AGRO-ECONOMIC EVALUATION OF FOUR VEGETABLE CROPPING PATTERNS FOR NORTH FLORIDA AS INFLUENCED BY CROP AND FERTILIZER MANAGEMENT LEVELS

By

MANUEL CELIZ PALADA

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1980

DEDICATED

TO

THE SMALL-SCALE VEGETABLE GROWERS IN
NORTH FLORIDA AND DEVELOPING
COUNTRIES IN THE TROPICS

ACKNOWLEDGMENTS

This research has been completed because of the help of a great number of people. The supervision and assistance from the members of the author's graduate committee, Dr. R. D. William, former chairman, Dr. D. N. Maynard, present chairman, and Dr. W. G. Blue, Prof. L. H. Halsey, Dr. S. R. Kostewicz, Dr. G. M. Prine, and Dr. G. B. Wall are gratefully acknowledged. Dr. William served as chairman of the supervisory committee for the entire course of the research and graduate training program and helped stimulate an environment conducive to the author's academic development. The author appreciates the interest and willingness of Dr. D. N. Maynard who served as chairman of the supervisory committee after Dr. William left the Vegetable Crops Department. The help and guidance of Dr. William and Dr. Maynard in developing and improving the author's skill in writing are highly appreciated. The helpful suggestions and assistance of Prof. Halsey in the conduct of the field experiment are gratefully acknowledged.

Acknowledgments are due also to Mr. L. C. Bryant, and other technicians of the Horticultural Unit and Soil Science Department Testing Laboratory who helped and assisted the author in conducting field work and analyzing soil samples. The author is thankful to Dr. N. Gammon, and Dr. W. G. Blue for allowing him to use the facilities of the Tropical Pastures and Soils Laboratory. Special appreciation is also extended to Dr. S. J. Locascio for allowing the author to use the facilities of the Vegetable Nutrition Laboratory. The help and assistance of his fellow graduate students and friends in Vegetable Crops Department are also appreciated.

The author is grateful to the Rockefeller Foundation for providing a graduate fellowship and to the persons who recommended him for this fellowship, namely, Dr. N. C. Brady, Director General, International Rice Research Institute (IRRI), Los Banos, Philippines, and Dr. Richard R. Harwood, Director, Organic Gardening and Farming Research Center, Kutztown, Pennsylvania.

Finally, the author wishes to express his sincere thanks to his wife, Elie; daughter, Daffodil; and son, Ted Peter, for their love, constant inspiration, encouragement, and understanding.

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By

Manuel Celiz Palada

March, 1980

Chairman: Donald N. Maynard
Major Department: Horticultural Science (Vegetable Crops)

Appropriate crop management technologies for year-round vegetable cropping systems are essential to increase productivity and improve farm income among small-scale vegetable farmers. A 2-year study was conducted to determine and evaluate the influence of crop and fertilizer management levels on productivity, income, and nutrient levels in soil from four vegetable cropping patterns for North Florida and to develop appropriate crop and fertilizer management practices for sequential vegetable cropping systems.

Seven vegetable crops were classified into three management groups (low, LM; medium, MM; and high, HM) and planted in four cropping patterns (HM-HM-HM, LM-LM-LM, HM-MM-LM, and HM-LM-MM). Vegetable crops included bulb onion (*Allium cepa* L.), collard (*Brassica oleracea* L. Viridis Group), English pea (*Pisum sativum* L.), mustard (*Brassica juncea* L. Czern. and Coss.), pole bean (*Phaseolus vulgaris* L.), southern pea (*Vigna unguiculata* L. Walp.), and crookneck squash (*Cucurbita pepo* L.). The four cropping pattern main plots were split into three fertilizer level sub-plots (low, medium, and high N and K) arranged in a randomized block design.

Cropping duration was longest in cropping pattern HM-HM-HM (bulb onion-pole bean-collard) and shortest in LM-LM-LM (English pea-southern pea-southern pea) and HM-LM-MM (bulb onion-southern pea-mustard). At the end of the cropping sequence, soil pH was lower than the initial value in all cropping patterns, but the difference between initial and final pH was greater in cropping patterns HM-HM-HM, HM-MM-LM, and HM-LM-MM than in LM-LM-LM. Soil organic matter content decreased, whereas total soluble salts increased in cropping pattern HM-HM-HM, where high levels of fertilizer were applied. Cropping pattern LM-LM-LM resulted in highest soil organic matter content after harvest of the third crop. Soil N and exchangeable K were significantly higher in cropping pattern HM-HM-HM than in the other cropping patterns. Exchangeable K increased as fertilizer level increased in all cropping patterns.

Increases in marketable yields were not observed with increasing fertilizer level except for bulb onion, squash, and English pea, where significant yield responses resulted from application of the medium fertilizer level. Cropping pattern HM-HM-HM resulted in significantly higher resource use and gross and net incomes, but rates of return to production inputs such as fertilizer, labor, cash, and management were similar among the cropping patterns. Planting low management and a combination of high, medium, and low management crops in sequential vegetable cropping patterns required low production inputs and were efficient and profitable. Such cropping patterns offer greater yield stability and the possibility of improved farm income.

INTRODUCTION

Vegetable growers in North Florida produced 12 vegetable crops commercially in 1978 (45). Enterprises range in scale from full-time businesses to part-time small-scale market garden operations (42, 89, 163). In general, vegetable growers in North Florida plant vegetable crops during the spring and fall seasons because the climate is more favorable than in summer and winter (175, 176). The higher temperatures and rainfall in summer and freezing temperatures in winter limit the production of most vegetables in North Florida (36, 63, 175, 176). Vegetable production in North Florida is characterized by few total hectares (19, 45) and lower yields compared to South Florida (29, 45).

Small-scale farmers generally produce vegetables using low levels of crop management (29, 45). In a survey of 50 small-scale growers in North Florida, a majority of the growers used low levels of fertilizers and pesticides (29). Marketing alternatives were limited and prices for most vegetables were below the break-even price (30, 50). Thus, the feasibility of increasing and improving vegetable production in North Florida is dependent upon both efficient cropping and marketing systems.

Several studies have been conducted to extend and improve vegetable production in North Florida (20, 164, 175, 176). For example, the use of black and white plastic mulches to reduce the effect of intense rainfall and high soil temperatures improved yields of muskmelon (*Cucumis melo* L.), watermelon [*Citrullus lanatus* (Thumb.) Mansf.], and squash (20). Production of vegetables under tobacco (*Nicotania tabacum* L.) shades also increased total yield of cucumber (*Cucumis sativus* L.)

(164, 175). By selecting adapted cultivars, many vegetable crops can be grown sequentially (63). For instance, promising cultivars of crucifers, cucurbits, leguminous, leaf, bulb, and solanaceous crops produced high marketable yields in Gainesville (61, 62, 64, 65, 66, 67).

These studies report only the management system of an individual crop from planting to harvesting without considering interactions between crops within cropping and farm management systems. Most of these studies are specialized, narrow in scope, and often oriented to a specific discipline. In contrast, cropping systems research involves the study of cropping patterns and their interaction with farm resources, other farm enterprises, and available technology on a year-round cropping basis (5, 68, 138).

Since different vegetable crops respond to different levels of management, research methods such as the cropping systems approach which integrates crop production with farmer's management capabilities are needed to develop appropriate technologies. The objectives of this study were to (a) evaluate productivity, resource use, and profitability of several vegetable crops planted in four cropping patterns for North Florida, (b) determine and evaluate the influence of crop and fertilizer management levels on productivity, income, and nutrient levels in soil from four vegetable cropping patterns, and (c) develop appropriate crop and fertilizer management practices for sequential cropping patterns. The principles and methodology developed from this research study can be used in both developing and developed countries where small-scale farmers have limited resources and low energy technologies.

