Intercropping With Sweet Potato (*Ipomoea batatas*) in Central America

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INTRODUCTION

Sweet potato (*Ipomoea batatas* (L) Lamb) was probably first domesticated in the lowlands of northern South America and the Antilles. Its early introduction into Middle America made it known to the Mayans who named it 'camotli', from which the Spanish name 'camote' is derived (Leon 1977; Bronson 1966). In spite of its early domestication in the area, sweet potato is not an important crop in any of the six countries of the Central American Isthmus (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama). Marketing problems are probably the main constraint to the widespread cultivation of this crop in the area. However, it is frequently cultivated for home consumption in the gardens of small farmers and less frequently cultivated as a cash crop in small areas near large cities.

Though scarce, such information as is available from different ecological areas, mainly in El Salvador and Costa Rica, reveals the potential of sweet potato for inclusion in cropping systems suited to the agronomic and socio-economic conditions of Central American small farmers (Bieber 1978; Moreno 1979). Multiple cropping, including the simultaneous cultivation of two or more crops in the same piece of land, is important in the region.

Since 1973, the Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) located in Turrialba, Costa Rica, has been conducting research to develop appropriate technology for small farmers in Central America. Problem-oriented on-farm experimentation conducted by local scientists in collaboration with CATIE's resident agronomists in each country receives most emphasis in the outreach phase of this program. More basic types of research aimed to find medium and long term solutions to small farmers' production problems are conducted at the headquarters to support the outreach activities (Moreno and Saunders 1978).

The description of existing cropping systems and environments, the design of technological alternatives, field experimentation, and monitoring of useful innovations are the basic stages of the research methodology.

The design of new cropping systems for small farmers necessarily involves a knowledge of the physiological response of the crops to the environment. Included in the concept of environment is the presence of other crops, since growing plants in association is one of the mechanisms by which Central American small farmers cope with the agronomic and economic risks involved in production.

Turrialba (9^o 53' N, 83^o 39' W) is 600 m above sea level and has a mean annual precipitation of 2700 mm. Evapotranspiration exceeds precipitation only between January and March. The mean annual temperature is 22^o C and mean annual solar radiation input is 154 kcal cm^{-2}. The soils of the field plot area are in the Rocky phase of the Instituto soil series and in the Inceptisol order and Tropepts suborder of the Seventh Approximation Classification system (Hardy 1961). Since 1973, several cropping patterns including sweet potato have been field tested in Turrialba. The component crops used in the design were maize (*Zea mays* L) cassava (*Manihot esculenta* Crantz) common bean (*Phaseolus vulgaris* L) and sweet potato. Sweet potato was included as a component because of its high vitamins and protein content, the possibility of using it as animal feed, its ability to grow in poor soils, and its drought tolerance.

In Turrialba, the main constraint to dry grain production is the short harvesting period (February-March) when average monthly precipitation is less than 100 mm. Lack of water and low temperatures during the dry period are the main constraints to cassava production. Excessive water in the soil profile during the rest of the year is probably the main constraint to sweet potato production.

This paper reviews and attempts to combine the results obtained at CATIE in intercrops of sweet potato with maize, common beans and cassava. The research results reported here have been obtained with the species, cultivars, planting distances and densities summarized in Table 1.

Table 1. Species, varieties, planting distances and density of planting of different cropping patterns based on sweet potatoes

Species	Varieties	Planting distance (m) within row	Planting distance (m) between rows	Density plants sq m
Common beans				
Phaseolus vulgaris	CATIE-1	0.2	0.5	10
Maize				
Zea mays	Tuxpeño Planta Baja	0.5	1.0	4
Sweet Potato	C-7			
Ipomoea batatas	C-15	0.4	0.5	5
Cassava				
Manihot esculenta	Valenca	0.5	1.0	2

INTERCROPPING SWEET POTATO WITH MAIZE

The first field trials during the process of designing cropping systems with these two crops grown in association were carried out with the cropping patterns represented in Figure 1B. This pattern was tested in two planting seasons: November-March and May-October. These trials were conducted between 1973 and 1975. Two rows of sweet potato (0.5 m apart) were interplanted between rows of 30-day-old maize 1 m apart. Maize was bent over after 4 months and harvested at 4.5-5 m months. Bending the cover plant is a practice that protects the cob from attack by pathogens in case of rainfall before harvesting. Sweet potato was also harvested at 4.5-5 months. NPK was applied at 175-33-42 kg/ha during the first planting season and at 150-40-63 kg/ha during the second planting season.

