Basic grains are produced on some 19.704 hectares, with the predominant production systems being: maize associated with photoperiod sensitive sorghum (Millon), maize in monoculture, two successive crops of bean monocultures, and maize relay cropped with beans. Most of the research in the areas was carried out with these systems or proposed modifications of them, such as substituion of photoperiod sensitive sorghum by non-photoperiod sensitive sorghum.

## FOOD GRAIN PRODUCTION SYSTEMS

### Millon (Photopheriod Sensitive Sorghum)

A collection of local varieties of photosensitive sorghum was made in the Esteli region. This material was compared with introductions form other areas where this crop is grown. In monoculture, the best materials were Criollo (local), Peloton (Honduras), and Esteli 4 (local). For association with maize, the best materials were Esteli (local), Criollo Sapo (El Salvador), and Chaparro (El Salvador), all of which yielded over 3 t $ha^{-1}$.

## Photoperiod Insensitive Sorghum

Work with this crop began in 1982 with the introduction of 52 varieties from the ICRISAT program in Mexico, as well as 111 experimental lines from ICRISAT in India. From this material, 10 lines were selected in 1983 for testing in 12 sites in 1984. From these trials, 3 genotypes (ISIAP Dorado, Selection SC-108-3XE and M5009) with yields of over 3 t $ha^{-1}$ were selected for validation trials in 1985 under the supervision of the Nicaraguan land reform and rural development agency.

## Maize Monoculture

NB-4, a late maturity variety, is recommended for monoculture due to its excellent stability over a wide range of environments (mean production of 5.7 t $ha^{-1}$). Other recommended late maturity varieties (white and yellow grains) for the Esteli region of Nicaragua are: Ilonga 8043, Across 8024, Piura 8224, Across 7622-Re, Los Baños 8027 and Santa Rosa (1) 8243; all of them with production above 6.3 t $ha^{-1}$ at research trial level.

While several local varieties, collected by the project, such as Esteli #2 and #6 and Jalapa #2, #8, #9, all with yields over 5.6 t $ha^{-1}$, also performed well in trials in the Esteli area, it would seem that higher yields could be obtained through the use of improved maize, which demonstrated greater yield stability, uniformity, and consumer preference.

CIMMYT drought selection C-4 produced over 6 T $ha^{-1}$ in a trial in a dry area of Esteli although rainfall was somewhat higher than average in the year of the trial.

## Maize - Photoperiod Insensitive Sorghum

Fertilization of improved (photoperiod insensitive) sorghum following maize was studied in three typical soils of the Central American semiarid tropics (Vertic Haplustolls, Typic Ustorthents, and Typic Hapludalfs). In all cases, application of 30 kg $ha^{-1}$ of N was highly economic. Higher levels were not economical. Phosphorus response differed according to soil type, being highest on the Entisol where 60 kg $ha^{-1}$ of $P_2O_5$ was economically justifiable, smaller on the Hapludalf, where the response was significant but not economically viable, and statistically insignificant in the Haplustoll. Response to potassium was only observed in the Entisol. For photoperiod insensitive sorghums following maize 30 kg $ha^{-1}$ of N can be recommended for all soils of the area while applications of phosphorus and potassium can only be recommended in the Typic Ustorthents which occur in the municipality of Pueblo Nuevo.

An economic study of this system, which is practiced on some 200.000 ha in Central America, produced the following results: average profit was $141.24 per hectare. Labor represented 54.7% of the costs, followed by 22.0% for services, 13.2% fixed costs and 10.1% for purchased inputs. The cost benefit ratio for the system was 1.24. The return per day of labor was $3.47, much higher than the average labor cost in the area ($2.72 per day). Return for capital invested in inputs was $1.04.

## Maize - Photoperiod Sensitive Sorghum

Substitution of the traditional varieties of maize and photoperiod sensitive sorghum (Millon) by materials introduced by CATIE from El Salvador (the improved maize variety M3B and the sorghum cultivar Criollo Sapo) and an increase in the $N$-$P_2O_5$-$K_2O$ fertilization from 45-39-13 kg $ha^{-1}$ to 51-58-4 kg $ha^{-1}$ resulted in a total grain yield of 4433 kg ha-1, 35% higher than that obtained in the traditional system. The improved system had a cost-benefit ratio of 4.7:1 as compared with 3.7:1 for the traditional system.