CHAPTER I

LITERATURE REVIEW

Concepts of Cropping Systems

A cropping system is defined as a collection of distinct functional units or of elements that are interrelated and interacting (31, 94, 118, 119, 138). These components are crops, soils, marketing activities, production inputs, farmer's management skills, and other environmental factors. The farmer sometimes manipulates some of these factors in order to achieve his goals.

Common terms used in cropping systems include:

A crop system comprises components required for the production of a particular crop and the interrelationships with the environment. These components include the necessary physical, biological, and technological factors as well as labor (31).

Monoculture involves the growing of only one crop on the same plot of land in one year (5, 31, 138, 157).

Multicropping is the growing of more than one crop on the same land in one year (5, 68, 138).

Sequential cropping is the growing of two or more crops in sequence on the same field per year (5, 138, 157).

Intercropping is the growing of more than one crop on the same field at the same time (5, 47, 69, 138, 157).

Relay intercropping is the planting of a second crop before the first crop is harvested (5, 47, 69, 138).

A cropping pattern is a yearly sequence and arrangement of crops or fallow on a given land area (5, 31). The interaction of cropping patterns with physical and socio-economic factors results in cropping systems for a given area (68).

Cropping Systems Research Approaches and Methodologies

Agricultural research generally has been designed to investigate component technologies based on objectives of increasing yields, production efficiencies, and profitabilities (37, 121). This research often benefits large, commercial farmers. Small-scale farmers, however, are seldom benefited because their objectives are influenced not only by risk, but also by religion, culture and tradition (80, 118). Improved technologies for small-scale farmers often fail and are sometimes unacceptable because these technologies are not appropriate to their farming systems. For example, in the central highlands of Guatemala, Hildebrand (80) reported that farmers do not fertilize their corn (*Zea mays* L.) although they recognize that fertilizers increase yields. These farmers would rather apply the fertilizer to their vegetables where return to cash or to fertilizer is greater than for corn. In northern Nigeria, where mixed cropping is practiced, Baker and Norman (8) reported that farmers are reluctant to adopt recommendations for single crops because these improved technologies were not relevant to the local environment or their multiple cropping system. Upland rice (*Oryza sativa* L.) farmers in the Philippines prefer a tall cultivar over the short and high yielding cultivars because weed competition is less serious (85).

A lack of appropriate methods for conducting multiple cropping research has hampered the development of more effective technologies for small-scale farmers (177). Development of relevant, farmer-oriented methodologies that utilize a multidisciplinary, farm-oriented, farmer participation, and resource utilization approach have recently been utilized by an increasing number of researchers (8, 23, 69, 77, 81, 97).

An interdisciplinary research team is a prerequisite in developing cropping system programs (48, 77, 79, 118, 119). Based on assessment of factors that limit production and farm income, the researchable parts of problems are identified. Research workers from different disciplines and farmers agree on researchable problems followed by a combined and joint research effort. In this approach, everyone in the team works and makes decisions together on a regular basis. These farming research teams are often composed of an agronomist, economist, and anthropologist or sociologist (31, 69, 77, 80). The entire team often conducts a survey to understand and interpret the small farmers' agro-socio-economic conditions. Each member of the team interviews the farmer to reduce interviewer bias and increase cross-disciplinary exchange. The group meets each night to discuss the day's interview.

The farmer participation approach in testing appropriate technologies in on-farm research is essential in cropping systems studies (8, 54, 69, 80, 145). On-farm trials can reduce perceived risk by allowing farmers to observe the technology under the rigors of their production environment. Farmers can express their opinions and criticisms during the early stage of research process so that technology is culturally, economically, and biologically viable. The communication between the farmer-participant and researcher permits small-scale farmers to become part of the research process and insures that the technology is appropriate (69, 118, 119).

Most studies using the farmer participation approach are associated with small farm development projects whose objectives are to develop, adopt, and transfer improved technologies to small farms in developing countries (37, 57, 79, 83, 178). For example, the Caqueza project near Bogota, Colombia, provided farmers with incentive for adapting a "complete package" of agricultural practices under a risk-reducing credit scheme (178). Dramatic increases in both yield [200% for corn and 50% for potato (Solanum tuberosum L.)] resulted from incorporation of improved production technologies consisting of new cultivars, optimum population density, additional fertilizer and insect control (178).

A methodology for the design and transfer of agronomic technology to increase bean production was studied on small farms in a coffee (Coffea sp. L.)-growing area of Colombia (82). The objective was to develop a low-cost, low-risk technology. Unlike most agronomic studies that emphasize yield maximization, the goal of this study was to increase economic returns with minimum risk. The three components of the study were to observe traditional bean production systems, design a technological package, and evaluate the economics of this package at the farm level. Farmer participation was an integral part of the methodology. The low-cost technology consisting of combined use of improved cultivars at optimum population densities and low levels of agrochemicals resulted in a 30% increase in bean production and a 54% net income (82).

In Asia, projects designed to introduce and validate technological innovations for small farms were developed (83, 162). For example, researchers in India tested rice technological packages in 1966 to screen cultivars in farmers' field (57). At the same time, economic data were obtained on the farmers' traditional production system which allowed researchers to design complementary inputs within the scope of the small farmers' land, labor, and capital resources. In the Philippines, a 50% adoption rate for high-yielding rice cultivars was observed within a 6-year period (73). Rice "microkits" were tried in other Asian countries to maximize the dispersal of technology to small farmers (44). These "microkits" contained five cultivars of rice to be planted in the farmer's field alongside the local variety. Two levels of fertilizer and two levels of insecticide also were included. Seed yield of the best variety was sufficient to plant one fourth hectare the following season. Through this approach, farmers multiplied the seeds of the best cultivars, thereby eliminating the necessity of purchasing government supplied seed (44).

A similar project was initiated in Nigeria by the International Institute of Tropical Agriculture with both rice and corn (158). The package included four improved cultivars and one local cultivar, two fertilizer levels, and a record book. One farmer in each village was selected by local extension agents and village leaders to test and manage the experiment. Results indicated that small farmer adoption rates were enhanced by these on-farm demonstrations of productivity and profitability (158).

In El Salvador, the basic multiple cropping system developed for complex relay and intercropping of corn, pole bean, cabbage (Brassica oleracea L. Capitata Group), cucumber, bush bean, and radish (Raphanus sativus L.) produced a net income of $772/900 m^2 (78).

The resource utilization approach is another method which is applicable for the study of cropping systems (16, 68). In this approach, the farmer seeks to integrate farm resources into farm enterprises by using available technologies and management skills. An example is intercropping practices in Southeast Asia and in Africa. Short-season crops such as corn or sorghum (Sorghum bicolor L.) are frequently intercropped with upland rice and cassava (Manihot esculenta L.) or pigeon pea (Cajanus cajan Millsp.) creating a 9 to 10-month cropping season with several harvests and a single major tillage operation. This system enables efficient utilization of land, solar radiation, water, and labor resources (8).

Most farmers use a combination of enterprises with different resource requirements. Some enterprises may be of lower productivity but higher in stability. Others may be labor or cash-intensive and highly productive, but unstable from the biological, management or economic standpoint. The net effect is to balance the farmer's resources in meeting his needs for productivity and stability (68).