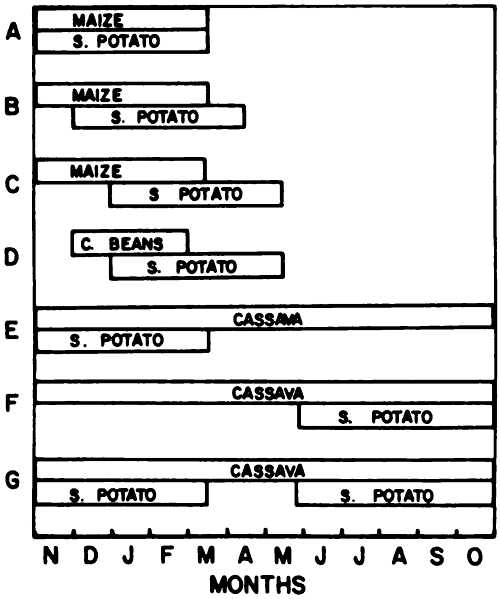


Figure 1. Cropping patterns with sweet potato, maize, common bean and cassava tested in Turrialba, Costa Rica 1974-1978

After these first trials further experimentation was carried out during 1975 to determine the influence of cropping pattern and levels of applied K on yields of this intercrop. Cropping pattern 1B was compared with sweet potato planted simultaneously with maize (Figure 1A), and with sweet potato planted 60 days after maize (Figure 1C) during the first planting season. Light available to sweet potato was modified by planting it in different cropping patterns. The same basic fertilization of 150-40 kg/ha for N and P was applied, but K was applied at three different levels, 63,125 and 187 kg/ha. Both maize and sweet potato were cultivated as monocrop checks during these trials. The maize monocrop received 110-52-35 and the sweet potato crop 65-10-30 N, P and K kg/ha.

For the first planting season, between 1973 and 1975, the average root yield of intercropped sweet potato in cropping pattern 1B was extremely low (1.1 t/ha) compared with its yield in monoculture (10.7 t/ha). Maize yielded 2.5 t/ha in association with sweet potato but only 2.1 t/ha as a monocrop. In the second planting season, yields were 3.5 and 2.0 t/ha for intercropped sweet potatoes and maize, while in monoculture these crops yielded 4.7 and 2.2 t/ha. Competition with sweet potato planted 30 days after maize did not significantly affect the yield of maize. No significant difference in yield was obtained with this crop association whether it was cultivated once a year followed by fallow in the same plot or whether it was rotated with either maize, sweet potato or maize associated with sweet potato.

It was assumed that the yield of maize associated with sweet potatoes was higher in association than monocrop during the first planting season probably because of excessive N. During the second planting season the higher levels of P and K applied probably increased sweet potato yield which competed with maize to reduce its yield.

The comparison of cropping patterns 1A, B and C showed a decrease in sweet potato yield as its planting date was delayed with respect to the maize. A 72% yield reduction (Table 2) was caused by delaying planting 30

Table 2. Yield of sweet potato fresh roots and maize grain (14% HOH), in different cropping patterns, total accumulated radiation intercepted by sweet potato from 0-90 days and accumulated rainfall during sweet potato life cycle. Turrialba, Costa Rica,1976

Cropping pattern	Maize (t/ha)	Sweet potato (t/ha)	Accumulated radiation (0-90 days) intercepted by sweet potato (kcl/sq cm)	Accumulated rainfall during sweet potato cropping cycle (mm)
Maize / S. potato	2.21	9.61	22.9	659
Maize / S. potato	3.47	2.66	14.8	338
Maize / S. potato	3.45	2.16	12.1	699

days, which could in part be attributed to water stress, since rainfall was approximately 50% lower than normal during this cropping cycle. The best treatment yielded 2.5 t/ha of maize and 11.4 t/ha of sweet potato when both crops were planted simultaneously and fertilized with 187 kg K/ha. No significant differences in radiation or temperature in the open field between sweet potato planting dates were recorded, but differences in radiation intercepted by sweet potatoes interplanted with maize at different dates were significant (Table 2) and probably accounted for most of the difference in yield.

Radiation, nutrients, temperature and soil moisture are known to determine sweet potato yield (Hahn 1977). In Turrialba, light and nutrients are the most probable factors modified in associations with maize. Maize, being a C-4 crop, develops its canopy before sweet potato, intercepting most of the available light. According to Arze (1975), an average of 243 cal/sq m/day of solar radiation was available for sweet potato in the interspaces of Tuxpeño Planta Baja C-7 maize. An average of 437 cal/sq m/day was available for a sweet potato monocrop. This reduction of approximately 50% in light intensity is enough to reduce dry matter production and probably both lignification of stele cells and cambial activity as well.

A reduction in sweet potato yield when it was cultivated in association with maize has been reported, but no further information is available (Tang Dept of Agric 1960). In several trials carried out in Turrialba a significant and positive correlation was found between radiation intercepted by sweet potato and both leaf area and total biomass (Escobar 1975; Lizarraga 1976).

As previously stated, differences in soil moisture available for each planting date of sweet potato probably affected the performance of cropping pattern 1B when tested against cropping patterns 1A and 1C. In all these trials no correlation was found between root yield and K and P content in the aerial biomass or the roots. A high N content in the sweet potato foliage negatively affected yield as previously reported elsewhere (Hahn 1977). In maize tissue the percentage of Ca and Mg increased as competition with sweet potato decreased. Whenever the planting date, sweet potato extracted relatively large amounts of Mg from the soil. Simultaneous planting of sweet potato and maize resulted in the strongest competition for available Mg between these two crops. Also Ca and Mg content of maize tissue decreased as the applied K increased. Adequate amounts of Mg are thought necessary to prevent imbalance of this element in the soil and plant tissue when K fertilization is used to obtain an adequate balance with applied N (Zuniga 1976). In the three cropping patterns K, Ca and Mg average levels in the soil decreased from 1.05 to 0.72, 4.70 to 3.71 and 2.14 to 1.62 me/100 ml of soil between planting and harvesting time.

