MULTIPLE CROPPING IN TROPICAL AMERICA

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In Tropical America, as in most other parts of the developing world, improving agricultural production is viewed as an immediate goal to avert severe food shortage and, in the process, to contribute to the betterment of rural life. A possible way to achieve this goal is the development and adoption of more efficient systems of crop production.

This paper focuses on multiple cropping, in practice and research, as a means of increasing food production in Tropical America, especially at the small farmer level. Implicit in this objective is the improvement of rural life through balanced nutrition, higher and more even distribution of income, fuller utilization of hand labor, protection of the environment, and upgrading of general well-being.

DEFINITION AND CHARACTERISTICS OF TROPICAL AMERICA

Tropical America is defined as the geographical area between the Tropic of Cancer and the Tropic of Capricorn (23°30' lat. N and 23°30' lat. S). Argentina, Uruguay, Paraguay, and Chile are the only Latin American countries not considered as part of the tropical area. The ecological background of the American Tropics was summarized by Duckham and Masefield (1).

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Regarding farming systems, Tropical America can be divided into three altitudinal zones (2).

1. The lowlands: the area from sea level to 1000 m altitude, with a mean annual temperature of 24-30°C and a mean annual rainfall of over 2000 mm which is distributed in two major patterns (one being an almost continuous wet season throughout the year and the other a definite 6-7 month very wet period alternating with a 5-6 month dry season).
2. The middle or temperate lands: the area from 1000 m to 2000 m altitude, with a mean annual temperature of 18-24°C and a mean annual rainfall of 1200 mm, which has a marked 3-6 month dry season a year.
3. The highlands: the area above 2000 m altitude, with a mean annual temperature below 18°C and a mean annual rainfall of less than 750 mm, which is also characterized by a marked but longer (6-8 month) dry season during the year.

Contrary to what may occur in other tropical regions of the world, the areas of high rural population, comprising mainly small farmers, are primarily located in the middle land and highland regions such as the Central tablelands in Central America and the Andean Plateau in South America. Agriculture in Latin America is known to have originated in these areas through the rise of the Maya Civilization in Mexico and Guatemala yin Central America and the Inca Civilization in Peru and Bolivia in South America (3, 4). In turn, the rooting of these civilizations and consequent high concentration of population in the middlelands and highlands was encouraged by, among other factors, the milder climatic conditions and higher and more stable fertility of the soils there than in the lowlands. Competition from high population density has forced more intensive use of available agricultural land. Under such conditions multiple cropping tends to be practiced more widely. On the contrary in the lowlands, mainly in South America, many variants of the old shifting cultivation system can still be observed where population pressure on agricultural land is light.

THE SMALL FARMER AND CROP PRODUCTION

A small farmer may be defined as one who operates a production unit of less than 7 hectares (5) and practices traditional crop husbandry methods. The vast majority of small farmers may also be classified as the poorest group in rural Tropical America. Since the small farmers are so numerous, they play an important role in the economy of Tropical America. This large contribution occurs even though their crop yields are much lower than those reported by local experimental agricultural stations or by large commercial holdings dealing mainly with pure stands of a single crop.

Generally, industrial or large market-oriented crops such as coffee, bananas, cacao, sugar cane, cotton, and rice are produced on large to medium (> 10 ha) farms, under advanced technology, which includes the use of machinery, fertilizers, pesticides, and other high cost inputs. One the other hand, traditional basic food crops such as maize, bean, cassava, quinoa (*Chenopodium quinoa*) and others are produced on small to very small (< 10 ha) holdings, following traditional farming practices, in which fertilizers and other expensive inputs are scarcely or not used at all.

Statistical data show that 80% of the farms in Guatemala, 85% in El Salvador, 60% in Honduras, 43% in Nicaragua, and 46% in Costa Rica, belong to the small farm category (6). In Colombia, about 70% of the food consumed in the country is produced by small farmers, and 65% of the farms measure less than 10 hectares each (5). The percentage of small farmers may be even higher in the Andean plateau. For example, in Bolivia the rural sector comprises approximately 3.8 million people or about 70% of the whole population; the larger portion, approximately 85% of the rural population, is concentrated in the "Altiplano" or Andean plateau and in the valley (middlelands), under marked small farming conditions or "minifundio"; the remaining 15% is located in the lowlands, also under conditions of small scale farming (7).