Management of Vegetables in Cropping Systems

Vegetables are often grown as component crops in a wide array of cropping patterns (167). Thus, management of vegetable crops is dependent on the type of cropping patterns. Asian farmers plant field and vegetable crops following rice or other staple crops (47, 68, 70, 138). The vegetable crops planted depend on the availability of resources such as irrigation, labor, cash inputs, and market. High management vegetable crops such as cabbage, pole bean, cauliflower (Brassica oleracea L. Botrytis Group), and tomato (Lycopersicon esculentum Mill.) are grown after rice where there is sufficient irrigation and market incentive (24). Farmers use stakes, high levels of fertilizers and pesticides on crops like tomato and pole lima bean (Phaseolus lunatus L.) where crop market value is high. Conversely, low management crops such as mungbean (Vigna radiata L. Wilczek) and cowpea (Vigna unguiculata L. Walp.) are often planted after rice by farmers in rain-fed areas where market is limited and a major portion of the produce is consumed by the farm family (26, 114, 177). Although these crops require low management levels, studies indicate that they respond to improved levels of cultural management. For example, Herrera et al. (76) reported that adequate control of insect pests from vegetative to flowering stages significantly increased yield of mungbeans.

In Taiwan, vegetable crops are planted sequentially after irrigated rice field crops (47, 105). The rice-rice-vegetables cropping pattern is most common where variety of medium to high management vegetables can be grown during the period between the production of two rice crops. There is sufficient time for growing short-season vegetable crops such as bunching onion (Allium fistulosum L.), cabbage, mustard, lettuce (Lactuca sativa L.), radish, and bean. In certain parts of Malaysia where there are efficient irrigation and drainage systems, high management vegetable crops such as hot peppers (Capsicum frutescens L.), tomato, yard long bean [Vigna sinensis (Stickm) Savi ex Hassk. Sesquipedalis Group], and cucumber are planted after rice (165).

Some double cropping vegetables with field crops are also possible under irrigation during the warm season in North Florida (55, 133). For example, southern pea, pigeon pea, wax and black beans (Phaseolus spp. L.) were successfully grown as second crops after early or mid-season corn (55). Under double cropping, these crops required high plant populations and narrow row widths compared to lower populations and wider spacings when grown as single crops. With a short-maturing small grain crop like barley (Hordeum vulgare L.), it was possible to grow three crops in sequence with vegetables such as sweet corn, English pea, southern pea, and snap bean (51, 52). These crops are planted using zero tillage and no fertilizer except for the sweet corn. The vegetable legumes utilize the residual fertilizer from the preceding crop to make more efficient use of soil nutrients. Double cropping of vegetables was feasible in South Florida (21, 43, 129). Butternut squash produced high yields without additional fertilizer when planted after tomato grown under full-bed plastic mulch (21). In this study, complete or partial incorporation of fertilizer in beds under mulch resulted in higher yields of tomato and second crop butternut squash than banding all the fertilizer on top of the bed. Everett (43) reported that yields of tomato or cucumber planted as second crop on plastic mulched beds previously planted to fall tomato did not significantly increase at fertilizer rates higher than 70 kg/ha N and 100 kg/ha K regardless of placement methods. Thus, multiple cropping on mulched beds can reduce energy use and production costs by permitting efficient use of both physical and applied resources (21).

Small-scale farmers in the tropics have developed a variety of intercropping systems involving vegetable crops (6, 24, 79, 92, 169). For example, short-maturing crops such as mungbean, cowpea, and soybean (Glycine max L.) can be intercropped with tall, short-maturing crops such as corn (84). Paner (127) reported that vegetable crops can also be intercropped with tall, long-maturing crops such as mungbean in sugarcane (Saccharum officinarum L.). Also, tall permanent or perennial crops such as coconut (Cocus nucifera L.), rubber (Hevea brasilienses L.), banana (Musa sapientum L. Schaft) can be intercropped with ginger

(Zingeber officinale Roscoe), dasheen (Colocasia esculenta L.), arrowroot (Maranta arundinacea L.), mungbean, and other crops producing economic yield for small-scale farmers.

In Taiwan, small-scale farmers also plant short-duration vegetable crops under grape (Vitis spp.) vines during the dormant period or between young fruit trees such as mango (Mangifera indica L.) (169). This practice provided incentives for additional income. Intensive vegetable growers in Taiwan also interplant mustard spinach (Brassica campestris L. Perviridis Group) and bunching onion. Following the harvest of mustard spinach, cauliflower is transplanted between alternate rows of onion (169). In south-central Taiwan, farmers interplant cauliflower and pole lima bean or other crops in rotation with paddy rice (24, 169).

Management of intercropping systems is sometimes more complex than sequential cropping and may depend on several factors such as season, crop, farm resources, market, and farmer skills. For example, in Taiwan, farmers intercropped lima bean and cauliflower using three methods (24). Farmers with abundant labor and small landholdings planted high populations of cauliflower (21,000-30,000 plants/ha) with low seeding rates for lima bean (25-30 kg/ha) to obtain high farm income. Farmers who planted late in the season used low populations of cauliflower (15,000-16,000 plants/ha) with high seeding rates for lima bean (60-90 kg/ha) because they predict that the price of cauliflower will drop during the peak harvest period of vegetables while the price of lima bean will rise in response to reduced supply. Farmers who planted early in the season used 20,000-29,000 seedlings/ha for cauliflower and 50-70 kg/ha of lima bean seed because they predict that the price of early planted cauliflower will be very high.

Relay intercropping which is another method of crop intensification, can save time in the cropping sequence, permit the first crop to protect the second crop during the early stages of growth by acting as a "nurse crop" and distribute labor peaks throughout the cropping year (92, 117). In relay interplanting, the primary limiting factor seems to be competition for light, whereas moisture and nutrients are less critical (84). For example, experiments at IRRI demonstrated that mungbean and radish were least tolerant to shading because these crops can stand only two to three days of dense shade, whereas sweet potato (Ipomoea batatas L.) can stand four to five weeks of dense shade with little yield reduction when relay intercropped with rice (84).

Several vegetable crops relay interplanted into annual field crops or vegetable crops benefited small-scale farmers (7, 84). For instance, relay interplanting tomato, cabbage, bush snap bean, and sweet potato as early as 20 days before harvest of sweet corn did not reduce yield (7). Relay intercropping vegetables into rice increased total production, yet maintained critical planting dates for the main rice crop within the cropping pattern. For instance, small-scale farmers in central Taiwan relay interplant short duration vegetable crops during a 60 to 100-day period between two rice crops (96). Vegetable crops that require 10 to 30 additional days to mature can be planted and harvested before the critical rice planting dates. Summer melon (Cucumis melo L.), pickling melon (Cucumis melo L. Var. Conomon), or watermelon [Citrullus lanatus (Thumb.) Mansf.] are planted on small mounds of soil two weeks before rice harvest during the summer season.

During winter, a single crop such as sweet potato or edible-podded pea (*Pisum sativum* L. Macrocarpon Group) and many green leafy vegetables can be relay interplanted before rice harvest to increase total production within the 100-day period (169).

In North Florida, relay interplanting of sweet potato and pigeon pea in corn did not reduce corn grain yield (3). Higher yields of sweet potato and pigeon pea were obtained with early maturing corn at low populations than at high populations.

Relay intercropping vegetable crops has some limitations because of management constraints. For instance, the Taiwan method of planting sweet potato into puddled rice imposed difficulty in seedbed preparation particularly in fine textured soils (47). This method is also expensive since construction of ridges takes 400 to 500 hours/ha. Management of these ridges is extremely difficult in terms of weed control (47).

Soil and Fertilizer Management in Vegetable Cropping Systems

Soil and fertilizer management studies in vegetable multiple cropping systems are limited. As fertilizer costs increase every year because of high energy cost for their production, many researchers are finding methods to reduce fertilizer use or to increase efficiency (122, 123, 143). Oesligle et al. (122) stated that high analysis fertilizers, if available at any price, frequently constitute a direct input cost that is beyond the means of the marginal farmer. High fertilizer prices in developing countries imply that this input be used efficiently. Thus, consideration of the economics of management practices simultaneously with their biological potential is important when developing fertilizer practices for multiple cropping patterns (122). This is especially true for vegetable crops because of their high crop value, intensive cultivation, and responsiveness to fertilization (104). Soil and fertilizer management studies in multiple cropping usually deal with yield responses to residual fertilizers (21, 33, 134, 136) or to applied fertilizers in continuous cropping (75, 91, 152, 153). Associated with these studies are effects of previous crops on yields of succeeding crops (6, 13, 87, 88, 102, 112, 137, 144, 143). These studies provide some bases for fertilizer recommendations in sequential cropping systems.