The optimum N/K ratio used to fertilize sweet potato and maize has been studied for these crops in monoculture (Fujise and Tsuno 1967; Bishop, Smeltzer and Maceacaern 1972) but the simultaneous cultivation of these species presents some specific problems since an adequate level of N fertilization for maize is relatively high to attain good sweet potato root yield. Further experimentation was carried out during 1977 to find an appropriate fertilizer management for this two crop combination. Several treatments in which different levels of N and K were applied under a constant level of applied P (40 kg/ha) were tested with cropping pattern 1A.

In Table 3 these treatments are presented with data for dry matter yield of maize and sweet potato both in total biomass and edible fraction. Treatments 5, 6, 7 and 8 resulted in more total biomass, but treatments 5 and 6 produced the largest amount of edible biomass, suggesting an N:K relation of the order of 1:2 to attain the best performance by this crop combination under conditions similar to Turrialba. Above-ground dry matter of maize increased with applied N up to 120 kg N/ha and 187 kg K/ha which also yielded the largest grain dry matter production and grain yield (14% H_2O). Maize did not respond to increased levels of applied K in terms of grain dry matter or grain yield (14% H_2O) probably because of low values of the relation Mg:K and (Ca + Mg):K in the soil which decreased even further with high levels of applied K.

Maximum above-ground dry matter production by sweet potato was reached at 90 days; it increased proportionally from 5.6 to 8.1 t/ha from treatments 1 to 8 as applied N increased. At 150 days (Table 3) all treatments decreased to values in the range of 1.9 to 2.7 t/ha with no significant differences among them. Dry matter began to accumulate in the tubers immediately after above-ground biomass reached its maximum dry weight. It tended to decrease as applied N increased. The same was true for root fresh weight.

Based on data provided by McDowell *et al* (1974) and Merrit and Watt (1955), dry matter weight of the edible fraction of these two crops was transformed into energy (g calories) as a common unit to express yield. Sweet potato energy yields decreased as N applied increased; the opposite was true for maize yield. Again no full response to N was obtained in terms of g calories produced by maize or maize associated with sweet potato due to a low base ratio in the soil. Fertilization with 110 and 183 kg/ha of N and K produced the largest amount of energy when these two crops were grown in association. In Table 4 the amount of nutrients taken up by maize and sweet potato growing in association is presented. For maize, the order of importance of nutrients was K, N, Mg, Ca, P while for sweet potato it was K, N, Ca, Mg, S. Maize absorbed most of the P, Mg, Cu, Mn and Zn available while sweet potato absorbed most of the S, Fe and Al.

Table 3. Average dry matter production by 120-day-old maize and 150-day-old sweet potato grown associated under different levels on N and K applied. Turrialba, Costa Rica, 1977

Treatment	Applied element N (kg/ha)	Applied element K (kg/ha)	Maize shoots (t/ha)	Maize grain (t/ha)	Harvest index %	Sweet potato shoots (t/ha)	Sweet potato roots (t/ha)	Harvest index %	Total dry matter Whole plant[y] (t/ha)	Total dry matter edible fraction (t/ha)	Combined harvest index %
1	25	189	4.8	1.9 (2.3)[z]	28.2	2.0	2.7 (9.0)[z]	57.5	11.4	4.6	40.3
2	60	95	5.3	2.5 (3.0)	32.2	2.3	2.2 (7.4)	49.1	12.3	4.7	38.2
3	60	284	5.8	1.9 (2.3)	25.1	1.9	2.5 (8.4)	56.4	12.1	4.4	36.3
4	120	39	5.6	2.8 (3.3)	33.1	2.4	1.7 (5.5)	40.5	11.9	4.5	37.8
5	120	189	6.8	3.4 (4.1)	33.4	2.4	1.9 (6.3)	44.6	14.5	5.3	36.5
6	120	323	6.7	2.9 (3.5)	30.3	2.1	2.2 (7.4)	47.0	13.9	5.1	36.6
7	180	95	6.7	3.2 (3.9)	32.4	2.6	1.5 (5.0)	35.7	14.0	4.7	33.5
8	180	284	6.5	2.9 (3.5)	30.8	2.7	1.6 (5.5)	37.7	13.7	4.5	32.8
9	240	189	6.8	2.6 (3.1)	27.7	2.1	1.4 (4.7)	40.2	12.9	4.0	31.0

[z]Figures in parenthesis are maize grain yield (14% H_2O) and sweet potato fresh root weight, both in t/ha
[y]Maize root system not considered

Table 4. Nutrient uptake by maize and sweet potato grown in association. Turrialba, Costa Rica, 1977

Nutrients	Time of maximum uptake (days after planting)	Uptake (kg/ha) maize	Uptake (kg/ha) s. potato	Percentage in each crop maize	Percentage in each crop s. potato	Percentage of total taken up
N	120	76.6	55.4	50.0	50.0	27.5
K	90	113.0	96.6	54.0	46.0	43.7
P	120	13.7	5.0	73.5	26.5	3.9
S	120	3.0	5.6	29.5	70.5	1.7
Ca	120	22.0	32.6	40.0	60.0	11.4
Mg	120	26.0	16.0	62.0	38.0	8.9
Na	120	4.0	4.7	46.5	53.5	1.8
Cu	45	0.04	0.01	82.0	18.0	0.01
Mn	120	0.06	0.01	80.7	19.3	0.02
Zn	120	0.07	0.04	65.0	35.0	0.02
Fe	45	0.03	1.45	2.0	98.0	0.31
Al	45	0.08	4.00	2.0	98.0	0.83