MULTIPLE CROPPING IN PRACTICE

One of the features that characterize the small farmer in Tropical America is his intensive use of the land. He normally grows more than one crop a year under a wide range of multiple cropping systems. Those encompass sequential cropping and intercropping. These two groups of systems are often combined in many ways (mixed cropping).

It is well known that the Maya Indians in Central America and the Incas in South America grew their maize and bean either sequentially or in mixed cropping systems, as it is still being done in several areas in Tropical America.

Where sequential cropping is practiced we have noticed that usually two to three different basic food crops are grown during the year. If very short season crops, especially vegetables, are included in the system, the number of croppings per year may be higher than three. Also some grain crops, such as field bean and maize, are often harvested in the green stage to make room for subsequent croppings. Sequential cropping tends to apply more to the large and medium than to the small farmer.

In the intercropping system, the central or primary crop can be fairly typical of a region. Thus, in Central America it may be maize (8), whereas in the Amazon Basin and the lowlands of Colombia and Venezuela it may be cassava (9).

The contribution of intercropping in bean production alone was found to be 50% in El Salvador, 85% in Colombia, 58% in Mexico, and 80 in Brazil (10). Also in El Salvador, sorghum is almost exclusively produced intercropped with maize (11).

Intercropping of a food crop such as bean and an industrial crop such as sugar cane has been practiced or is receiving more attention in Tropical America. Also in fields of slow growing perennial species, such as plantation (cacao, coffee, or rubber) crops, timber, or fruit trees, many annual food crops may be interplanted, to provide subsistence food along with weed control and shade to the young seedling of the perennial crop. For example, a study made in the coffee growing area of Colombia in 1955-56 demonstrated that 33% of the coffee farms were intercropped (12). The more frequently intercropped food plants were plantains and other edible bananas, followed in importance by sugar cane, cacao, vegetables, and fruits.

We have noticed that the diversity and number of species intercropped by the small farmer on his plot tends to increase from the lowlands to the higher land regions. Thus in the lowlands maize, sorghum, cassava, cowpea, and pigeon pea are often the principal crops. In the middle lands and highlands, besides the ubiquitous maize and bean, one finds yams (*Dioscorea* sp.), sweet potato, irish potato, various cucurbits and other vegetables, among the most important crops. Especially in the Andean regions, quinoa, ulluco (*Ullucus tuberosus*), oca (*Oxalis tuberosa*), chili pepper, broad bean, wheat, and barley are frequently found in the farming systems (13).

MULTIPLE CROPPING IN RESEARCH

Only very limited systematic research has been carried out in Latin America to improve or develop agricultural production systems which are adjusted to the specific ecological, social and economic conditions of a region. Special attention has rarely been given to the working conditions of the small farmer.

At the beginning of the 1970s, the diffusion of multiple cropping research results from other parts of the world, especially the Philippines (14, 15, 16) stirred strong interest in the study of multiple cropping in Tropical America, with emphasis on small scale farming. Such interest has received institutional endorsement at several national and international Centers. The results of research carried out at these centers, in the area of production agrosystems, are just coming out or receiving widespread publicity. We will only briefly review here some of the multiple cropping studies that directly relate to the production of annual food crops, especially those that are basic components of traditional diets in Tropical America.

Annuals with annuals

Experimentally, 14 cropping systems were practiced over a nine-year period in Palmira, Colombia (17). Of particular relevance here were four, that spanned a one-year cycle. They were: 1) sequential maize (M-M), 2) continuous soybean (S-S), 3) maize followed by soybean (M-S), and 4) soybean followed by maize (S-M). The results showed that maize in rotation with soybean maintained high yields, similar to those of sequential maize fertilized with nitrogen.

