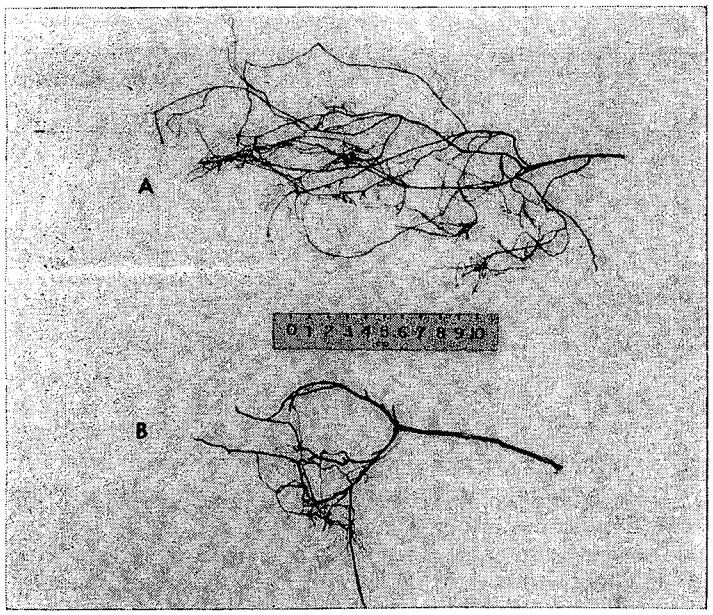

Fig. 4. Fibrous roots of tamarind trees growing on sandy-loam soil (A) and loam soil (B). Tecomán, Colima, México.

tribution in both soil types. There were no statistically significant differences in horizontal fibrous root densities in loam or sandy loam soils.

Results observed here seem to confirm that tamarind trees can be grown in any soil type along the central Pacific coast of México (7), because canopy volume was similar in trees on both soil types, although root density was different.

Conclusions

1. Canopy volume was greater in 'Haden' than in 'Kent' and 'Diplomatico' mango trees, but root density was similar for all cultivars.
2. Mango cultivars showed a tendency to develop highest fibrous root density at a 0-40 cm soil depth. Root density at 40-80 cm was greatest in 'Haden' trees.
3. 'Haden' trees had the highest root density at 90-175 and 175-260 cm from the trunk, while root densities of 'Diplomatico' trees were highest at 90-175, 175-260 and 345-430 cm from the trunk.
4. Greater root density occurred in sandy-loam than in loam soil for tamarind trees but tree size in both soil types was similar.
5. Fibrous root density of tamarinds grown in sandy-loam soil was greater than in loam soil at most soil depths and distances from the trunk, but vertical and horizontal root distribution patterns were similar on both soil types.

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THREE FACES OF INTERCROPPING IN DADE COUNTY, FLORIDA

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Abstract. **Intercropping is the practice of growing 2 or more crops simultaneously in the same field. It has long been used by traditional farmers in the subtropics and tropics as a means of increasing productivity per unit area, guaranteeing at least some yield even under adverse weather conditions, and of providing greater dietary diversity. High land costs in Dade County, Florida, have encouraged practices which increase early returns on capital invested in land and equipment. Three types of intercropping systems with edible horticultural products are currently being used by local growers: 1) tree crops with tree crops, 2) tree crops with vegetables and 3) vegetables with vegetables. Most cultural operations are performed with machinery typical for the main crops involved, supplemented by hand labor as needed; harvesting is done by hand.**

Examples will include specific crops as well as temporal and spatial arrangements for different systems.

Intercropping, or the growing of 2 or more crops simultaneously on the same land, is a practice which has been used by "traditional" or subsistence farmers around the world for many thousands of years. Some basic premises regarding intercropping were recognized at the American Society of Agronomy Special Symposium on Multiple

Cropping. These include:

(a) crop intensification in both time and space dimensions;
(b) inter-crop competition during all or part of crop growth; and
(c) management of more than one crop at a time in the same field (3).