INTERCROPPING SWEET POTATOES WITH COMMON BEANS

In Turrialba common beans are cultivated once a year to be harvested as dry grain during the short dry season (February-March). From 1974 to 1978 14 field trials were carried out under similar management conditions in which sweet potato was interplanted in alternate rows 30 days after beans (Figure 1D). This crop combination received a total of 145-61-45 kg/ha of NPK. Most of the N and P was applied at planting of the beans; the rest was applied immediately prior to sweet potato planting. Manual weeding took place two weeks after planting beans and immediately before sweet potato interplanting.

On the average common beans yielded 1.4 t/ha and sweet potato 7.9 g/ha. Yields in monoculture for these crops were 1.3 and 10.7 t/ha respectively. The crop association was cultivated only once and the soil was left fallow during the rest of the year. At 60 and 90 days the foliage biomass of sweet potato intercropped with common beans was not significantly different from the foliar biomass of sweet potato in monoculture. However, a delay in the rate of biomass accumulation in the root systems was recorded in intercropped sweet potato as compared to its monocrop. Number of roots/plant was 2.2-2.5 in sweet potato associated with common beans and 3.6-3.7 in sweet potato monoculture. This reduction in root number accounted for most of the yield reduction in intercropped sweet potato. Competition for nutrients during early stages in the development of intercropped sweet potato resulted in fewer roots/plant while lack of sufficient water for translocation of photosynthates probably accounted for the delay in the rate of biomass accumulation in the root system. No differences in intercepted radiation was registered between sweet potato monocrop and when intercropped with beans.

Land equivalent ratio values between 1.6 and 1.8 have been obtained with this crop combination. These high values are comparable with those obtained in combinations of long life-cycle crops such as cassava with short life-cycle crop such as common beans (Moreno and Hart 1979).

Maize and common beans is the most widely cultivated crop combination among small farmers of Central America. Maize is planted at the onset of the rainy season and beans are relay intercropped between maize stalks at the end of the rainy period. In most cases common beans reach higher market prices than maize and consequently the level of input used in their production is higher too. The intercrop of sweet potato in 30-40-day-old beans represents a valuable production alternative to make better use of fertilizer and other inputs that are normally applied to common beans. Early maturing and drought resistant sweet potato cultivars should be tested on-farm in intercrop with common beans to further validate this production innovation which could also represent an important source of animal feed.

INTERCROPPING SWEET POTATO WITH CASSAVA

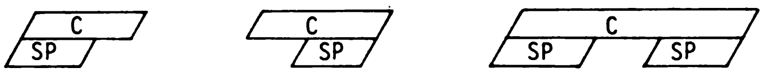
Cassava has slow initial growth and does not usually cover the ground completely until 90 to 120 days after planting. During this initial stage, intercropping with a short cycle crop such as sweet potato improves utilization of light and soil. Some cassava genotypes have their leaf area reduced by leaf loss 200-240 days after planting, making it possible for another crop to be planted in the interspaces of cassava stalks 120-160 days before its harvest (Moreno 1980).

Three cropping patterns with cassava and sweet potato (Figure 1E, F and G) have been tested in Turrialba since 1974. Two rows (0.5 m apart) of sweet potato were intercropped in cassava rows (1 m apart). In cropping pattern 1E sweet potato was planted simultaneously with cassava and harvested manually after 140 days. Sweet potato was harvested before cassava roots had fully developed. No significant damage to the cassava root system was caused when digging for sweet potato roots. Loosening the soil at this stage seems to favor the development of the cassava roots. In cropping pattern 1F, sweet potato was interplanted towards the end of the cassava life cycle to make full full use of available radiation in the cassava interspaces immediately after it began to lose its foliage. At harvest cassava plants are first hand-pulled which loosens soils enough to facilitate sweet potato digging. These two cropping patterns received an average yearly total of 150-48-75 kg/ha of N, P and K. While N and P remained constant, K application was increased from 45 to 63 and 125 kg/ha during 1975-76, 1976-77 and 1977-78. In cropping pattern 1G, two crops of sweet potatoes were interplanted with cassava. A total of 185-49-75 kg/ha of N, P and K were applied every planting season. Potassium was also increased to 125 kg/ha during 1976-77 and 1977-78.

Table 5 summarizes yields of these crops in different cropping patterns during four planting seasons. Intercropping cassava and sweet potatoes simultaneously reduces cassava yield by 37% as compared with its yield when sweet potatoes were intercropped at the end of its life cycle. Monocrop cassava yields averaged 17 t/ha over the four planting seasons. The cultivation of sweet potatoes at the end of cassava life cycle does not reduce cassava yield significantly as previously reported for other crops (Moreno 1980).

