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PRODUCTIVE POTENTIAL OF AN ANNUAL INTERCROPPING SCHEME IN THE AMAZON

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ABSTRACT

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A multiple cropping system, modeled after the traditional planting scheme of the local farmers, was the basis for an experiment conducted on a Typic Paleudult near Yurimaguas, Peru. The system utilized intercropping and relay planting to produce four and five crops per year in 2 consecutive years. One objective of the study was to quantify the effect of 1-, 2- and 3-m row spacing of the tall component crops, corn (*Zea mays* L.) and cassava (*Manihot esculenta* Crantz), interplanted with short-statured companion crops. The latter were soybeans (*Glycine max* L. Merrill) and cowpea (*Vigna unguiculata*) in the 1st year and upland rice (*Oryza sativa* L.), peanuts (*Arachis hypogaea* L.) and cowpeas in the 2nd year. Monoculture checks were grown simultaneously with each of the intercrop components. The effect of various N rates on the productivity of each cropping pattern was also studied.

As the row spacing widened, corn and cassava yields decreased while yields of the short companion crops increased. The 1-m intercropping pattern was 30% more efficient in producing crop yields than the corresponding monocultures, as measured by the area-time equivalency ratio (ATER = 1.3). This treatment also produced income and calories at a rate equal to or higher than monoculture rotations or the individual monoculture checks. The 2- and 3-m intercrops produced income, calories and protein at rates similar to the monocultures, and had ATER values near unity. Only corn (in both years) and soybeans (in the 1st year, non-nodulated) responded to N applications. ATER values were not affected by N application rates. The rate of production of income, calories and protein by the intercropping system increased with additions of N in the 1st year but not in the 2nd.

A multiple cropping system such as used in this experiment (with 1-m row spacing) would be equally or more productive biologically, economically and nutritionally than the corresponding monocultures and may provide other benefits such as greater income stability, reduced weed pressure and reduced susceptibility to soil erosion.

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INTRODUCTION

Mixed cropping is commonly practised in the tropics, especially by small-scale, subsistence farmers. In recent years, researchers have attempted to analyze and improve on this practice (Papendick et al., 1976; Sanchez, 1976). Generally they have focused on two-crop intercrops, i.e., mixing of two crops in certain row patterns and/or populations. Work reported by Finlay (1974) and Herrera and Harwood (1974) indicates that the more intensive or intimate this interspecies competition, the more likely there will be an intercropping productivity advantage over monoculture practice. Also, there is evidence that applied nutrients, particularly N, can affect the performance of intercropped mixtures (North Carolina State University, 1974; Palada and Harwood, 1974).

The growing season at Yurimaguas, Peru in the Amazon Basin is year-long. Local farmers commonly plant rice alone or with corn at the beginning of the rainy season in recently cut and burned fields. After a few weeks, cassava and plantain are relay planted among the rice seedlings. These interfere very little with the rice as they begin to grow. After rice harvest, the cassava and plantain are in, or approaching a period of rapid growth and quickly develop a new canopy. These crops are then harvested during the next 6—12 months.

The purpose of this study was to study a quantified, year-long intercropping system based on the concept of relay planting for continuous crop growth. This involved imposing different row spacings of the taller crops (relay-planted corn and cassava) on solid standards of various short-statured crops. A nitrogen fertilizer variable was included to determine the effect of N on the intercropping system.

METHODS

The experiment was conducted at the Yurimaguas Experiment Station located 7 km south of Yurimaguas, Peru on a fine loamy, siliceous, isohyperthermic Typic Paleudult. The soil is well-drained and friable but, prior to amendments, the topsoil is acid (pH 4.3, 1.4 meq/100 g of KCl-extractable Al and 44% Al saturation) and low in bases (Ca, 1.4; Mg, 0.12; and K, 0.25 meq/100 g) and low in available P (3 ppm) by the modified Olsen extraction. The experiment was initiated in April, 1974 on a field cleared of virgin forest by hand cutting and burning in August and September, 1973. A single crop of rice, without treatment or tillage, had been grown immediately after removal of unburned logs.