Temporal variations found in intercropping systems range from combinations of 2 or more perennial crops, through interplantings of perennials with annuals, to systems with 2 or more annual crops. Within these major categories, differences in the duration of intercrop competition depend on the crops which are used (21).

Farming practices in developed countries such as the United States, especially mechanization and to some extent the use of synthetic chemicals, have encouraged a shift away from intercropping towards monoculture, particularly when crops are grown on large tracts of land. There are an increasing number of exceptions to this trend away from intercropping as growers and researchers rediscover the advantages intercropping offers (21, 22).

Advantages & Disadvantages of Intercropping

Various reasons for the continued use of intercropping by traditional farmers have been cited by numerous authors. These are:

(a) increased productivity/yield advantages (29, 33, 35, 37).
(b) better use of available resources: (*i*) land (1, 9, 20, 28); (*ii*) labor (6, 14, 20, 24, 27, 28, 30, 31); (*iii*) time (6, 7); (*iv*) water (19, 25); (*v*) nutrients (8, 16, 31, 36).
(c) reduction in damage caused by pests: (*i*) diseases (1, 15, 18, 29, 31, 34, 38); (*ii*) insects (1, 2, 11, 23, 31, 32); (*iii*) weeds (11, 14, 26).
(d) socio-economic and other advantages: (*i*) greater stability (1, 3, 9, 15, 16, 17, 27, 38); (*ii*) economics (5, 12, 24, 27); (*iii*) human nutrition (1, 2, 9, 30, 38); (*iv*) the "biological aspect" (14, 17, 34).

Some of these same advantages apply to intercropping systems in developed countries. In addition, a major motivating factor may be the high price of land for agriculture, especially near major urban centers. This latter is certainly the case in Dade County, Florida (M. Ellenby & J. Green, growers, personal communication). Dade County growers who raise tropical or subtropical fruit and/or vegetable crops are limited by climate to a narrow geographical range encompassing the southernmost county in the continental United States.

Disadvantages to using intercropping include such diverse aspects of production as:

(a) difficulties in mechanizing many cultural operations (S. Goldweber, retired University of Florida, personal communication);
(b) increased competition for water, particularly in areas where supplemental irrigation is unavailable (10, 25);
(c) problems of pesticides, particularly herbicides, for one crop being incompatible with other crops in the system (S. Goldweber; J. Green, personal communication);
(d) the necessity of applying pesticides such as fungicides and insecticides to crops which may not need them in order to insure adequate coverage of those which do (S. Goldweber, personal communication);
(e) the possibility of one component of the system acting as a trap crop for insects which may damage another component (1, 32); and