Table 5. Yields of cassava (C) and sweet potato (SP) intercropped in three different patterns during four planting seasons. Turrialba, Costa Rica, 1974-1978

CROPPING PATTERN[z]



Year	C	SP	C	SP	SP	C	SP
	Yield (t/ha)						
1974-75	10.7	9.0	14.8	5.9	7.8	10.4	7.9
1975-76	4.3	9.8	12.2	6.2	10.7	6.4	7.1
1976-77	9.6	3.5	16.6	0.6	6.0	10.1	0.3
1977-78	13.5	1.6	16.7	0.0	1.0	15.9	0.0

[z]Cassava harvested 12 months old; sweet potato harvested at 4.5-5 months

Sweet potato yields were fairly constant from 1974 to 1976 but they were significantly reduced in the three cropping patterns from 1976 to 1978. This yield reduction affected mainly the sweet potatoes planted at the end of cassava life cycle. No significant increase in pests or pathogens was registered during this period of lower yields. However, as shown in Figure 2A and B a reduction in extractable Mg affected the three cropping patterns, especially cropping pattern 1G, during the four planting seasons. Extractable K was also reduced although this reduction did not affect cropping pattern 1F with the same intensity. Apparently increased K applied during

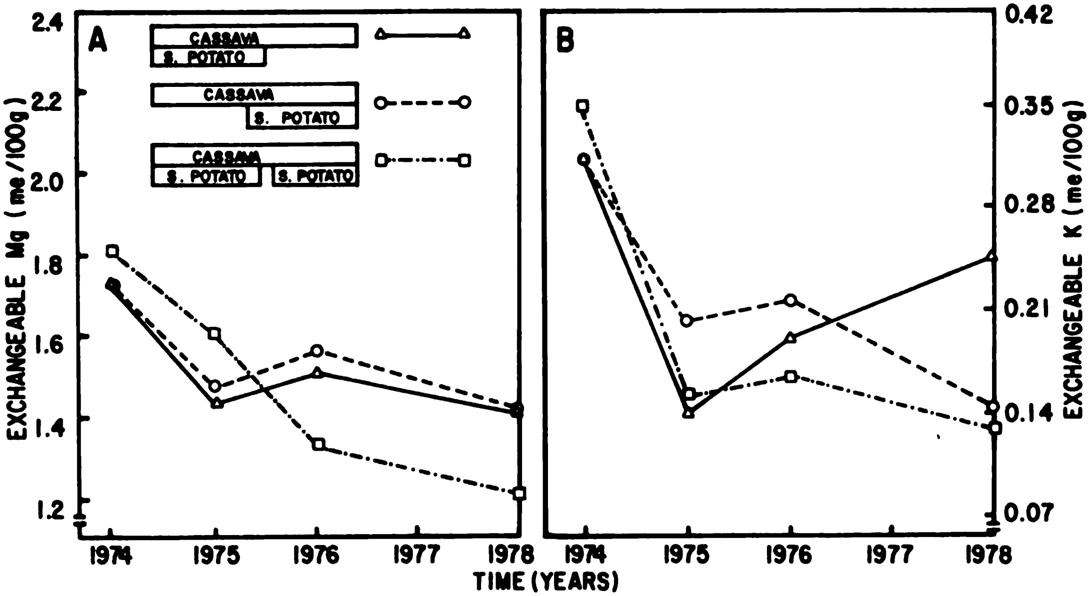


Figure 2. Effect of time and cropping systems on the soil exchangeable nutritients of an Inceptisol at Turrialba, Costa Rica. A) exchangeable Mg and B) exchangeable K (Burgos 1980)

the last years of the field experiments was not enough to cover the crops' uptake.

The production of roots and leaf dry matter for cropping pattern 1G during 1974 to 1976 is shown in Figure 3. Sweet potato (5 plants/sq m) reached a peak of approximately 1 t/ha about 90 days after planting, accounting for most of the leaf biomass during the initial stages of this crop association. Dry matter accumulation in the root system increased after 90 days. Cassava (2 plants/sq m) reached its maximum weight in dry matter in the leaves between 210-270 days after planting. The dry weight of its root system increased markedly after 180 days. Growth of the second sweet potato was delayed and reached its maximum weight in leaf dry matter 120 days after planting. Its lower level of intercepted light during early stages of its life cycle probably accounted for this delay. This second crop of sweet potatoes was harvested at 160 days when its root system was still accumulating dry weight and no signs of root quality deterioration were observed. Probably a 30-40 days delay in harvesting could have significantly increased root yield. Radiation available for sweet potatoes interplanted simultaneously with cassava was reduced to 75-80% of the open field radiation 100 days after planting. Most of the above ground biomass of the sweet potato was formed during this period. Translocation of photosynthates and accumulation of biomass in roots occurred when radiation in the interrows of cassava was decreasing from 75 to 30% of the open field radiation. The second sweet potato crop was established when approximately 50% of the open field radiation was available. Approximately 80% of the solar radiation was available when it reached its maximum leaf dry matter weight (120 days). This available radiation increased to 88% at harvesting time. More light available for the first sweet potato crop was probably the cause of its better yield in terms of root dry weight.