The planting pattern consisted of relay intercrops: the 1st year, corn with soybeans followed by cassava with cowpeas, and the 2nd year, corn with rice followed by cassava with peanuts and cowpea (Fig. 1). The cassava was relay planted in the existing corn rows so that by corn harvest, cassava was well established and beginning its period of rapid growth. Each species in monoculture was planted at the same time the species was planted in the intercropped system.

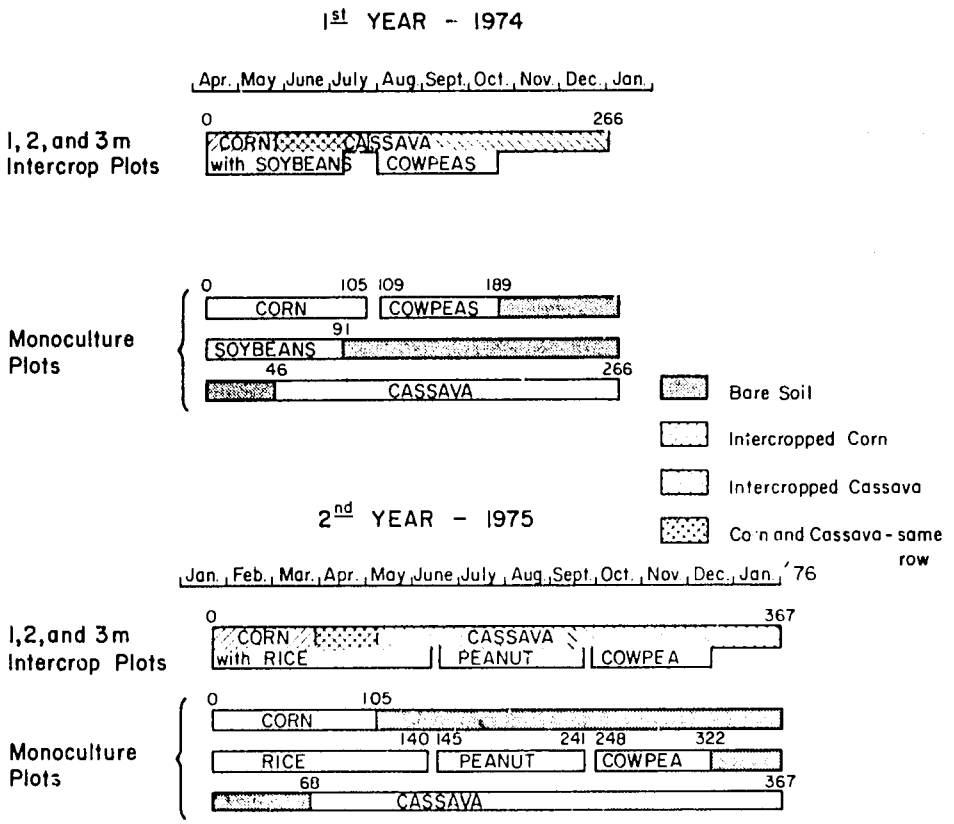

Fig. 1. Planting pattern of intercrop and monoculture plots for both years of study.

The experimental design was a split-plot arrangement replicated three times. Row spacings of 1, 2 or 3 m of the corn and cassava were the main plots and N rates of 0, 45, 90 and 180 kg N/ha were the split plots.

Corn plants were spaced 25 cm apart in the row and cassava 67 cm. This was constant for all three intercrop row widths and for the monoculture checks. Row spacing for corn in monoculture was 0.75 m and for cassava 0.75 m in 1974 and 1.0 m in 1975. The short-statured component crops, soybeans, peanuts and cowpeas, were all planted in 50 cm rows with 25 cm between holes (seeding was done with a planting stick) with three, one and two seeds/hole, respectively. This pattern and the corresponding seeding rates of the three legumes were held constant for all intercrop and monoculture plots. Rice was the only short-statured crop whose seeding rate was affected by the row spacings of the corn-cassava rows. In monoculture, rice was seeded in 25 cm rows at a rate of 50 kg/ha. However, in the intercrop patterns one row of rice was deleted for each row of corn, i.e., every fourth, eighth and 12th row was deleted in lieu of corn in the 1-, 2- and 3-m row spacing treatments, respectively. This resulted in seeding rates of 37, 44 and 46 kg/ha.