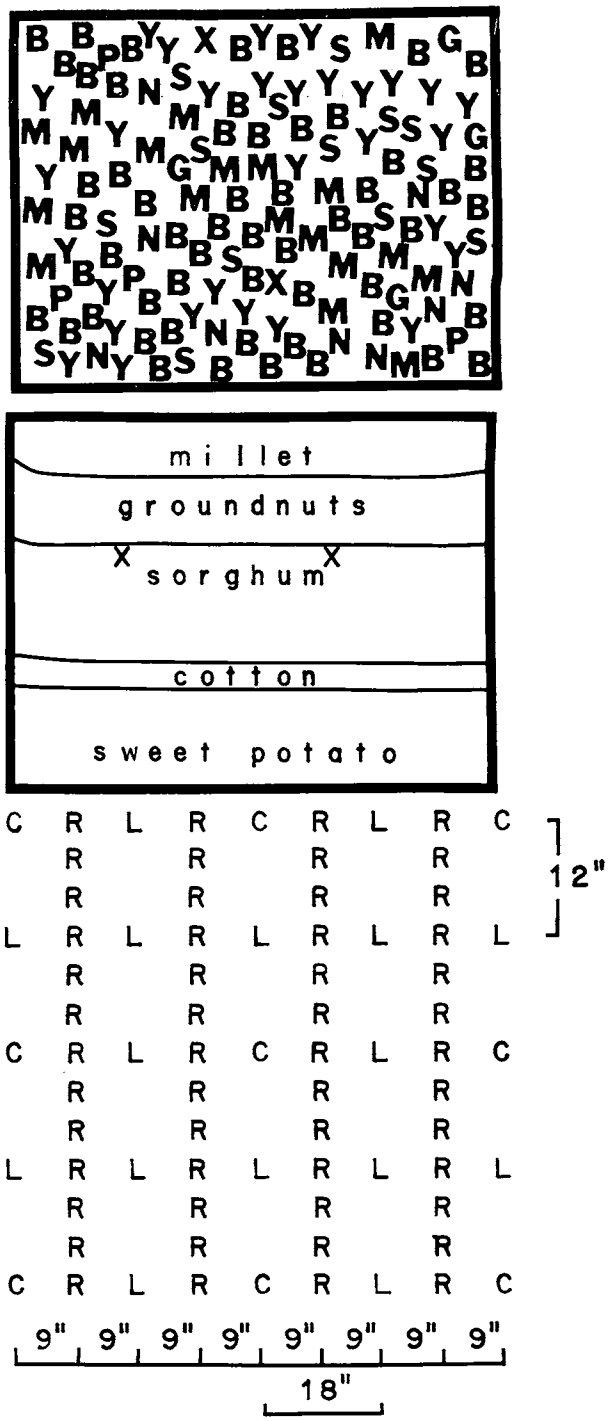

Fig. 1. Spatial arrangements in intercropping. (top) mixed intercropping—no distinct arrangement (17, 21); (middle) strip intercropping—"different strips wide enough to permit independent cultivation but narrow enough for crops to interact agronomically (17, 21);" (bottom) row intercropping—one or more crops planted in rows (4, 21). B = beans; G = groundnuts; M = maize; N = yams; S = melon; X = other (mango, sugarcane, tomato, oil palm, etc.); Y = cassava; C = cabbage; L = lettuce; R = radish.

(f) the possibility that foliar diseases may be worse because of the increased density of the canopy (1, 21).

These disadvantages apply to intercropping systems in both traditional agriculture and those which can take full advantage of current technology, such as intercropping systems in Dade County.

Intercropping Systems Used in Dade County, Florida

The 3 major spatial types of intercropping which are found in various parts of the world are illustrated in Fig. 1.

In Dade County, Florida, there are rare occurrences of mixed intercropping, primarily in backyards. Strip intercropping is also found to a limited degree, particularly with crops such as cucumbers and yellow crookneck squash which have very similar cultural requirements. The most common type of spatial arrangement in Dade County, Florida, is row intercropping, where the intercrop is planted either within or between the rows of the main crop.

Three general categories of plant combinations used with edible horticultural crops which either have been used or are currently being used in Dade County, Florida, are:

(a) fruit crops with fruit crops, within- and between-row;
(b) fruit crops with vegetable crops, within- and between-row; and
(c) vegetable crops plus vegetable crops, within- and between-row as well as strip intercropped.

Specific examples are discussed below.

Intercropping of Tree Crops with Tree Crops

The practice of intercropping tree crops with other tree crops is not unique to Dade County. "Filler" trees have been used in temperate regions of the United States, particularly with standard apple trees. Examples of filler trees include peaches and apricots (13). On the other hand, in India, Aiyer (1) described fruit gardens where coconuts, mangos, jackfruit, guava, oranges and other citrus trees were planted with arecanut trees, in a mixed intercropping system. He noted that they were often too crowded for the different trees to produce good yields.

The custom in Dade County has been to intercrop primarily in young groves, before the main crop has attained its mature size (R. Baterna & M. Ellenby, growers, personal communication). At present, most of the intercrops are high value crops, often intended for gourmet markets, as are some of the main crops (M. Ellenby & J. Green, personal communication).

Examples of specific mixtures of fruit (or other tree) crops with fruit crops are found in Table 1. Due to the unique nature of the Rockdale soils in Dade County, rock plowing and cross-trenching of groves are recommended prior to planting (S. Goldweber, personal communication).

Table 1. Examples of intercropping fruit crops with fruit crops in Dade County, Florida.