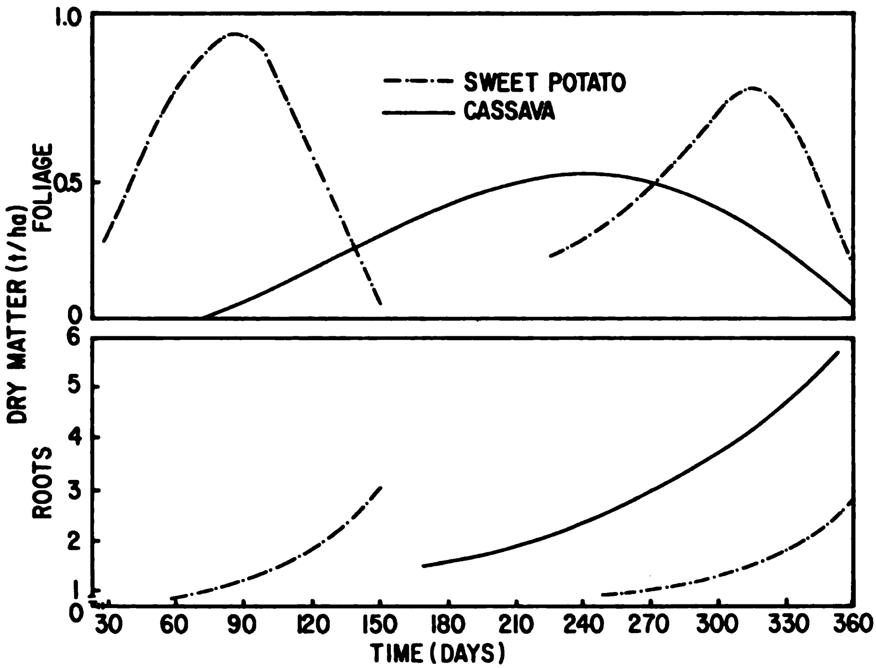


Figure 3. Yields of leaves and tuber dry matter on time for two crops of sweet potatoes and cassava intercropped in Turrialba, Costa Rica (Gallegos 1976)

THE POTENTIAL OF SWEET POTATOES IN INTERCROPPING SYSTEMS

Sweet potato is usually planted as a monocrop in different cropping patterns, particularly in regions with a well defined dry season where it is included as a cash crop to make use of residual water and fertilizer. In Turrialba, sweet potato yielded a fresh root weight of approximately 18 t/ha with one application of 133 kg/ha K, following an association of maize and common beans (Brioso de Leon 1979). However, when land is scarce and labor is abundant, there are also the possibilities for intercropping sweet potatoes with several other species. Sweet potato is intercropped in certain areas of the Antilles, particularly during the establishment phase of perennials such as plantain and bananas.

Competition for light and nutrients is probably the main factor that modifies the performance of sweet potato when intercropped as compared to its performance in monocrop. Research should be intensified to find both cropping patterns that allow adequate amount of radiation to be intercepted by intercropped sweet potato and to ensure fertilizer practices that ensure an appropriate level of nutrients for the intercrops.

In the case of sweet potatoes and maize, light seems to be more important than nutrients in its effect on root fresh weight yield. Preliminary results from Turrialba indicate that cropping patterns with double rows of maize and four rows of sweet potatoes result in good yields of both crops. This cropping pattern permits enough light to be intercepted by sweet potatoes and allows for N fertilization to be individually applied to the maize (unpublished results, CATIE, Turrialba, Costa Rica). In spite of the competitive nature of the relationship between these two crops (Figure 4), this

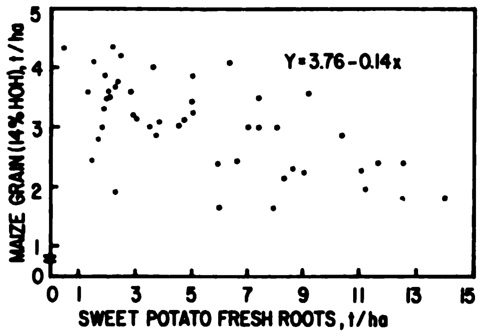


Figure 4. Yields of maize grain (14% HOH) and fresh tuber sweet potato from several trials (1975-76) with these crops in association. Turrialba, Costa Rica (Mateo 1976; Jaramillo, 1977)

crop combination produces a considerable amount of total biomass a year since it can be cultivated twice in certain regions with bimodal rainfall distribution, such as Turrialba. The relationship described in Figure 4 was obtained after pooling results from several field trials (Mateo 1976; Jaramillo 1977).

Nutrients rather than light seem to be the main limiting factor for intercropping cassava and sweet potatoes. Erect types of cassava provide sufficient light for a sweet potato crop planted simultaneously with them, and cassava cultivars that have their leaf area reduced at the end of their life cycle allow for another sweet potato intercrop to be harvested simultaneously. Management of Mg and K in the fertilization seems to be critical for the sustained production of this crop combination under soil conditions similar to Turrialba. This is probably true for intercrops of sweet potato with other root crops.

Intercrops with sweet potatoes represent also a valuable production alternative for mixed animal and crop farm systems where the animal component depends on farm crops. Several research results shows promising perspectives both for meat and milk production (Baker 1976; Ruiz *et al* 1977).

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General Discussion

(Session IV)

HO: What are the major advantages of using cut root pieces over using cuttings: which mature first?

BOUWKAMP: The major advantage is that the procedure is less labor intensive and adapts to mechanization. Root pieces require a slightly longer growing season than production from sprouts.