Data from an experiment on continuous (sequential) cropping without fertilizers, with upland rice or with sugar cane, for five consecutive years, on an alluvial soil near Santa Cruz, Bolivia, cited by Sánchez (18), indicated that there was no important reduction in yield during the period. The highest yield of rice was obtained in the fourth year, and that of sugar cane in the first. A report of an experiment in Yurimaguas, Peru (19) showed also that there was no considerable yield reduction in the first four out of five continuous crops of upland rice. The third crop was actually better than the previous ones, perhaps due to a better rainfall distribution.

An experiment was planted at Turrialba in a soil of volcanic origin to test five cropping systems at three soil fertility levels (19). Food crops were included in three of the systems. The first was a rotation of bean, rice and maize; the second, maize intercropped with bean, followed by two additional maize crops; and the third, an intercropping of cassava and bean, followed by rice. Rice failed in the study due to the blast disease caused by Pericularia orizae, making it difficult to evaluate the systems as originally planned. However, yield comparison between bean grown alone and bean intercropped with cassava or maize indicated that the cassava crop had no effect on bean yield, while maize reduced it down to nearly one-third.

Lépiz (20) reported data from an intercropping trial of maize and bean, carried out in Chapingo, Mexico, for three consecutive years. He used a single fertilizer level (80-40-0) and different population densities for each crop, including the density of the traditional maize-bean system of the small farmer (20,000 maize plants and 20,000 bean plants per hectare). Intercropping at various seeding densities, including those traditionally adopted by the local small farmers, resulted in grain yields and income superior to those of the respective single crop grown under optimum densities as established in technical recommendations for the area.

A scheme based on intensive relay planting of dry bean and vegetables in maize was tested by Hildebrand and French (21) in El Salvador. Agronomically as well as socio-economically it was shown to be, on balance, a potential improvement of the traditional systems practiced by the small farmer in that country.

Flor and Francis (22) presented results from agronomic and economic experiments of bean (F) and maize (M) row intercropping in Palmira, Colombia, under different spatial or chronological arrangements. Using as reference the monocrops of maize (44,000 plants/ha = 100% M) and bean (222,000 plants/ha = 100% F), we calculated that, in one experiment, the land equivalent ratio (LER) values for agronomic production associated with 100% M + 50% F (in two distinct spatial arrangements) or 100% M + 100% F ranged from 163 to 189. The association involving a full plant stand of maize and bean (100% M + 100% F) was the best. In another experiment any one of four ways of row intercropping 44,000 plants/ha of maize and 222,000 plants/ha of bean, produced about twice as much gross income as the bean monocropping at 222,000 plants/ha; there was no maize monocropping. In the last experiment reported in that same paper, a calculation of agronomic LER values would show that maize relay-planted 5 to 15 days after the sowing of bean (F/M) was a better practice than bean relay-planted 5 to 15 days after the sowing of maize (M/F) or than bean-and-maize row intercropping (F + M); both relay and row intercropping were better than monocropping with either crop. Basically similar results were obtained in intercropping studies on pole bean and maize carried out in Palmillas within the scope of the pPuebla Plan, Mexico (23).

A more comprehensive study of farming systems for the American Tropics has been initiated by the Tropical Crops and Soils Department of CATIE at Turrialba, Costa Rica, in which various crops and cropping systems are compared agronomically and socio-economically. In one of the Department's field experiments established in November 1973 in Turrialba, 54 crop patterns based on maize, bean, rice, cassava, and sweet potato were tested at up to four levels of technology, thus forming a total of 216 different "cropping systems". In all the systems, sowing density per crop was maintained uniform.

Data of 25 systems, selected as representative of the different cropping patterns, with maize (M), bean (F), cassava (Y), and sweet potato (C) were reported (24). Systems with rice were not included in the report because this crop was completely lost due to adverse climatic conditions and severe damage by diseases and soil insects. Moreover, the report considered only two levels of technology, low and high, differing in the amount of inputs used, such as fertilizers and pesticides.