In sequential cropping patterns, the basic precept is that the farmer manages only one crop at a time. From the soil management point of view, improved practices for single crop stands are not entirely applicable to sequential cropping systems because of the influence of previous crops on soil physical properties, water, and nutrient availability to succeeding crops (143). Soil and fertilizer management practices should be geared to the crop sequence or rotation rather than to individual crops.

Sanchez (143) stated that the residual effects of N fertilization are influenced by many variables such as the rate of application, recovery of added fertilizer by previous crop, leaching, immobilization, denitrification, and rainfall pattern. Thus, residual effects should be considered in fertilizing succeeding crops. For example, in India, soybean yields increased from 1.3 to 1.9 tons/ha when N application to the preceding rice crop was increased from 0 to 180 kg/ha (136). The residual N fertilizer, however, decreased nodulation in soybean.

Jones (91) reported that when corn followed cotton (Gossypium hirsutum L.), the response to N was maximum at 84 kg/ha, whereas corn following sorghum, peanut (Arachis hypogaea L.), and cowpea required 168 kg/ha to achieve maximum yield. Experiments in Sudan Gezira (22) have shown that sorghum and wheat (Triticum aestivum L.) were responsive to fertilizer N and were affected by residual N, whereas hyacinth bean (Dolichos lablab L.) did not respond to residual N but yield consistently increased by increasing residual P.

Residual N from previous crops had a greater influence on tomato yield than fertilizer applied specifically to the tomato crop (123). For example, Osterli and Meyer (123) found that tomato yields responded favorably to 336 kg/ha N applied to the previous sugar beet (Beta vulgaris L.). When additional N was applied directly to tomato there was no significant increase in fruit size and quality.

Hayami (72) stated that optimum elemental concentrations for most vegetable crops are about 5 to 10 times those required for rice. Under lowland puddled soil conditions in tropical Asia, Hayami (72) found that fruiting vegetables such as tomato and cucumbers accumulated nitrate N preferentially from the initial growth stage. Since this form of N would be found only before the soil is puddled, growers can benefit if they plant tomato and cucumber before rice. However, with proper soil, fertilizer, and water management, growers may also benefit by growing these vegetables after rice. Leafy and heading cabbages absorb ammonium N and required an increasing amount throughout the growing period. These crops are suited for production in post rice soils (72).

In Florida, high management vegetable crops such as tomato and pepper (Capsicum annuum L.) are double cropped with either low or high management vegetables and field crops (21, 33, 43, 52, 55, 95). The objective is to utilize applied fertilizer more efficiently and increase productivity by eliminating added costs. Kretschmer et al. (95) suggested that field corn is a good crop to follow fall tomato and other heavily fertilized vegetable crops on sandy soils in Florida. When corn was planted following these crops, additional applications of P, K, and micronutrients, were not necessary. Yields of carrot (Daucus carota L.), green onion, lettuce, and radish were significantly higher in plots where no additional fertilizers were applied than in plots applied with fertilizers after a fall tomato (33). The low yield of vegetables in the fertilized plots was the result of high total soluble salts that inhibited germination and reduced seedling survival.

As cropping intensity increases, high levels of added chemical fertilizers may cause rapid shifts in soil properties such as pH (12, 52, 85, 98, 135, 140), total soluble salts (34, 53, 73, 103, 161), organic matter (1, 2, 10, 71, 98, 111, 114, 147, 151, 166). N (38, 39, 135, 142, 146), P (139, 141), and K (14, 135, 137). Consequently, shifts in soil properties may create a soil environment that can restrict crop growth and limit cropping potential of soils. For example, shifts in pH may result in excesses and deficiencies of both micro and macronutrients (85).

An example of the effect of intensive sequential cropping on soil properties was studied by Nair et al. (114). Rice, wheat, and mungbean or potato were grown sequentially per year. In spite of high amounts of nutrient removal, there were no appreciable changes on soil organic carbon, total N and available P and K (114). On double cropping of paddy rice in Taiwan for 48 years, average rice yields were similar among fertility treatments with the same amount of N added (100). The effects on chemical properties were also similar with those observed by Nair et al. (114), and suggested an equilibrium level without major differences among treatments.

Continuous cropping does not always result in stable or increased yields. Yield levels of succeeding crops depend on resultant soil fertility which is influenced by changes in soil chemistry (143). Double or triple cropping sequences involving sweet potato, taro (*Colocasia esculenta* L. Schott), sorghum, and cowpea conducted in New Guinea on volcanic alluvial soils showed progressive yield decreases with time (15). These decreases were related to decreases in soil fertility parameters. Crops were not fertilized but when cropping was alternated with legumes or green manure, the fertility decline was delayed. Intensive cropping of this nature required fertilization to sustain long-term sequential cropping (116). In a 2-year continuously cropped rotation of early and late crops including corn, cotton, bean, sweet potato, peanut, finger millet (*Eleusine corocana* L.), and sorghum, yields of all crops declined steadily during the first two cycles (153), but application of N, P, K, and farm yard manure increased yields. After a few years of continuous cropping, K deficiency limited yields, especially of sweet potato.

Several reports indicated that soil organic matter changes with continuous and with intensive cropping systems (40, 98, 111, 114, 166). The changes can be an increase or decrease depending on the crop species, tillage level, and fertilizer level. For example, rotation of spinach (Spinacea oleracea L.) and cabbage with green manures such as alfalfa (Medicago sativa L.), timothy (Trifolium pratense L.), red clover (Lolium multiflorum L.), and sweet clover (Melilotus indica L.) resulted in higher carbon and N in the soil than rotations with continuous vegetables (40). Continuous cropping of corn for three consecutive years followed by four seasons of cultivation with cropping sequences of corn-corn-cowpea, pigeon pea-corn, soybean-soybean, corn-soybean, and cowpea-cowpea resulted in greater decline in organic matter than the no-tillage plots (98). The rate of decline was much higher under cowpea and soybean where smaller amounts of crop residues were produced than with corn. Standifer and Ismail (151) also found that organic matter was lower in conventional tillage plots than in minimum tillage plots after four years of multiple cropping crimson clover (Trifolium incarnatum L.), sweet corn, and cowpea. Stevenson (154) reported that rotations including legumes maintained higher organic matter contents than continuous cropping with non-leguminous crops.

A combination of moderate manuring and medium rates of complete fertilizer application is most effective in producing high yields of vegetables without depleting soil fertility (111). In a continuous corn-green manure crop rotation, Thompson and Robertson (160) found that organic matter in the high fertilized corn plots was more than in the unfertilized plots. In India, Havanagi and Mann (71) reported that soil organic carbon was increased by application of farm yard manure and by rotation including both green manure and legume crops.

The preceding crop species can have beneficial or detrimental effects on yields of succeeding crops. For example, onion and lettuce planted after sweet corn with a winter crop of vetch (Vicia sativa L.) developed a severe root rot gradually reducing the yield and often killing the vegetables (87, 88). They postulated that during the decomposition of corn residue under cool temperatures of spring, a toxin was formed which injured plant roots (88). Mack et al. (102) observed that average crop yield indices following cabbage, onion, summer pumpkin (Cucurbita pepo L.), and carrot were significantly greater than those crops following sweet corn, potato, and tomato. The low yields following sweet corn, potato, and tomato might have been the result of low soil fertility after growing these crops. Some vegetables planted after rice respond favorably to N application but not to residual N. For instance, yields of sweet potato and tomato planted after rice significantly increased when N was applied directly to the vegetable crops (6). Jones (91) also reported that corn yields were higher when preceded by peanut than by cowpea. The differences were larger without N application and decreased at the optimum application of 84 kg/ha. Detrimental effects have also been observed with grain legumes. Experiments proved that mungbeans have a depressing effect on yield, particularly at low levels of N (83). Apparently, mungbeans secrete certain toxins which depress growth.