CHEN: What is the parameter for screening sweet potato for storage stability? How about the range of storage period of sweet potato among the varieties tested?

BOUWKAMP: For a given year, all varieties are stored the same length of time. Among years the length of storage was very similar - there was only approximately two weeks difference.

ANONYMOUS: I notice that you used the term 'root piece' for your propagation material. In the literature, however, the terms 'seed piece' and 'tuber piece' are also used. Which is correct? Would it not be to our advantage to adopt a consistent terminology?

BOUWKAMP: The term root piece is correct since the planting material is a piece of a root not a seed or a tuber. It would be helpful to adopt a consistent terminology and I would suggest root piece since the storage organ of the sweet potato is a root not a seed or a tuber.

URITANI: Please explain the difference in the effect on growth and yield between cut pieces from the proximal end and those from the distal end?

BOUWKAMP: If there is strong proximal dominance, the proximal ends survive better and produce more sprouts per hill than the distal ends. I know of no data which suggest a yield difference.

RASHID: Have you taken into account the effect of temperature in interpreting your results?

SAJJAPONGSE: Yes.

KAO: About your irrigation experiments, how do you explain the different results obtained in your fall crop and spring trial? When did you harvest to measure root yield?

SAJJAPONGSE: The difference in root yields between the fall and the spring trial was due to difference in temperature and number of days to harvest. In fall, the temperature was low and sweet potato was harvested at 170 days whereas the temperature in spring was very high and sweet potato was harvested at 140 days. Long term projects will include a wide range of temperature and sweet potato growth.

URITANI: Your sweet potatoes could have suffered from physiological deterioration when submerged in water. This may mean that sweet potato is rather susceptible to high soil moisture. Is this right?

SAJJAPONGSE: I don't think sweet potato is very sensitive to flooding. During irrigation, the plots were not submerged. They were moist. Under this situation then, I don't believe that sweet potatoes in our trials suffered from any physiological deterioration.

MEYNHARDT: Variations between replicates were large in your experiments. Did you use disease-free material, especially virus-free material, as your experimental material?

SAJJAPONGSE: We did not have virus problems in our trials. We believed that we used clean materials in our experiments.

WARGIONO: Did you observe any correlation of yield with weevil damage?

SAJJAPONGSE: We did not do this in our studies.

ANONYMOUS: Was irrigation practiced in your compaction experiment? Do you think the poor yield in the case of low bulk density is related to moisture stress or not?

SAJJAPONGSE: The soil compaction experiment was conducted in pots and we kept the soil moisture content to about field capacity throughout. It was easy to control soil moisture. I don't think the poor yield was affected by soil moisture.

HAHN: There were no differences in yield among treatments when irrigated and when high soil compaction was applied. Why is that so? What does it mean?

SAJJAPONGSE: Although there was no statistical difference in yield among treatments, at least a trend was established which indicated the effect of irrigation and soil compaction on yield. The non-significance was probably due to the great variation between replicates.

HAHN: What is the significance of irrigation and soil compaction studies for small sweet potato growers in Asia?

SAJJAPONGSE: At the time of root formation (30-40 DAP), irrigation should be withheld. The best bulk density of soil was 1.3 to 1.5 g/cc. These principles could be practiced by farmers in general if high yield is expected.

LEE: At the time of irrigation, did you apply irrigation water up to a certain soil moisture content or did you apply a fixed amount of water?

SAJJAPONGSE: It was more or less a fixed amount of water. We filled up the furrow on each side of the bed and then let the water penetrate through the bed. Since our soil has a light texture, the excess water would leach away rather easily and moisture at field capacity would be obtained.

AGATA: What do you think is the mechanism of high production under 30-40 DAP conditions?

SAJJAPONGSE: Irrigation should be withheld at 30-40 DAP, so that more photosynthate from the leaves can be translocated to form tuberous roots.

WARGIONO: As you showed in your slides, topping increases yield and starch content. Could you explain why? Which topping treatment will you recommend?

BARTOLINI: Topping increased yield and starch content of the roots because it minimizes the competition between the shoots and the roots in drawing photosynthates. The roots acted as a magnetic sink to draw the photosynthate instead of it going to the shoots and buds. Limiting vegetative growth enhances starch concentration in the roots. I recommend late topping since roots are already initiated and developed at this stage.

URITANI: Which is more suitable to get high yield, topping at the initial stage or at a later stage?

BARTOLINI: Our results showed that high yields could be obtained by topping both at the early and later stage compared to no topping. Topping early at about 1½ to 2 months and late at 3 to 4 months appeared suitable to obtain high yield.

ANONYMOUS: How were the sweet potatoes topped? For example, what was the length of shoots cut? One could possibly explain your increased yields with the 6-8 week topping due to a change in dry matter allocation. However, your yield increase late in the season when vine growth has decreased substantially would be difficult to explain.

BARTOLINI: Topping is cutting off a 35 cm apical portion of the sweet potato with about seven leaves. Topping was done twice, thrice, four times, and continuously at biweekly intervals. BNAS 51 is a heavy foliage sweet potato variety. Topping late in the season limits its vegetative growth. Thus, most of the photosynthates are channelled to the roots instead of the leaves.