Main crop	Intercrop
Avocados (*Persea americana* Mill.)	—Avocados (close planted & later transplanted)
	—Acerolas (or Barbados cherry, *Malpighia glabra* L.)
	—Bananas (*Musa* sp.)
	—Limes (*Citrus latifolia* Tan.)
	—Papayas (*Carica papaya* L.)
Calamondins (*Citrus mitis* Blanco)	—Horseradish tree (*Moringa oleifera* Lam.)
Limes	—Papayas
Longans (*Euphoria longana* Lam.)	—Atemoyas (*Annona squamosa* x *A. cherimola*)
	—Papayas[z]
	—Sugar apples (*Annona squamosa* L.)
Lychees (*Litchi chinensis* Sonn.)	—Atemoyas
	—Sugar apples
Mamey sapotes [*Calocarpum sapota* (Jacq.) Merr.]	—Limes
	—Sugar apples
Mangos (*Mangifera indica* L.)	—Limes
	—Papayas
	—Papayas and Calamondins

[z]Discontinued after 1 yr because of cultural problems with this system.

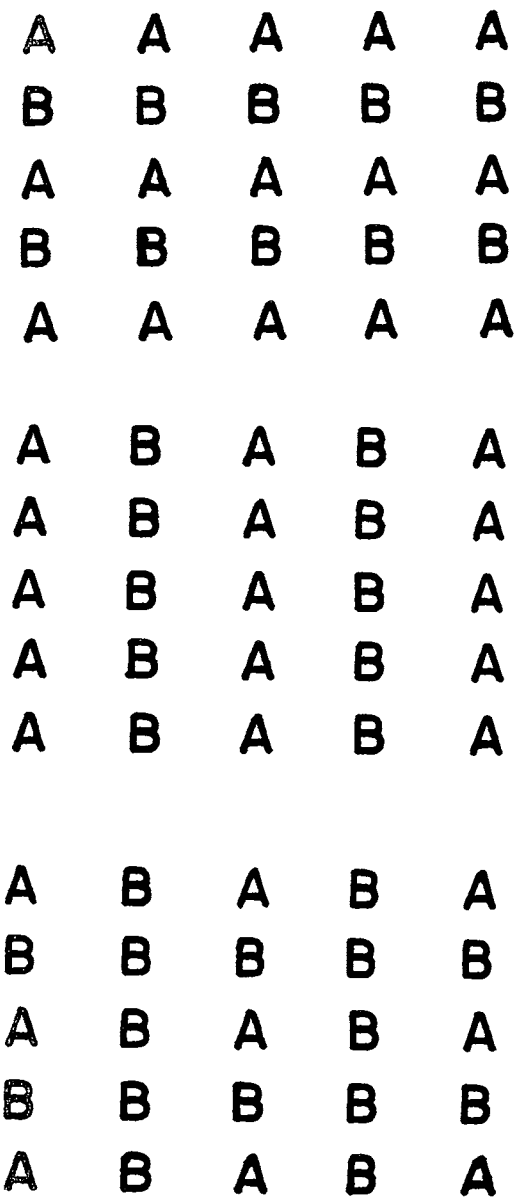

Fig. 2. Spatial arrangement in mixtures of fruit crops + fruit crops found in Dade County, FL: (top) within-row; (middle) between-row; (bottom) within- & between-row. A = major or permanent crop; B = minor or temporary crop.

The spacings used in cross-trenching determine the positioning of the main tree crops within the grove. Intercrops are planted either within-row (in one of the trenches created for the main crop) or between-row, in which case they are not in a trench. Spatial arrangements are illustrated in Fig. 2.

Equipment is generally that which will ultimately be used with the main crop. In some cases, the intercrop may require more cultural operations than the main crop. In instances such as this, the main crop might receive superfluous treatments because of the nature of the cultural practices (M. Ellenby, personal communication). Equipment has limited the choice of intercrops to those which can be managed with equipment purchased for the main crop (S. Goldweber, personal communication).