The varieties used in 1974 were as follows: Mezcla Amarillo Planta Baja (corn), Improved Pelican (soybean), Huallagina (cassava) and V.S. Moh (cowpea). Varities used in 1975 were: PD(MS)6 (corn), IR4-2 (rice), Huallagina (cassava), Blanco Tarapoto (local peanut) and Chiclayo (local cowpea).

By cowpea planting time during the second year, the cassava was 6 months old and the 1-m spaced plots had developed a closed canopy. No cowpeas were planted between the 1 m cassava rows because of complete shading.

The N fertilizer treatments were split in the three applications in the first year, 1) at the time of planting the initial crops, 2) at cassava planting time, and 3) at cowpea planting. Each crop was present for only two of the three applications. All crops except cowpea received two-thirds of the total rates with this pattern. The corn, cassava and soybean monocultures thereby received rates of 0, 30, 60 or 120 kg N/ha, and cowpea received 0, 15, 30 or 45 kg N/ha. Because cassava did not respond to added N the first season, N rates were split equally in two applications during the second season; one-half at initial planting of corn and rice, and one-half at 60 days after emergence, i.e., immediately after cassava planting. In this manner, corn and rice received the total N rates directly, while cassava got one-half as direct application. The second year monocultures of corn and rice received 0, 45 and 90 and 180 kg/ha in accordance with treatment plans while one-half of those rates were applied to the cassava at planting. The second cassava planting did not receive N fertilizer. Neither peanuts nor cowpea were given direct N applications.

Prior to the planting of the first crop, 0.9 ton dolomitic lime per ha, 50 kg P/ha (as ordinary superphosphate), 10 kg S/ha (as powdered sulfur) and 0.5 kg B/ha (as borax) were incorporated into all plots by hand hoeing. Potassium was applied to all plots at the rate of 40 kg/ha (as KCl) each time N was applied, for a total of 120 kg/ha per season. Before initiating the second multiple cropping year, 1.0 ton of calcitic lime per ha and 50 kg P/ha (as ordinary superphosphate) were incorporated into all plots with a rototiller. K fertilizer (KCl) was broadcast at the rate of 50 kg K/ha four times during this second year. The first two corresponded to the two N applications while the third K application was made at planting of peanuts and the fourth at planting of cowpeas.

Economic analysis was based on Yurimaguas market prices as of December 1975. They were as follows: corn, US$0.22/kg; rice, $0.20/kg; peanuts, $0.41/kg; soybeans, $0.41/kg; cowpea, $0.35/kg and cassava (fresh), $0.06/kg. Calorie and protein data were calculated from data provided by the U.S. Health, Education and Welfare Department-FAO (1972) for East Asia.

RESULTS AND DISCUSSION

Component crop evaluation

The planting pattern of the first year developed successive intercrops, namely corn and soybeans followed by cassava and cowpeas. Corn and cassava yields decreased as the row spacing widened and their populations decreased (Table I). These crops were taller, and, therefore, dominant in the system. Their yields declined at wider row spacings primarily due to decreased populations, but perhaps also to competition from the short-statured crop for soil nutrients and water. Monocultures of corn and cassava were grown at near optimum population only, and not at the same populations of each respective row spacing treatment. This is based on previous research at the Station. Monocultures were necessary to distinguish between the effects of the reduced population and the effects of competition from understory crops. All understory intercrop yields were reduced by increased crowding of the corn or cassava and perhaps competition for resources, including light.

Successive intercrops were also developed from the planting scheme of the second year, i.e., corn and rice, cassava and peanuts and cassava and cowpeas. The effects of the corn and cassava row spacings were similar to those of the first year (Table I). The taller crops decreased in yield as their rows increased in width, while the understory shorter crops increased in yield.