Economic Evaluation of Vegetable Cropping Patterns

Cropping patterns are sometimes assessed in terms of various economic parameters (105, 113, 120, 131, 132). Methods and analytical tools have been developed to enable farm management researchers to evaluate yield responses of new crop cultivars, various levels of mechanization, input-output relationships and net income (105). These methods, however, were often developed and used for single crop enterprises. Menegay (105) reported that current analytical tools for measuring, evaluating, studying, or comparing multiple cropping patterns are limited in scope and flexibility.

Two general economic criteria involving land use and production are commonly used in evaluating performance of cropping patterns. Several indices such as multiple cropping index (MCI), diversity index (DI), harvest diversity index (HDI), simultaneous cropping index (SCI), cultivated land utilization index (CLUI), and crop intensity index (CII) have been used to measure this criterion (105, 106, 107, 157). Crop intensity index (CII) is more precise because it provides an assessment of farmer's actual land use from an area-time perspective and defines the composition of land use (107). The use of indices to compare economic performance of cropping patterns is more appropriate in studies conducted under actual farm conditions where farm sizes are variable and cropping patterns within a farm vary from parcel to parcel.

Level of returns to resources and other production inputs is the most commonly used criterion in evaluating economic performance of cropping patterns because it relates inputs and products in terms of a common denominator which is usually money (48, 49, 105, 120, 132). Levels or return are usually measured and expressed in terms of returns to physical resources such as land ($/ha), irrigation water or rainfall ($/inch) or returns to purchased and applied production inputs such as fertilizer ($/kg) or labor ($/hr). Price (132) stated that rates of return to resources should be regarded as secondary criteria after net returns criteria are met. Measuring rates of return to resources is useful if a farmer is interested in profit maximization. A farmer will achieve this goal through maximizing return to his limiting resource (120). For example, a farmer with large amounts of available labor compared to cash will adopt cropping patterns that produce high rates of return to cash (132). Conversely, an appropriate cropping pattern in an area characterized by a marked shortage of labor at certain times of the year will maximize returns per unit of labor (120).

The rate of return to both physical and applied resources is affected by farmer's crop management interacting with physical, biological, and socio-economic factors. Hence, motivation and production decisions of farmers are influenced by these factors (24). For example, small-scale farmers in Taiwan intercrop tomato for processing with mango to utilize more fully their land and family labor resources. Production practices for tomato intercropped with mango are similar to those in the monocrop and intercrop with sugarcane, but adverse physical and environmental factors reduced yields. Net returns and farm income were much lower when tomato was intercropped with mango than when tomato was a monocrop or intercropped with sugarcane (24). Since there was no close relationship between fertilizers applied and yield in tomato intercropped with mango, lower levels of fertilizer application reduce input costs without significant yield loss (24).

Some Taiwan farmers plant sweet potato stem cuttings near rice stubble with no tillage and minimum input requirement. Others use complete tillage before planting or intercropping with corn and edible sugarcane. The tillage method requires higher inputs, whereas the intercrop method involves the least inputs. Survey data showed that yields were increased with increased net returns, but the correlation value between yield and net return was low with tillage method suggesting that added costs did not result in higher yields (24). There was no significant relationship between capital inputs notably fertilizer and yield. Farmers may be applying excessive capital inputs to sweet potato but returns to fertilizer and material costs were lower than returns from tomato. The highest net return and farm return were not associated with high yield but with low cost (24). Although the intercrop method produced intermediate yields, production costs were lowest, and therefore, farm returns, net return, and revenue-cost ratio were highest (24).

Charreau (28) reported that improved cropping patterns consisting of high tillage and fertilizer levels were more profitable in the central zone of West Africa where rainfall was higher than in the northern zone. This was a situation where potential of improved technology to increase productivity and profitability was limited by climatic factors.

The goal of most cropping systems research has been to improve productivity and income among small farms (8, 31, 69, 70, 118, 177). Since adoption of cropping patterns not only depends on economic returns but also on farmer's motives, studies should emphasize improvement of farmer's traditional cropping systems before recommending alternative cropping patterns. Cropping systems of small-scale farmers are usually characterized by diversity, stability, and low productivity (70). To improve income, productivity should be increased without sacrificing diversity and stability.

Improving crop management practices attempts to increase productivity. Researchers develop improved production technologies for each stage of crop production from tillage to harvesting by varying levels of production inputs or introducing a new technique. These studies generally focus on one crop with yield maximization as the main objective, but exclude economic considerations (16, 24). For some crops, a significant increase in agronomic yield may not be economically acceptable to farmers (24). Although economic evaluation of different crop management practices is common, similar studies for year-round cropping patterns are limited. Most studies compare costs and returns from various types of cropping patterns using standard cultural practices which are in some situations higher than the farmer's management level (25, 85). For example, in Chiang Mai, Thailand, Calkins (25) reported that the cropping pattern peanut-tomato-rice had higher economic potential than tomato-mungbean-rice because a heat-tolerant tomato cultivar was planted in the first pattern resulting in yields with high market price. In the Philippines, the cropping pattern rice-watermelon was the most profitable, whereas the cropping patterns rice-mungbean and rice-sweet potato resulted in equal net returns as the rice-rice or rice-sorghum (127). Economic evaluation of the cropping pattern rice-sweet potato using three power sources was studied by Banta (9). Costs and returns were different among the three power sources but returns to labor were higher using handtractor compared to either animal power or hand labor (9). He suggested that the use of a machine in intensive cropping patterns can provide better labor efficiency but may not be economically profitable.

In a study of economic performance of rice-based cropping patterns, labor requirement was slightly higher in a rice-rice pattern than in rice-upland crops patterns (86). Cash requirements were higher with rice-upland crops because of high costs of upland crop seeds and insecticides (86). The upland crops included vegetables such as mungbean, cowpea, and muskmelon. The rice-mungbean pattern produced the highest net return because mungbean received a high market price (86).

Increasing intensity of cropping patterns increased gross and net returns to labor in four cropping patterns evaluated in Hissar District, India (35, 138). Singh et al. (149) reported that the more intensive pattern involving corn-potato-tomato and mungbean was more profitable than cotton-wheat or pearl millet (Pennisetum glaucum L.)-wheat-mungbean. Darlymple (35) also reported that net returns per hectare and net returns per hour of labor increased with increasing cropping index. A more complex intensive cropping pattern involving sequential and relay intercropping of pole bean, corn, cabbage, cucumber, bean, and radish resulted in high net returns in El Salvador (78).

Although some studies involving economic evaluation of cropping patterns were conducted in experiment stations using small plots, results have shown high level of accuracy because of high degree of control. Therefore, these studies should compliment or support those evaluated under actual farm conditions.

CHAPTER II

AN EVALUATION OF FOUR VEGETABLE CROPPING PATTERNS FOR NORTH FLORIDA

Introduction

Vegetable production in North Florida among small-scale growers is characterized by relatively few total hectares (45), a short cropping period (63), limited and inefficient marketing systems (29, 50, 129), and a low level of crop management (42). Climate and soil conditions favor the growing of vegetables during spring and fall seasons, whereas higher temperatures and intense rainfall during summer and freezing temperatures (36) in winter limit production of vegetables.