Intercropping of Tree Crops with Vegetable Crops

Using vegetable as intercrops in tree crops is much less common than intercropping tree crops with other tree crops. An exception may be in India, where Aiyer (1) has described

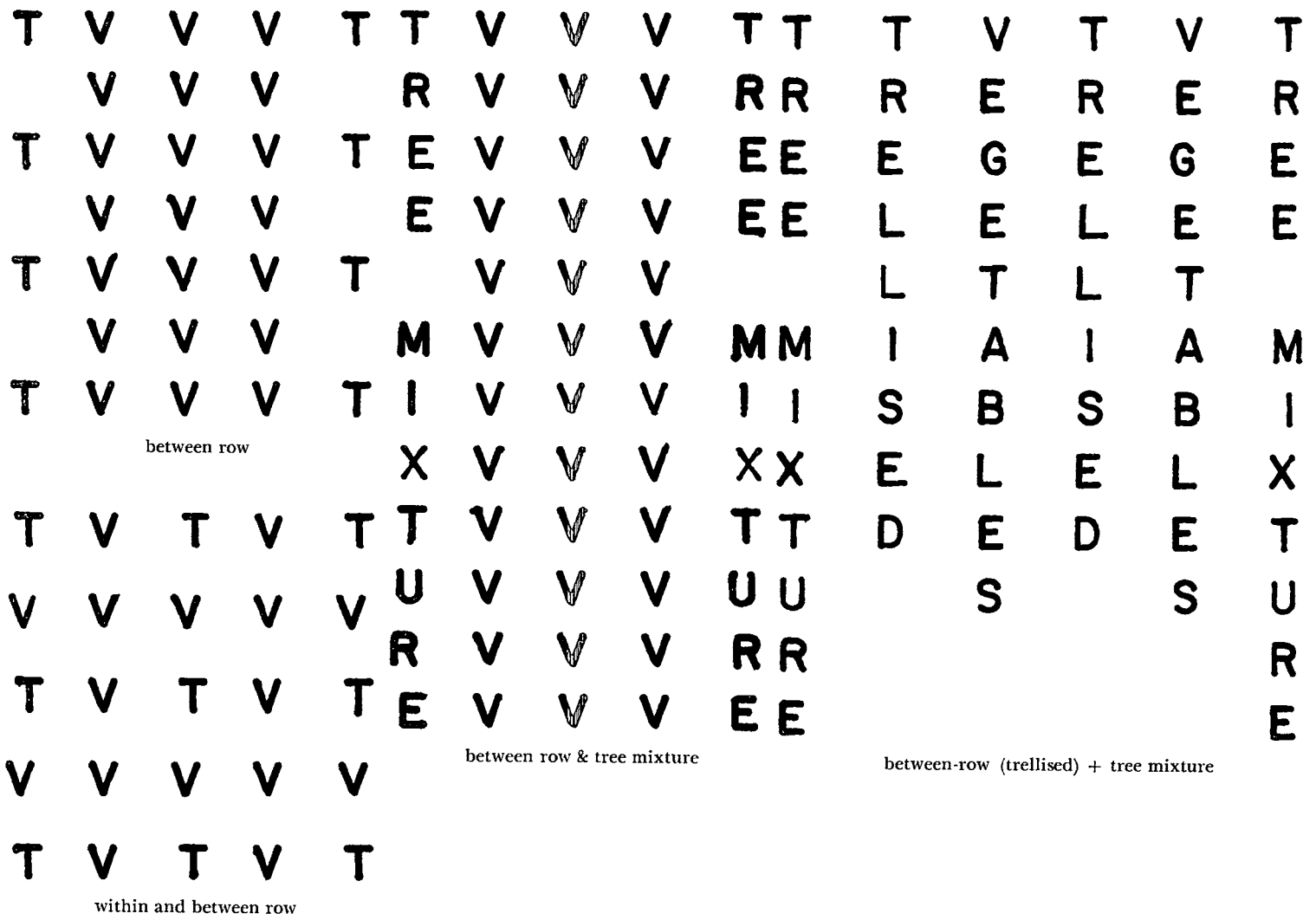

Fig. 3. Spatial arrangements in mixtures of fruit crops + vegetable crops in Dade County, FL: between row (upper left); within and between row (lower left); between row & tree mixture (middle); between-row (trellised) + tree mixture (right). T = tree crop; V = vegetable crop.

the use of vegetables as "catch crops" (short duration crops grown until the main crop comes into bearing) in betel leaf gardens. Dade County may be another exception.