TABLE I

Component crop yields (t/ha) of the intercropping system

System	1974				
	Corn	Soybeans	Cassava	Cowpea	
Monoculture-overstory	3.17 a	—	16.6 a	—	
Intercrop — 1 m	2.41 b	0.47 a	16.3 a	0.24 a	
2 m	1.46 c	0.90 b	9.9 b	0.55 b	
3 m	0.95 d	1.03 b	8.4 b	0.67 b	
Monoculture-understory	—	1.40 c	—	1.09 c	
	1975				
	Corn	Rice	Cassava	Peanut	Cowpea
Monoculture-overstory	1.48 a	—	19.5 a	—	—
Intercrop — 1 m	1.06 a	1.57 a	15.7 a	2.00 a	—
2 m	0.51 b	2.22 b	6.3 b	2.74 ab	0.24 a
3 m	0.40 b	2.21 b	5.6 b	2.88 b	0.32 a
Monoculture-understory	—	2.33 b	—	3.25 b	0.49 b

Yields followed by the same letter within a column are not significantly different at $P_{0.05}$ by Waller-Duncan K-ratio test.

Of all the crops grown, only soybeans in the first year and corn in both years responded to N (Fig. 2). The soybeans were not inoculated because no inoculant was available at the time of planting. Root inspection during the growing season showed no appreciable nodulation from native *Rhizobium*. Therefore, this crop, which would normally not respond to N, was influenced by N applications as shown in Figure 2a. There was a significant row spacing by N rate interaction as the closer corn rows suppressed soybean yields and its response to N. These results indicate that competition factors, perhaps the most important being light, limited soybean growth so that the crop could not utilize greater amounts of N.

In the first year, corn gave a curvilinear response up to 120 kg N/ha in monoculture (Fig. 2b). The intercrop systems also indicate a curvilinear corn response, but at the 3 m spacing a yield plateau was established at the 30 kg N/ha rate. In the second year, a nearly linear response was observed through N rates of 180 kg/ha for all systems (Fig. 2c), but the rate of response declined as row spacing widened as it had the first year.

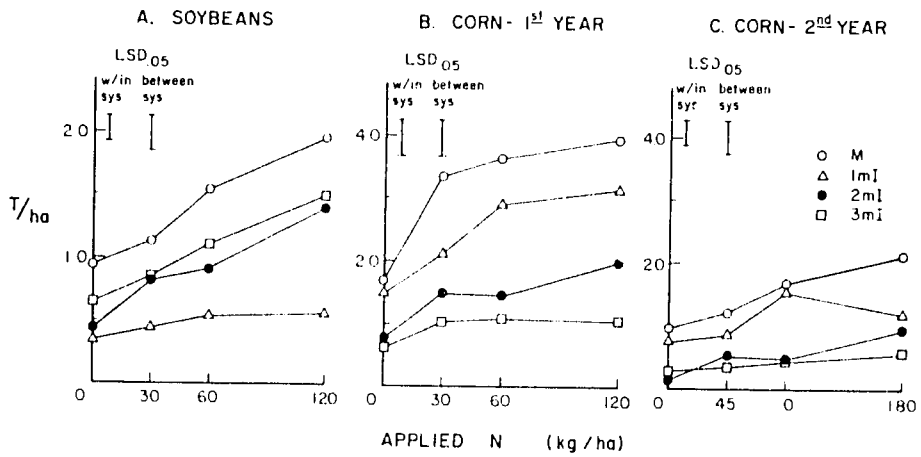

Fig. 2. Effect of applied N (as urea) on yield of soybeans and corn (1st and 2nd year) in monoculture and intercropping patterns.

Intercropping system evaluation

The above results are the yields of the individual component crops as affected by the treatments. A more difficult task is evaluating the system as a whole. The Land Equivalency Ratio (LER) proposed at IRRI (1974) is commonly used to evaluate the effectiveness of intercropping (Oyejola and Mead, 1982). This parameter has a serious shortcoming because it does not consider the time required for growth of monocultures or intercrops as well as the time during which no crops are grown. Intercrop productivity should be considered as a function of time as well as area. Hiebsch (1980) provides considerable evidence that most intercropping advantages as measured by