Phosphorus response was most consistently observed in maize and photoperiod sensitive sorghum in soils derived from volcanic material (Typic Ustorthents). In mollisols, maize exhibits a small response to phosphorus while in those with more vertic properties, response to phosphorus was smaller. There was no response to sulfur in the Entisols but in the mollisols, there was some evidence of an P x S interaction.

Several important aspects of plant competition in the maize-photoperiodic sorghum system used extensively in the Pacific zone of Central America, were investigated. Later planting of sorghum increased maize yields but decreased sorghum yields. Replacing of photoperiod sensitive sorghum by photoperiod insensitive sorghum, which is planted later, increased maize yields but may result in no sorghum yield at all if rainfall is inadequate in the latter part of the rainy season, as it often is. Another advantage of photoperiod sensitive sorghum is its greater biomass production, used in animal feeding.

As a result of experiments in which competition was reduced by eliminating maize and sorghum plants at different stages of development and in which water was supplied by irrigation, it was concluded that much of the adaptability of photoperiod sensitive sorghum is due to its ability to accumulate dry matter slowly over a long period even under conditions of low moisture availability. Thus, its biomass and grain production could not be increased by later planting or with supplemental water even though these practices increased maize production. Cutting off the sorghum at ground level, 45 days after planting increased maize yields and the sorghum recovered to produce almost 2 t $ha^{-1}$ of grain.

Photoperiod Insensitive Sorghum - Bean

Research on the sorghum-bean association, less frequently practiced than the maize-sorghum system but more adapted to drier areas, revealed advantages for the traditional photoperiod sensitive sorghum in terms of biomass and sorghum grain production. Two plantings of beans invariably produced more beans than a single planting, but sorghum yields were always reduced by a second bean planting. The first planting of beans and sorghum invariably produced more grain than the second plantings indicating the importance and greater reliability of the early rains even though late rains may bring more total precipitation.

Bean - Bean System

Use of 1.5 qq Mz of 12-44-3 fertilizer and 0.5 qq Mz urea in place of 2 qq/mz of 12-44-3, the traditional practice in the area, reduced production costs by $44.50 per hectare with the Revolution 79 bean variety. This system had a cost-benefit ratio of 6:1 compared with 3.4:1 for the traditional fertilization with the Chile Rojo variety.

Average profit of the system was $166.62 per hectare. Labor represented 53.7% of the total cost, followed by 17.2% for services, 16.8% for purchased inputs and 12.3% for fixed costs, the cost benefit ratio was 1.33. The return per day of labor has doubled the average labor cost in the area when the study was made. Return of capital invested in inputs was $1.24.

None of the preemergence herbicides at the rates and combinations studied (linuron 1.0 to 2.0 kg $ha^{-1}$, alachlor at 1.0 to 2.4 kg $ha^{-1}$, pendimethalin 0.7 and 1.3 kg $ha^{-1}$ and combinations of linuron 1.0 and alachlor 1.0 or pendimethalin at 0.7 kg $ha^{-1}$ and linuron at 1.5 kg $ha^{-1}$) caused phytotoxicity to bean cultivar, Revolution 79, planted in a Vertic Haplustoll irrigated soon after planting. However, these herbicides failed to control the broadleave weeds, especially *Bidens pilosa*, which predominated in the system.

Genotype selection in beans was a major activity of the project since its initiation in 1982. Material was brought from CIAT and Central American National Programs and compared with materials collected.

In 1984, 133 materials were tested and a selection of local and improved materials was made for on-farm testing in the second planting. Of this material 6 local varieties (Chile Rojo, Rojo Pardo, Mono Esteli, Rojo Seda, Chile Ligero and Rojo Musuli) and two improved lines (H772202-62CMCM and BAT 1514) were selected, all of which yielded over one t $ha^{-1}$ and showed better yield stability than the previously recommended materials, Rojo Nacional and Revolution 79. These selections are presently recommended to the land reform and rural development agency for validation.

## Pearl Millet

Introductions of pearl millet made in 1982 did not prove an attractive alternative to farmers in the region. In terms of biomass production, the pearl millet was comparable to the photoperiod sensitive sorghum traditionally used in the area. However, it could not accumulate dry matter over a long period of erratic rainfall as could the photoperiod sensitive sorghum and the grain was not an acceptable substitute for sorghum.