In general, average yields of vegetable crops grown by small-scale farmers in North Florida are lower than in South Florida (29, 45). For example, average yields of eight out of ten vegetables were higher in South Florida than in North Florida (45). Climate, cropping systems, labor, and market constraints limit production levels and profit margins from vegetable production in North Florida (29, 30, 50). In addition, low income (42) and limited education levels (115, 170, 172) among small-scale growers contribute to marginal vegetable production enterprises.

Crop management levels utilized by many vegetable growers also contribute to lower yields in North Florida. Crop management level is defined as capital, labor, and other production inputs including production skills that the farmer allocates to produce various crops. Examples are levels of irrigation, weed control, insect and disease management, tillage, mulching, staking, crop establishment, and fertilizing. Insect, disease, and fertilizer management levels were low among small-scale growers in North Florida (29).

Double cropping, or the planting of two crops in one year, is practiced commonly in Florida (129). In 1973-74, 147,200 hectares of vegetables were harvested, but only 80,000 to 100,000 hectares were planted to vegetables (129). For example, four or five crops of radishes are generally harvested from the same field in the Everglades and Zellwood (Shuler, per. comm.). Some growers alternate part of their radish hectarage with other crops such as sweet corn, celery (*Apium graveolens* L.), carrot, and leafy crops.

Double cropping tomato on full-bed plastic mulch with other crops is practiced by many growers. Some tomato growers in Quincy plant pickling cucumbers or winter squash after tomato. In South Florida, Bryan and Dalton (21) obtained high yields of butternut squash planted after fall-grown tomato on full-bed plastic mulch. Csizinszky (34) reported that several vegetable crops can be grown after tomato without additional fertilizer. As the land area planted to more than one vegetable crop per year increases, year-round cropping systems studies are required to provide information on appropriate crop management practices for efficient production systems and improved returns to production inputs.

Several studies have been conducted to extend the production season and improve vegetable production in North Florida (20, 164, 175, 176). The use of black and white plastic mulches to reduce the effect of heavy rainfall and high soil temperature during summer increased yield and improved quality of several vegetable crops (20). The use of black plastic mulch was more profitable for cantaloupe, whereas clear mulch was most effective for watermelon. Squash produced highest yield when grown with white on black mulch (20). Growing vegetables under tobacco shades increased total yields of cucumber, but reduced tomato and pole bean yields (164, 175).

Sequential planting of selected vegetable cultivars also extended the production season to late spring and summer in Gainesville (61, 63, 64, 65, 66, 67). Halsey and Kostewicz (63) reported high marketable yields for some vegetable crops grown during extended seasons. Vegetable crops included in their cultivar and date of planting experiments were snap bean, southern pea, lima bean, cabbage, collard, squash, and onion. In sequential plantings involving seven vegetable crops arranged in four cropping patterns, Palada et al. (126) reported no significant yield increase with increasing levels of fertilizer, but returns to management on a dollar/ha basis were higher in high management crops than in low management crops.

Research aimed at developing appropriate crop management technologies for sequential cropping patterns is needed to improve vegetable cropping systems throughout Florida. The purpose of this study was to evaluate resource use, productivity, and profitability of several vegetable crops planted in four year-round cropping patterns for North Florida.

Materials and Methods

This 2-year study was conducted at the Horticultural Unit of the University of Florida at Gainesville (29° 45' N latitude, 82° 20' W longitude) beginning in October 1977, and terminating in October 1979.

The soil was classified as Kanapaha fine sand (loamy, siliceous, hyperthermic, Grossarenic Paleauquult) with 1% organic matter and a CEC of 2.52 meq/100 g (27). The climate is warm (average max 31°C; min 11°C) and humid (average 229 mm rainfall/month) from April to September, whereas October to March is cool (average max 24°C; min 0.55°C) and dry (average 76 mm rainfall/month).[1]

Soybean was planted as a cover crop prior to initiating the experiment. Soybean was mowed to a stubble and the land disc plowed before fumigating with 66 liters/ha SMDC (sodium N-methyl-dithiocarbamate). The fumigant was injected into the soil with a gravity-flow distributor using two coulter applicators. Basal fertilizer was broadcast and rototilled into the soil at varying rates depending on crop requirement (Table 1). Raised beds were formed using a disc-hiller and bed press. Subsequent land preparation between crops consisted of mowing, disc plowing, rototilling, fertilizing, and bedding. Seven vegetable crops including 'Texas Grano 502' bulb onion, 'Blue Lake' pole bean, 'Morris Heading' collard, 'Early Golden Summer Crookneck' squash, 'Wando' English pea, 'Zipper Cream' southern pea, and 'Florida Curled Leaf' mustard were classified into low (LM), medium (MM), and high (HM) management groups. These management groups were based on average costs of fertilizers, pesticides, cultural labor, and 5-year average harvesting costs for producing each vegetable crop in Florida (Table 2).

Four basic cropping patterns were developed using combinations of seven vegetable crops (Figs. 1 and 2). Two cropping patterns were

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[1]Climatic data, Horticultural Unit, University of Florida (mimeo).

Table 1. Cultural practices for vegetable crops grouped in three management levels and grown in four cropping patterns at Gainesville, FL, 1977-79.

Vegetable crop and planting method	Management group	Seeding rate	Spacing		Total fertilizer		
			Row	Plant	N	P_2O_5	K_2O
		kg/ha	m	cm	----	kg/ha	-----
Direct seeded							
Bulb onion	High	3	1.1[z]	2.5	120	120	160
English pea	Low	60	1.1	2.5	30	40	40
Mustard	Medium	3	1.1	2.0	60	120	80
Pole bean	High	30	1.1	25.0	120	120	160
Southern pea	Low	30	1.1	2.5	30	40	40
Squash	Medium	3	1.1	30.0	60	120	80
Transplanted							
Collard	High	1	1.1	33.0	120	120	160

[z]Two rows per bed spaced 15 cm apart.

Table 2. Average fertilizer, pesticide, cultural labor, and harvest costs for high, medium, and low management vegetable crops in Florida, 1973-77.

Management group	Crop	Production inputs				
		Fertilizer	Pesticide	Labor	Harvest	Total
		Costs, $/ha				
High	Bulb onion[z]	240	140	220	890	1,490
	Pole bean[y]	250	180	750	1,380	2,560
	Collard[z]	200	60	260	750	1,270
	Mean	230	130	410	1,010	1,770
Medium	Mustard[z]	60	60	160	750	1,030
	Squash[y]	200	130	130	880	1,340
	Mean	130	100	150	820	1,190
Low	English pea[z]	50	70	170	420	710
	Southern pea[x]	100	50	180	550	880
	Mean	80	60	180	490	800

[z] 1976 estimate using data of J. L. Johnson and R. C. Atkinson (90).

[y] Source: D. L. Brooke (19).

[x] Sources: A. W. Colette (29), and R. E. Levins and R. D. Downs (99).

three high management crops planted in sequence (bulb onion-pole bean-collard), and three low management crops planted in sequence (English pea-southern pea-southern pea). The other two cropping patterns were a combination of low, medium, and high management crops planted in sequence as follows: HM-MM-LM (bulb onion-squash-southern pea), and HM-LM-MM (bulb onion-southern pea-mustard). These patterns were designed to estimate the effect of crop management sequences on resource use, total productivity, and profitability.

The four cropping patterns were arranged in a randomized block design with four replications. Each plot measured 21 m long by 4 m wide. Rows were oriented in an east-west direction. Bulb onion, southern pea, English pea, squash, and mustard were field-seeded on raised beds using an Earthway seeder. Pole bean was hand-seeded into holes 2 cm deep. Collards were grown in peat pots and transplanted after 30 days. Planting practices and seeding rates were based on recommended practices (109, 110, 171).

Crops were planted in a single row per bed, except for bulb onion which was seeded in double rows. Each plot consisted of three beds 40 cm wide and 15 cm high spaced 1.10 m apart. A 5-m section of the center bed was harvested for yields.