LER > 1, disappear when production is compared on an equal area-*time* basis. In other words, intercropping advantages can often be explained simply on the basis of differences in land-time utilization (Cordero and McCollum, 1979) rather than enhanced utilization of light, water, and soil nutrients (Willey and Osiru, 1972). Because of this deficiency, Hiebsch (1980) developed an area-time equivalency ratio (ATER) defined as follows:

$$\text{ATER} = \sum_{C=1}^{n} \frac{R_C^I}{R_C^M}$$

where R_C^I = rate of yield (Quantity/area-time) of crop C in intercrop, R_C^M = rate of yield of crop C in monoculture. This can be rearranged to:

$$\text{ATER} = \frac{1}{(AT)^I} \sum_{C=1}^{n} (AT)_C^M \frac{Q_C^I}{Q_C^M}$$

where $(AT)^I$ = area × time of land utilization of intercrop, $(AT)^M$ = area × time of land utilization of crop C in monoculture, Q_C^I = quantity of product of crop C in intercrop, Q_C^M = quantity of product in crop C in monoculture.

This value weights the component crop according to their time in the intercropping system. That is, it compares the rate of yield of intercrop with rate of yield of the monoculture. Such an area-time consideration is critical for the year-long pattern of successive intercrops used in this experiment because the LER would be totally unrealistic, consistently having values greater than 2.

Fig. 3a shows the ATER values calculated for the intercropping systems during both years. The results are quite consistent between years, with the 1-m system giving considerably higher ATER values than unity and significant-

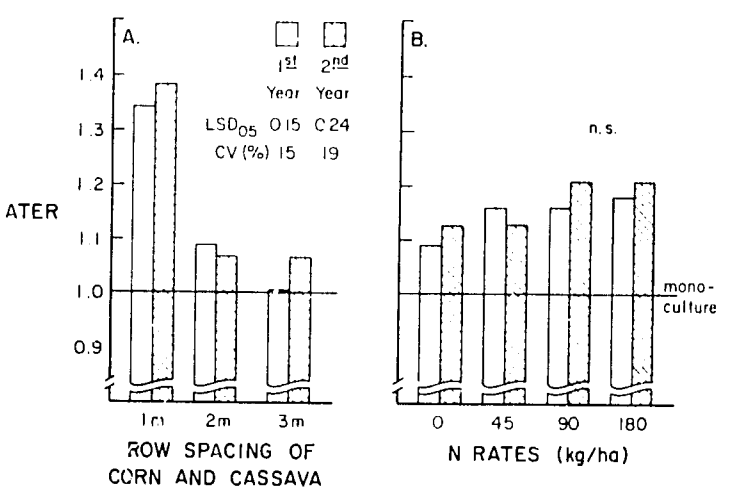

Fig. 3. Effect of row spacing and N rates on ATER values of intercropping patterns of both years.

ly greater than the 2- and 3-m systems. These 1-m intercrop ATER values indicate a true biological advantage for such an intercropping scheme over the monoculture. An ATER value of 1.3 means it would require 1.3 ha days of monoculture production to produce the same quantities of the same commodities as 1 ha day of intercrop production. Or, an ATER of 1.3 indicates the intercrop to be 30% more efficient at producing these particular crops. Such a response in the 1-m system is consistent with published work by Fisher (1979), Wahua and Miller (1978) and Mutsaers (1978) which showed an enhanced yield advantage in intercropping at high population densities and consequently at increased interspecies competition. As the row spacing of corn and cassava widened, the intercropped system approached a monoculture of the understory crop. Therefore, as expected, the ATER values approached that of a monoculture, 1.0.

There was no significant effect of N fertilizer on ATER values (Fig. 3b), nor was there an interaction between row spacing and N levels. This is not surprising considering most of the component crops in the two years did not respond to N fertilizers.

A more straightforward and perhaps less complicated manner of comparing intercropping systems with monoculture is to evaluate them on some common term, e.g., a financial and/or nutritional parameter. Thus, the production of the component crops may be directly additive. However, the *rate* of production of each system is the correct basis for comparison of the monocultures and the intercrops (McCollum, in press). Comparing absolute totals of dollars or calories would not be valid, again due to time; i.e., the great differences in season length among the individual crops and cropping systems. Thus, ATER values were also used in these comparisons.