As with combinations of tree crops and tree crops, the custom in Dade County has been to intercrop primarily in young groves, before the main crop has attained its mature size (R. Baterna & S. Goldweber, personal communication). At present, many of the vegetable intercrops are high value crops, often intended for gourmet markets (R. Baterna & M. Ellenby, personal communication).

Examples of specific mixtures of fruit (or other tree) crops with vegetables are found in Table 2. Like combinations of tree crops and tree crops, the unique nature of the Rockdale soils in Dade County, makes rock plowing and cross-trenching of groves prior to planting a necessity (S. Goldweber, personal communication). As with other tree crops, the spacing used in cross-trenching determines the positioning of the main tree crop within an intercropped grove. Vegetable intercrops are planted either within-row or between-row. At present, the latter is more common. Spatial arrangements are illustrated in Fig. 3.

Equipment needs for combinations of tree crops and vegetable crops are different from those where combinations of various tree crops are used. Two quite distinct types of equipment are generally considered necessary: (a) that which will ultimately be used with the main crop and (b) that which is used with the vegetable (or temporary) crop. In some cases, growers have decided against vegetables as intercrops because they lacked the necessary equipment (J. Green, personal communication).

Intercropping Vegetable Crops with Vegetable Crops

While intercropping systems where vegetable crops are grown with other vegetable crops are probably more common than systems where vegetable crops are grown with tree crops, they are not as common as systems where tree crops are grown with other tree crops (21, 22).

Unlike combinations of tree crops and tree crops, combinations of vegetable crops with other vegetable crops are, of necessity, temporary. Usually, however, one crop is somewhat more permanent than the other so it can be considered the "main" crop. One example is the combination of Oriental eggplant with chili peppers in which the eggplant is the main crop. In this case, the chili peppers are removed from the system when they begin to compete with, or crowd out, the eggplant.

Examples of specific mixtures of vegetable crops with vegetables crops are found in Table 3. Like combinations of tree crops with tree crops and tree crops plus vegetable crops, the unique nature of the Rockdale soils in Dade County makes rock plowing, though not cross-trenching,

Table 2. Examples of intercropping fruit crops with vegetable crops in Dade County, Florida.

Main crop	Intercrop
Avocados	—Bush beans (*Phaseolus vulgaris* L.) (between-row) —Calabaza (*Cucurbita moschata* Duch. ex Lam.) (in-row and between-row) —Yellow crookneck squash (*Cucurbita pepo* L.) (between-row)
Calamondins	—Chili peppers (*Capsicum frutescens* L. & *C. annuum* L.) (in-row) —Sweet potatoes for leaves [*Ipomoea batalas* (L.) Lam.] (in-row)
Limes	—Bush beans (between-row)
Mangos	—Bush beans (between-row) —Calabaza (in-row & between-row) —Yellow crookneck squash (between-row)
Tree mixture: Mangos & Calamondins & Papayas	—Bitter melon (*Momordica charantia* L.) (between-row; trellised) Chinese okra [*Luffa actangula* (L.) Roxb.] (between-row; trellised) —Jute or tagabang (*Corchorus olitorius* L.) (between-row —Luffa [*Luffa cylindrica* (L.) M. J. Roem.] (between-row; trellised) —Oriental eggplant (*Solanum melongena* L.) (between-row) —Winged bean [*Psophocarpus tetragonolobus* (L.) DC] (between-row; trellised) —Winter melon [*Benincasa hispida* (Thunb.) Cogn.] (between-row)