Fertilizer rates for each crop (Table 1) were based on fertilizer and vegetable production studies conducted in Florida (21, 56, 58, 59, 60, 74, 93, 159, 168). Basal fertilizer for each crop was applied and incorporated into the soil prior to planting. Depending on the crop, supplemental fertilizer was sidedressed or topdressed one or three times during each crop cycle. Insects and diseases were controlled using the recommended practices for Florida. Weeds were controlled by cultivation and handweeding, except for first crop of bulb onion where DCPA (dimethyl tetrachloroterephthalate) at 6.7 kg a.i./ha and chlorpropham (isopropyl _m_-chlorocarbanilate) at 1.0 kg a.i./ha were sprayed preemergence. Information about cultural practices for each crop is summarized in Table 1.

Crop and cropping pattern duration including the interval between crops were recorded. Crop duration was counted from seeding to last harvest. Bulb onions were graded according to standard sizes of large (diameter greater than 7 cm), medium (5 to 7 cm), and small (less than 5 cm). Production costs and returns to management were based on 2-year average prices of production inputs and market prices at the time of harvest. These production costs and market prices (46, 108, 150) were compared with 5-year averages (19) to determine long-term profitability.

Results and Discussion

Crop environment. The first cropping year (1977-78) was characterized by higher rainfall (1,495 mm) compared to the second year (726 mm) (Figs. 1 and 2). Most rainfall occurred during July and August in 1977-78. The rainfall pattern for 1978-79 followed the 13-year weekly average, except that the dry period was extended (Fig. 2).

The winter of 1977-78 was colder than 1978-79 (Figs. 1 and 2). The lowest weekly minimum temperature was -1.4°C in 1977-78 and 0.02°C in 1978-79. Low temperatures in winter retarded the growth of bulb onion and English pea resulting in an extended growing period. The

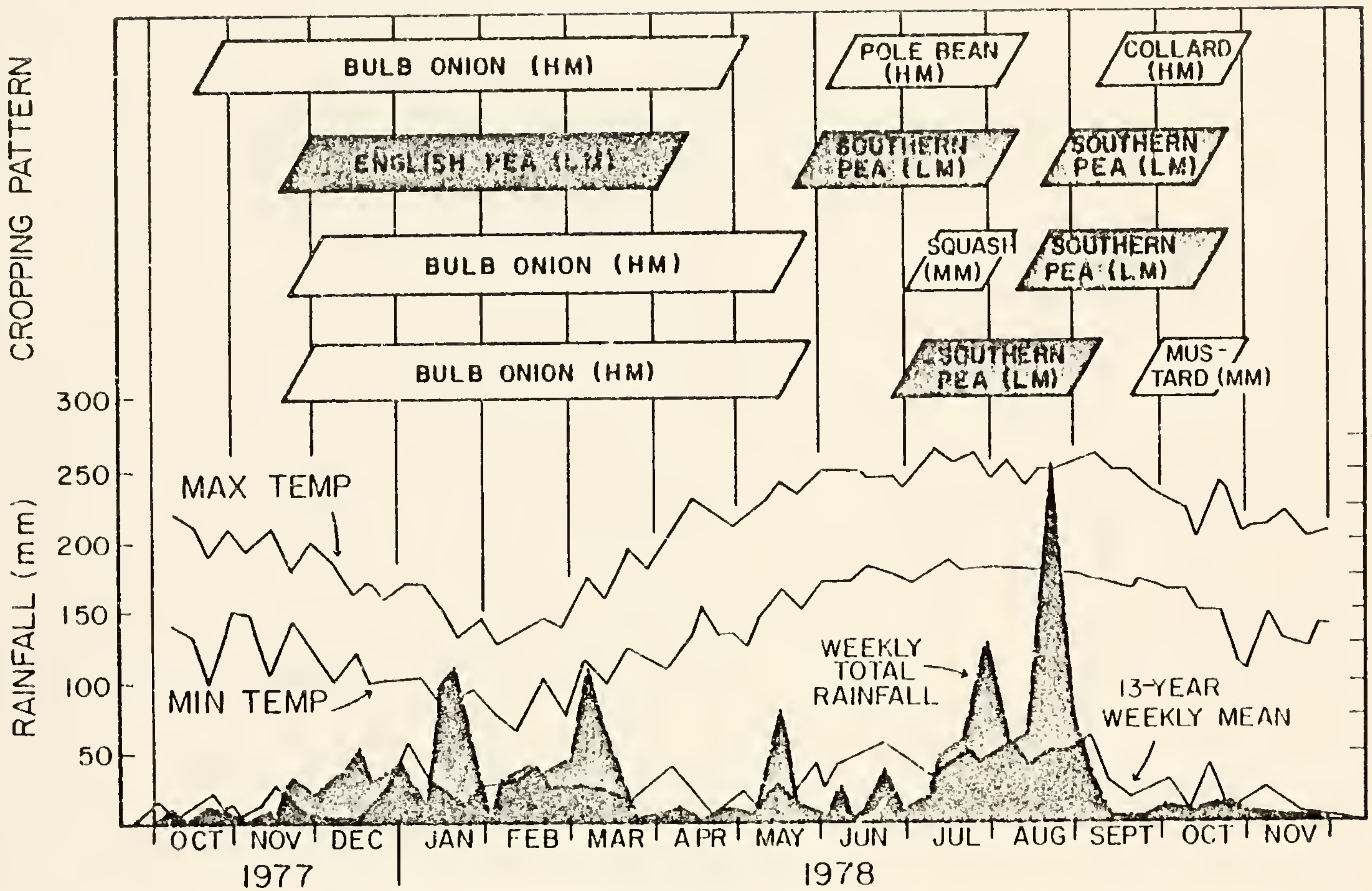

Fig. 1. Four vegetable cropping patterns plotted against rainfall and temperature at Gainesville, FL, 1977-78.