## Soil Conservation

Higher yields of beans, maize, and sorghum were obtained on a Typic Hapludalf with 14% slope when barriers of different materials were constructed along the contours. The best barriers were agave, leucaena, and stone walls.

The use of stone walls following the contour not only increased yields of maize, beans, and sorghum but provided a guide for ploughing and planting along the contour and reduced stoniness. It was readily accepted by farmers who constructed such barriers on their own initiative in areas adjacent to the experimental plots.

## WET DRY TROPICS

The area selected to represent the wet-dry tropics ecological zone was the districts of Los Santos and Guarare in the Los Santos province of Panama. It extends from N latitude $7^{\circ}15'$ and from $79^{\circ}45'$ to $81^{\circ}41'$ W longitude. Altitude varies from 100 to 300 meters above sea level, and rainfall varies from 1000 to 1500 mm annually, with 5 dry months. Most of the soils are Tropepts.

The two districts occupy a total of 534 $km^2$ and contain 4772 farms. About half of the area is used for agriculture. The principal crops are maize, tomato for processing, rice and onions. Most of the farmers in the area try to produce vegetables with irrigation but both the marketing and irrigation infrastructure are poorly developed.

A total of 19 crop production systems were identified in the characterization of the area; of these, four were selected for improvement: 1) tomato or onion followed by maize for fresh ears; 2) monoculture maize for grain; 3) rice-vegetable rotations and 4) rain-fed onions.

The chief problem in the tomato or onion maize rotation are excessive fertilization for the vegetables and a general lack of knowledge of how to manage the maize crop following vegetables.


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Similar questions about land preparation appears to be limiting to the monoculture maize system. The chief problems in the rice-vegetable systems are weed control and lack of adequate irrigation. The main justification for producing rain-fed onions is the lack of availability in local markets during the month of August.

## Tomato - Maize System

Planting maize without tillage following harvest of the processing tomato crop reduced land preparation cost by 40% as compared with traditional practices and did not affect yield or fertilizer response of the two recommended maize varieties (Across 7728 and X-304-C). Highest yields and returns were obtained using the hybrid X-304-C with 68 kg $ha^{-1}$ of urea.

## Rice - Vegetable System

Of eight locally used rice cultivars tested, Gorila and Melena are recommended because of their higher yields, resistance to lodging, and earliness, which leaves more time for the vegetable crops.

If the rice crop follows vegetables, the only fertilization necessary is 68 kg $ha^{-1}$ of urea at seeding and an additional 68 kg $ha^{-1}$ 60 days later.

It is recommended to double the presently used plant density by planting the rice at a row spacing of 0.3 to 0.35 m, leaving 0.3 to 0.35 m between hills.

In dry years, 3 supplementary irrigations: during vegetative development, at flowering, and during grain fill are recommended to reduce risk and increase cost benefit ratios.

In onions, the recommended weed control practice is an application of pendimethalin (3.5 L c.p. $ha^{-1}$) pre-transplant and an application of oxyfluorfen (1-2 L c.p. $ha^{-1}$), which will control the grassy weeds, *Rottboelia exaltata* and *Echinocloa colonum* as well as the broadleaves (*Melampodium divaricatum* and *Caperonia palustris*).

## Rain - fed Onions

The recommended production alternative for rain-fed (non-irrigated onions) is to use Granex 429 variety, transplant either on May or from September to November, and plant in two rows per bed (60 cm wide, leaving 10 cm between plants).

## Maize - Pasture System

For maize to be alternated with a grazing system, where a previous vegetable crop is not planted, the method of land preparation used for the tomato-maize system is recommended but the fertilization for the maize hybrid X-304-C should be increased to 181.8 kg $ha^{-1}$ of 12-24-12 and 90 kg $ha^{-1}$ of urea.

## Sweet Pepper - Fallow - Maize System

Highest yields of sweet pepper and lowest dry weight of weeds were found in plots treated in early postransplanting with chloramben 3.5 + devrinol 5 kg/ha, or with devrinol 8 kg $ha^{-1}$ by itself when the predominant weed species were grasses (*Digitaria sanguinalis* and *Echinocloa colonum*).

The herbicide oxyfluorfen 0.6 kg $ha^{-1}$ and the combinations including linuron 2 kg $ha^{-1}$, applied at early postransplanting over the crop caused severe phytotoxicity to the sweet pepper plants.