The 1-m intercrop produced both dollars and calories at a rate statistically equal to or higher than any other system in both years (Table II). The rate of protein production for this system, however, was relatively low (Table II). The narrow row spacing of the carbohydrate-rich corn and cassava crops favored calorie production at the expense of the high protein, understory legumes. However, this does not mean that this system was inadequate in producing proteins. Calculating from data by Organización Mundial de la Salud (1966), a family of seven (two parents, one grandparent and four children) would require protein at a daily rate of 0.34 kg. Even as little as one-third hectare of 1-m intercrop, which would have produced protein at the rate of 0.70 kg/day in the first year and 0.45 kg/day in the 2nd year, would be more than adequate in supplying family needs assuming no storage difficulties. This same family requires 13.8 Mcal/day and one-third hectare system of the 1-m intercrop system would have provided 33.7 and 25.7 Mcal/day in each of the 2 years, respectively, approximately double the requirement. This means the family, from the diversity of crops grown, could meet its calorie and protein requirement and have crops, especially high calorie ones such as corn or rice, remaining for the cash market. Corn and rice are the only commodities that presently have a reliable market in the Yurimaguas area.

TABLE II

Rate of gross income, calorie and protein production of the various cropping systems in each year of study

	Gross income ($/ha per day)	Calorie production (Mcal/ha per day)	Protein production (kg/ha per day)
1st year			
Intercrops:			
1-m rows	6.72 a	102 a	2.09 c
2-m rows	5.56 b	77 b	2.42 bc
3-m rows	5.14 bc	68 bc	2.47 b
Rotation:			
Corn-cowpea	5.57 b	76 b	2.77 b
Monocultures:			
Soybean	5.99 ab	58 c	5.13 a
Cassava	4.51 c	74 b	0.53 a
2nd year			
Intercrops:			
1-m rows	6.30 a	78 a	1.35 bc
2-m rows	5.82 a	59 bc	1.48 abc
3-m rows	5.88 a	58 bc	1.52 ab
Rotation:			
Rice-peanut-cowpea	6.12 a	48 c	1.75 a
Monocultures:			
Corn	2.96 b	47 c	1.22 c
Cassava	3.91 b	65 ab	0.46 d

Values within any column followed by the same letter are not significantly different by Waller-Duncan K-ratio test ($P_{0.05}$).

Results in Table II show that the 1-m intercropped system was significantly more profitable than the monocultures. Income evaluation has a shortcoming in that it is specific to prices at a given time. Under a different price structure the same yield of these same commodities could generate different relative incomes. However, the diversity and nature of interplanted crops may add to income stability. It is often said that many subsistence farmers in LDC nations have risk aversion. This is understandable as crop failure can mean severe hardship. Francis and Sanders (1978) conducted an extensive economic analysis on a local situation in Columbia comparing monoculture and intercropping of beans and corn over a wide range of price ratios. Given low or moderate yields, monoculture beans were almost always the most profitable on paper, but also carried the most risk. The probability of breaking even, however, was always highest in corn-bean mixtures. The inter-

cropping system used in this experiment may also promote such stability. Thus, the 1-m intercrop, which produced a high rate of income (relative to the other systems) under the local price structure, may also provide more security than monoculture production because of more stability across agronomic conditions.

Observations made during this experiment indicated several potential advantages of intercropping. In addition to reduced risk, reduced weed pressures and less susceptibility to soil erosion were noted. For the intercropping systems, only two weedings per year were required to satisfactorily control weeds. The monocultures needed two to four weedings per crop. The continuous crop growth kept at least a partial canopy over the soil at all times after the initial planting. This not only shaded weeds but meant there was never a large continuous area of bare soil such as existed from harvest through succeeding crop establishment for each monoculture crop. Thus, susceptibility to erosion should be reduced in the intercrop system compared to a system of monocultures.

It is concluded that an intercropping scheme such as is used in this experiment could be expected to be equally or more productive, biologically, economically or nutritionally, than the corresponding monocultures either alone or in sequence.

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