As rated by their LER value, the majority of multiple cropping systems were more efficient than their monocrop analogues in producing food and total biomass. The most outstanding were: 1) the rotation of bean with two subsequent crops of maize (F-M-M); 2) the intercropping of bean with maize followed by a crop of maize (F + M-M); 3) the intercropping of bean with cassava followed by maize (F + Y-M); and 4) the intercropping of maize with cassava followed by sweet potato (M-Y-C). Food and total biomass production, both in monocropping as well as in multiple cropping, were greater at the higher technology level. At the same time, within each technology level, multiple crops yielded more than monocrops and utilization of solar radiation was increased by multiple cropping and high level of technology.

Fertilizer use was perhaps the most important factor determining the best yields in high technology. In decreasing order, the efficiency of the major nutrient elements, measured as the ratio of amount of nutrient applied to amount of food produced was [illegible] > P.

The multiple cropping systems were more efficient than monocropping in suppressing weeds.

Airborne diseases were more evident and their consequences more serious in monocrops than in multiple crops, where some species acted as natural barriers against spore dispersal. On the other hand, some multiple crop patterns favored a microenvironment with high relative humidity and shade, leading to the development of other types of diseases.

The multiple cropping systems in general permitted a broader utilization of hand labor and were more profitable than monocropping.

Annuals with perennials

In his textbook on cacao, Hardy (25) stresses that in the early stages of field establishment, cacao needs the protection of temporary shade plants, row intercropped with the cacao seedlings. For this purpose many food crops such as maize, pigeon pea, cassava, malanga, and especially bananas and plantains, can be utilised.

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Among various food crops intercropped in a young rubber (*Hevea brasiliensis*) plantation on the Atlantic Coast of Costa Rica (26), maize or cassava gave the best economic and agronomic results. Besides producing food for local consumption, the practice of intercropping helped save an average of $24/ha in hand labor, particularly for weeding, during the first two years of establishment of the rubber plantation.

Experiments carried out in Puerto Rico on intercropping sugar cane with various crops (27), showed that planting distances influenced the production of sugar, regardless of whether the cane was grown alone or intercropped. Yields of intercropped legume species, such as soybeans, red or white beans, and cowpea were satisfactory. Intercropped cucumber, melon, or tomato did not reduce sugar cane yields. However, the intercropping of cane with maize reduced sugar cane production.

Two other trials of intercropping sugar cane with common beans and cowpeas were conducted in Pernambuco, Brazil (28). Results were inconclusive as to the best distance of rows in the intercroppings. Pulse yields in the intercropping treatments were lower than in the corresponding monocroppings, but there was no reduction in sugar cane production.

Also in Pernambuco, Mangueira *et al* (29) conducted two experiments for five years in Serra Talhada Station, to review previous inconclusive experimental results reported by other researchers on the relative efficiency of the traditional system of cotton (*Gossypium hirsutum*) production in the Northeast region of Brazil. The system involves intercropping of cotton (C) with common bean (B), maize (M), forage Opuntia (O), or sesame (S). In the first experiment were tested cotton as a monocrpp (C), cotton intercropped with Opuntia (C+O) and cotton intercropped with maize and beans (C+M+B); in the second, the treatments were cotton as monocrop (C), intercropping of cotton with maize and beans (C+M+B) in two row patterns of the maize and bean crops, intercropping of cotton with sesame (C+S), and intercropping of cotton with maize and forage Opuntia (C+M+O). During the five year period cotton yields in general were higher in the intercropping than in the monocropping systems, excepting intercropping with sesame.

Taungya system experiments with eucalyptus in Brazil (30), and with Cordia alliodora, Cupressus lusitanica, Swietenia humilis, and teak (Tectona grandis) in Turrialba (31), have shown that intercropping the timber species with food crops during the first years of establishment of the plantation yielded many economic advantages, including the saving of labor in weed control.