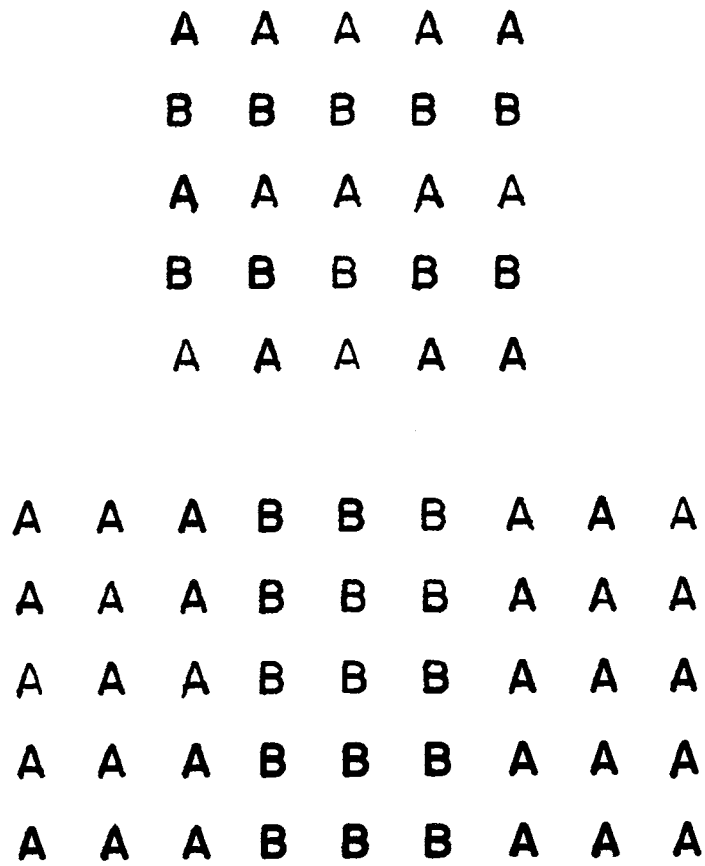

Fig. 4. Spatial arrangements in mixtures of vegetable crops + vegetable crops in Dade County, FL: (top) within-row row intercropping; (bottom) strip intercropping. A = major crop; B = minor crop.

prior to planting a necessity. Spatial arrangements are illustrated in Fig. 4.

Equipment is usually that which will ultimately be used with the main crop. This may well be identical to equipment normally used with the minor crop. In some cases, intercropping may make hand labor a necessity because of the close proximity of the crops (R. Baterna, personal communication). Combinations of vegetable crops may create more problems in terms of using pesticides, particularly herbicides. With some crop combinations, herbicides which can be used safely with the main crop may be phytotoxic to the intercrop or not labelled for use with that crop. With other combinations, fungicides or insecticides which are necessary for one crop may not be required on the other crop. They may have to be applied anyway because of the way the crops are planted.

The Future of Intercropping in Dade County, Florida

Intercropping has been used in Dade County for a number of years and has involved various fruit and vegetable crops (S. Goldweber, personal communication). Unless land prices change dramatically in the near future, it is likely to continue to be practiced both in young groves and with some vegetable crops. It will be interesting to see whether some of the crops which are currently considered the minor or temporary crop become more important financially than the main crop. With some of the more unusual or gourmet items, this possibility definitely exists. At present, the 2 major constraints to production are: (a) the lack of equipment which is versatile enough to handle a variety of operations, particularly in intensely managed systems, and (b) the problems of finding pesticides which can be used efficiently with the various crops in the system. The equipment problem may be solved if companies which manufacture tractors, sprayers, and so on recognize this need and see a large enough market. The pesticide constraint will likely be more difficult to overcome.

Despite the constraints to production, intercropping with edible horticultural products should be able to maintain its current dynamic position in Dade County's agriculture.

Table 3. Types of intercropping of vegetables with vegetables in Dade County, Florida.

Main crop	Intercrop
Oriental eggplant	—Chili peppers (within-row)
Winged bean (trellised)	—Oriental eggplant (between-row)
Yard-long bean (trellised)	—Jute or tagabang (between-row)
Yellow crookneck squash	—Cucumbers (strip intercropping)

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