## TRAINING

IFAD support enabled the expansion of the CATIE graduate program to include courses in soil physics and management, plant breeding, and agroecosystems not previously offered.

Eight of the 33 graduate theses produced by the Plant Production Department from 1982 to 1985 received IFAD support.

A total of 1200 professionals received training from IFAD during the period of the grant (53 short-courses). Sixty five percent of these courses were given outside of Turrialba.

IFAD support enabled the PPD to offer three 12-14 week courses in farming systems research. A total of 65 professionals from Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, Peru, Panama, Bolivia, Brasil, Dominican Republic, Paraguay and Colombia, completed these courses.

The IFAD support to PPD, in the form of specialists paid by the grant, experience gained in grant activities, and the presence of a training coordinator permitted the formation of a graduate curriculum with four areas of specialization (soils, plant protection, plant science, and production systems) in the PPD.

A three week intensive course on weed management in systems of production of small farms was offered to professionals of national institutions for nine Central American and Caribbean countries. Professors from 12 different nations taught in the course which was jointly financed by FAO, the International Plant Protection Center of Oregon State University and CATIE.

## INSTITUTIONAL SUPPORT

The IFAD grant financed the computarization and indexing of the 2000 papers presented at meetings of the PCCMCA (Cooperative Central American Project for the Improvement of Food Crops) from 1954 to 1981. Most of the research on food crops done in Central America is reported at these meetings and having this data systematized has made these results readily available for the first time to researchers within and outside the region.

The work in tolerance to flooded soils required the realization of certain analyses not previously carried out at CATIE. Thus a capacity was developed to determine exchangeable manganese, water soluble manganese, readily reducible manganese, redox potentials and oxygen diffusion rates.

Several pieces of equipment were acquired by CATIE under the IFAD grant to improve its research capability in areas where rainfall is limited. These included a plant water status console, an infrared thermometer, pressure plate aparatus, electrical resistance blocks and meters, standard evaporation tanks, recording rain gauges, and pyranographs.

Data processing was also improved by the purchase of two microcomputers. Equipment for slide reproduction and preparing of audiovisuals increased capability for training and outreach activities.

### Seed Multiplication and Distribution

The genotype evaluation component has also collaborated in the conservation, multiplication, and distribution of the material which performed best in trials or in which there was research interest either at national or international level. Seed has been supplied for research to CATIE personnel not involved in the IFAD project. The genotype component has served as a linkage between national programs and international organizations for obtaining and distributing germplasm of different crops. A small germplasm bank exists, containing presently some 600 introductions of various crops. The principal objective of this bank has been the conservation, multiplication and distribution of material to researchers. Seeds are available of *Phaseolus vulgaris*, *P. lunatus*, *Dolichos* sp., *Canavalia* spp., *Vigna* spp., *Psophocarpus tebragonolobus*, *Arachis hypogaea*, *Glycine max*, *Cajanus cajan*, *Sorghum bicolor*, *Zea mays*, *Oryza sativa*, and *Manihot esculenta*. During 1984-85, more than 200 shipments of planting material were made to countries in the area.

## OUTREACH

A cropping systems working group was formed for the six Central American Countries. This group met in September, 1983 in Turrialba and in July, 1984 in Guatemala city. The first meeting served to discuss the institutionalization of the CATIE farming systems research methodology. The second meeting focussed specifically on problems of validation and technology transference, as many of the Central American countries are presently involved in these aspects of farming systems research.

Among the resolutions of the first meeting were the encouragement of the formation and training of multidisciplinary teams of research by national institutions. It was felt that they should be integrated with the rest of the public agricultural sector. CATIE could participate in such training through its graduate program and short courses.

The second meeting identified specific problems in validation and technology transfer activities. There were problems in selection of personnel, obtaining background information, selection of farmers for participation, and analysis of data obtained. It was felt that CATIE could provide guidelines for activities in these areas.

The outreach coordination activities under the IFAD grant have included:

1. Contacts and consultancies with technical personnel and authorities in different institutions of the countries of Central America and the Caribbean

2. Representation of the Plant Production Department in scientific meetings, seminars, and field days

3. Coordination of activities of the Department outside of Turrialba especially of the prototype teams

4. Evaluation of other farming systems activities of CATIE in the Central American countries

5. Organization of the cropping systems working group among farming system researchers of the area

6. Participation in support research activities in the lowland humid tropics in the area of cropping systems snd soil management