PROPOSED TRENDS IN MULTIPLE CROPPING RESEARCH AND PROMOTION

At present, the majority of Latin American governments are giving top priority to the improvement of the standard of living of their rural populations, particularly at the small farmer level. However, and in spite of the importance of the subject, only very limited information is available about the small farmer's real situation.

In traditional scientific spheres there is a general belief that the small farmer is a subsistence group, producing only for home consumption. In Latin America, however, although a good portion of the small farmer's crop production is consumed by his immediate family, a sizable portion of it is always sold to obtain cash for satisfying other needs. Among many of the small farm products that find their way to the urban markets are beans, maize, cassava, sweet potatoes, vegetables, plantains, and yams which generally are not grown by the large of medium-sized farmers.

On one hand a variety of traditional production systems, which have remained unchanged for decades or longer, are still practiced by a large number of small farmers in Tropical America in spite of the existence of the much heralded "modern technology". On the other hand, the local agricultural experiment stations can be seen testing new technological packages, with resources and approaches totally different from those of the small farmer across the fence. Concern is often voiced about the lack of adoption by the small farmers of the experimental results published by the stations, but in general only scant effort has been dedicated to the analysis and lessening of such discrepancy. A common a priori judgment has been that what the small farmer practices is primitive technology and should be simply wiped out.

However, experimental results from testing some of the small farmer's production systems, as briefly reviewed here, show or imply several advantageous features.

Even with low technology, total production of an area under intercropping is more profitable than under monocropping. The use of intercropping ensures food production against abrupt climate, pest, and price fluctuations. Multiple cropping systems are better adjusted to the small farmer's available resources, such as abundant hand labor, lack of capital for buying inputs, permanent availability of solar energy, and limited land area. Intercropping or rotation systems by involving different species, that often present differential reactions to diseases and insects and provide better ground cover, allow a more efficient management of diseases, insects, weeds, and soil and better use of solar energy. Also, the growing of a large array of different crops in the year offers broader diversification of food products.

From these and other considerations, it seems urgent that a new research approach be adopted to produce technology more useful to and acceptable by the small farmer.

The development of new technology on farming systems needs a team approach with specialists in at least the areas of ecology, biology, agriculture, economics and sociology, all working toward the development of sound agricultural systems, adjusted to the tropical climate and to the socio-economic conditions of the farmer.

Plant breeders should develop earlier varieties with plant architectures adapted so as to complement and not to compete with each other for resources when grown in multiple cropping schemes. Special attention should be given also to the selection of genotypes that are more productive and less dependent on large amounts of fertilizers and water and are insensitive to day length. New types and formulae of fertilizers best suited for intercropping and rotation under the climatic conditions of Tropical America need to be developed. Special emphasis should be placed on the economic use of fertilizer along with consideration of methods and times of application. Moreover, the mineralization of crop residues should be taken into account to cut down still further the amount of commercial fertilizers required.

More integrated control methods of diseases, insects and other pests (including weeds), with a minimum use of chemicals, have to be developed. The outlook seems promising through the combined practice of intercropping, rotation, and use of resistant varieties along with appropriate timing of planting.

For intercropping more research should be done on planting densities and planting chronology.

In developing farming systems for small producers, testing for yield stability through crop management has to be of foremost importance as its lack has been the main feature of the shifting cultivation in the tropics.

Some other studies should involve crops (annual and perennial, and food and non-food species) and animals, evaluating income stability of the farming systems.

Because the small farmer in Tropical America ordinarily respects traditions and possesses a low level of literacy, great care must be taken in transferring to him research results. Considerable and direct technical assistance, especially in the early phases of the process of technology transfer will be required. Adoption by the small farmer of new techniques is likely to be easier the more he directly participates in the development of such techniques, is convinced of their practical value, and finds them compatible with his beliefs.

In Tropical America, like elsewhere, multiple cropping research and practice in itself will not substitute the need for profound social and political reforms to lessen social and economic disparities. But, looked at from many angles, multiple cropping is, on balance, a most promising means of utilizing resources. It is an essential lever in engineering stepped-up food production programs to avert world famine and consequent social and political turmoils.

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