VON UEXKULL: Your data showed that incorporation of 3 tons straw increased K intake to 119 kg K_2O/ha. Assuming the rice straw had 1% K_2O, it would have added 30 kg K_2O to the soil. How do you explain such a big increase in K intake?

WARGIONO: With the positive effect of rice straw in increasing soil texture and CEC, sweet potato growth was good and good yield resulted. Consequently the total nutrient uptake increased.

CHEN: As we saw yesterday in Tong-Shun, when the soil condition is wet, the sweet potato harvester cannot remove soil from the root. Is there any other type of harvester that can function well under wet soil conditions?

WILSON: Harvesting sweet potatoes is facilitated by relatively dry soil conditions. Too dry soil results in increased root damage. Vibrating or shaking devices on the elevator chain aid the separation of soil from roots.

VILLORENTE: With the extent of farm mechanization of sweet potato you have discussed, what is the minimum area being cultivated to sweet potato in the US? How much is the investment involved in acquiring, operating and maintaining the machine?

WILSON: Many fields of less than half a hectare which are grown in the US are probably harvested by hand or simple plow. Usually 8-20 hectares are required to justify some degree of mechanization. Simple equipment can be purchased for several hundred to a few thousand dollars. For example, harvesting aids (riding harvesters) sell for $500-$1,000 each. More sophisticated equipment will cost several thousand dollars. Maintenance costs correspond to sophistication of equipment.

WINARNO: What pesticides are generally used for sweet potatoes before sorting and what dose did you use?

WILSON: They are all spelled out in the NC Sweet Potato Production Bulletin, 'Growing and Marketing of Quality Sweet Potatoes'.

URITANI: Do you have a problem of wounding damage to sweet potatoes with mechanization?

WILSON: Yes, proper equipment adjustment and operation are critical to minimize damage. Curing sweet potatoes is important for disease control and enhanced storability and quality maintenance. It is critically important for mechanically harvested sweet potatoes and should be done as soon as possible after harvest.

SELLECK: Would the white potato digger used for sweet potato be more effective if sweet potato tops were dessicated with herbicides prior to harvest? What herbicides are used commercially for weed control? What are the promising new herbicide candidates?

WILSON: Probably not. Vine removal by cutting eliminates or minimizes interference with digging. Eride, Amiben, Dacthal and Vernam are used commercially. A promising herbicide is Surflan.

TICKOO: What are the net economic returns per hectare for some of the most important cropping sequences? Is sugarcane an economical component of cropping systems in Taiwan owing to its long growing period?

WAN: If labor is inexpensive and abundant as in the 1960s, the additional crop in multiple cropping means extra profit to the farmers. The sugarcane as a component of a cropping system is largely used in Tainan where water is limited so that growing more than one rice crop is impossible. Therefore sugarcane has been used as a rotational crop. However, it is only economical if the world market price for sugar is reasonable, regardless of its long growing period.

ANONYMOUS: You have mentioned that the acreage of sweet potato in Taiwan is decreasing in favor of rice. How do these two crops compare in economic returns to the producers?

WAN: The gross profits from rice and sweet potato per hectare are approximately NT$80,000 and NT$70,000, respectively. However, there are less inputs for sweet potato so that the net return for the two crops is not much different. The problem is that the government has a price support system for rice but not for sweet potato.

WUSTMAN: Do you find any significant difference in sweet potato weevil incidence when growing sweet potatoes under various cropping patterns?

WAN: We did not find weevil a problem in cropping systems involving sweet potato on paddy fields. There is weevil on uplands, but it is not serious even there.

ANONYMOUS: From your slides, it seems the yield data for intercropping were made 20 years ago. Do you have any recent data from modern farmers in Taiwan now? Would you tell us what kind of major problems are involved in the intercropping system?

WAN: Intercropping is a labor intensive system. In the early 1960s labor was abundant and inexpensive so that our main concern was production increment per hectare. However, in recent years, there has been shortage of labor. Therefore, it is not possible for farmers to continue such intensive farming, and we are trying to study labor-saving farming methods.

ANONYMOUS: Where do farmers in Taiwan get their planting materials?

WAN: Sweet potato can be grown in Taiwan all year round, so that farmers can get cuttings from field plantings. For the fall plantings, roots are bedded in spring to obtain new planting materials.

WARGIONO: Which cropping system will you recommend and which one will give the highest income?

WAN: This depends partly on the location within Taiwan where different cropping systems are adapted. For example, a three-year rotational irrigation scheme has been practiced in Tainan area so that the rice-sugarcane-sweet potato scheme is the most profitable.

ANONYMOUS: What percent of total cultivated land is under respectively two, three and four crops a year in Taiwan?

WAN: We do not have this kind of data. However, we have the general multiple cropping index in Taiwan, which was around 163 in 1979.

ANONYMOUS: Mr Zara of the University of the Philippines at Los Baños showed a marked difference in the response of sweet potato to shading by coconut. You showed that in Costa Rica sweet potato was strongly suppressed by intercropped maize. Did you test this with different varieties?

MORENO: No, we don't have available data from different varieties but the search for shade tolerance among sweet potato varieties is very important in the development of multiple cropping systems, There is negative correlation between root yield of sweet potato and maize grain when these crops are grown together. With good management, particularly N/K ration, adequate for both crops, and better spacing arrangements between these two crops, a land equivalent ratio value above one can be obtained.