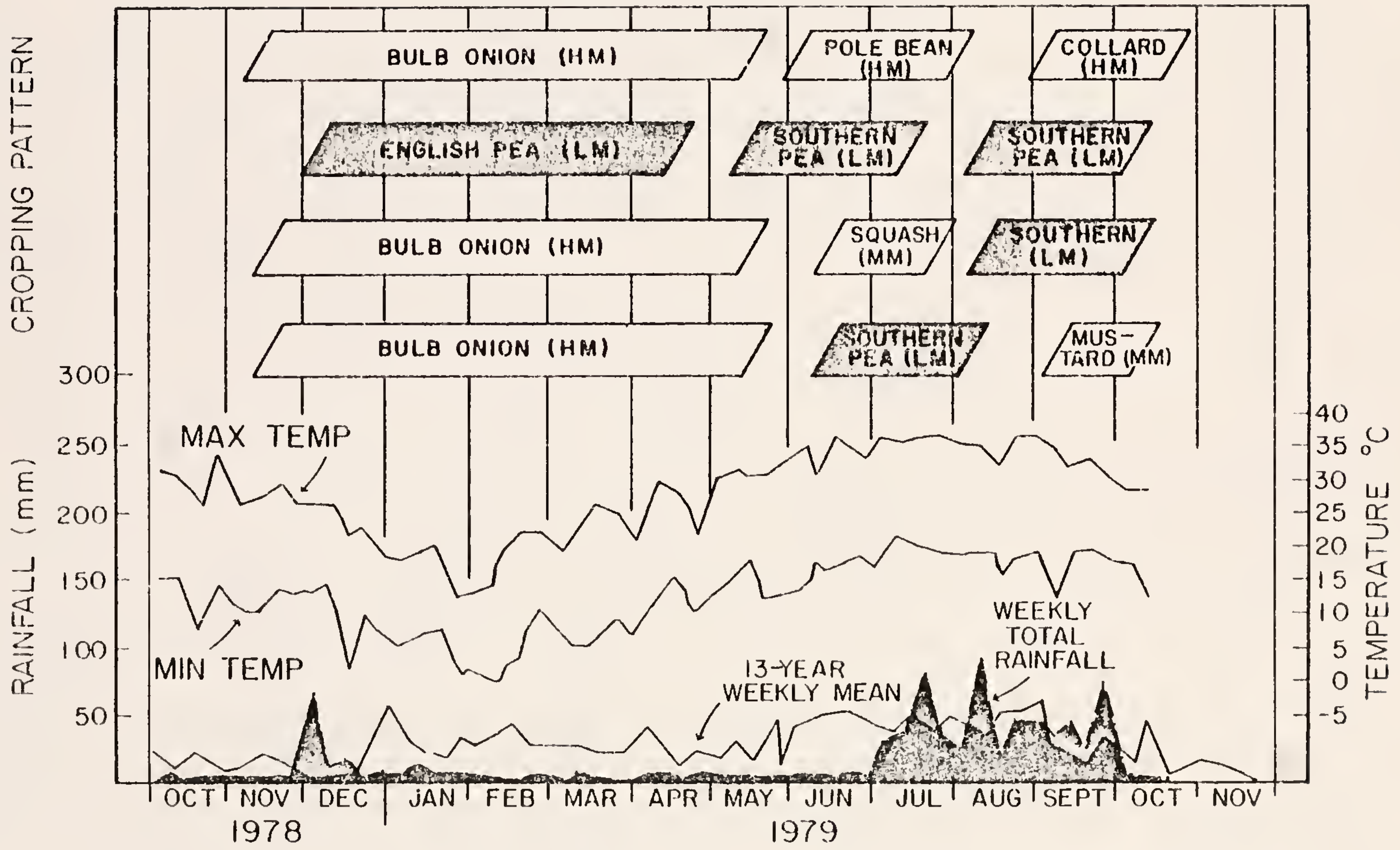

Fig. 2. Four vegetable cropping patterns plotted against rainfall and temperature at Gainesville, FL, 1978-79.

highest weekly maximum temperatures were 38°C in June 1978, and 36°C in July 1979 (Figs. 1 and 2). The growing period of the second crops in all cropping patterns coincided with high rainfall and temperature.

Crop duration. Using average data for 2 years, the longest cropping duration was 322 days in cropping pattern HM-HM-HM while the shortest duration of 300 days was observed in cropping patterns LM-LM-LM and HM-LM-MM (Table 3). The interval between crops was longest (68 days) with cropping pattern LM-LM-LM and shortest (44 days) with HM-HM-HM. In general, crops grown during winter had prolonged growing periods. This prolonged growing period delayed the planting of second crops in cropping patterns HM-HM-HM, HM-MM-LM, and HM-LM-MM.

Marketable yields. In general, marketable yields of vegetables were affected by planting dates (Table 4). Cropping patterns involving bulb onion resulted in late planting and reduced yields of second crops. For example, yields of pole bean and squash following bulb onion were low because these crops were planted in June when harvesting coincided with high rainfall and temperature. A difference of two to four weeks in planting dates reduced marketable yields of these crops compared to normal spring planting.

Cropping patterns involving large crop residues also delayed planting of succeeding crops. Bulb onion produced lower yield when planted after southern pea where large crop residue remained in the soil than onion planted after collard and mustard. Janes (88) observed that onion planted after sweet corn and vetch had reduced growth and died, whereas onion following spinach and beet produced satisfactory growth.

Table 3. Crop duration and interval between crops in four vegetable cropping patterns over two cropping cycles in the period 1977-79, Gainesville, FL.

Cropping pattern[z]	Crop		Crop duration	Interval between crops
			--------- days	-------------
HM-HM-HM	Bulb onion		199	19
	Pole bean		74	20
	Collard		49	5
		Total	322	44
LM-LM-LM	English pea		152	24
	Southern pea		78	11
	Southern pea		70	33
		Total	300	52
HM-MM-LM	Bulb onion		192	24
	Squash		43	11
	Southern pea		72	17
		Total	307	52
HM-LM-MM	Bulb onion		192	24
	Southern pea		70	18
	Mustard		38	14
		Total	300	56

[z]HM=high management; MM=medium management; LM=low management.

Table 4. Marketable yields of vegetable crops in four cropping patterns at Gainesville, FL.

Cropping pattern	Crop	Cropping year		T-test between years[y]
		1977-78	1978-79	
		-Marketable yield, MT/ha-		
HM-HM-HM	Bulb onion	33.5	14.9	**
	Pole bean	1.7	1.5	NS
	Collard	15.3	6.1	**
LM-LM-LM	English pea	3.8	6.5	NS
	Southern pea	3.9	4.1	NS
	Southern pea	2.4	1.6	NS
HM-MM-LM	Bulb onion	14.1	5.5	**
	Squash	no data[z]	2.1	-
	Southern pea	5.8	1.2	**
HM-LM-MM	Bulb onion	14.1	9.8	NS
	Southern pea	1.6	2.2	NS
	Mustard	7.4	3.2	**

[z]Crop failure due to herbicide damage.

[y]** = Significant at 1% level; NS = Not significant.

Marketable yields of bulb onion were significantly greater during the first year of the cropping cycle than in the second year (Table 4). Within a cropping year, onion planted early in the season produced higher yields than late-planted onion. A difference of 4 weeks in planting bulb onion during 1977-78 resulted in a 20-metric ton yield difference. Larger onion plants were produced in early plantings which tolerated low temperatures in January and February. Guzman and Hayslip (56) and Corgan and Izquierdo (32) observed that yield of bulb onions decreased as planting was delayed during the period from September to December. Halsey (61) reported that bulb size decreased after October planting dates in Gainesville.

Marketable yields of pole bean were lower compared to normal planting in North Florida (Table 4). Bryan (20) obtained yields of 4.5 metric tons/ha from an early spring planting. In Dade county, average yields ranged from 5.6 to 7.8 metric tons/ha (19). High rainfall and temperature at flowering and pod set resulted in low yields. Pole bean, therefore, represents a risk when planted during late spring.

A total of 15.3 metric tons/ha of marketable collards was picked from four successive harvests of mature leaves (Table 4).which were similar with yields reported by Halsey and Kostewicz (67). Yields during the second year were significantly lower (6.1 metric tons/ha) because planting coincided with higher temperature and rainfall during late summer.

Marketable yields of English pea were lower in 1977-78 than in 1978-79 because prolonged low temperatures severely retarded early growth which predisposed some plants to killing frost in January and February. Halsey and Kostewicz (64) reported low production throughout the fall months, whereas yield of about 6.7 metric tons/ha were harvested when planted from January to March in Gainesville.

Yields of southern pea were not significantly different between years except in cropping pattern HM-MM-LM (Table 4). High residual nutrients in the soil from previous squash (126) and earlier planting dates resulted in higher yields in 1977-78 than in 1978-79. In general, the third crop of southern pea produced low yields. Several reports (60, 63, 64, 101) indicated that yields from fall plantings were lower compared to spring plantings of southern peas. Lorz (101) reported that crops planted in late spring produced excessive vines at the expense of yield.

Planting squash in early summer in cropping pattern HM-MM-LM resulted in yields equivalent to 2.1 metric tons/ha (Table 4). Halsey and Kostewicz (66) harvested comparable yields when squash was planted in early summer because of foliar disease incidence associated with high humidity and temperature.

Biological stability. Biological stability is defined as the degree to which the outcome of any event is predictable.[2] One method of increasing the degree of biological stability in cropping patterns is to plant crops at the proper time. In cropping patterns HM-HM-HM and HM-MM-LM, the inclusion of pole bean and squash resulted in unstable yields due to improper time of planting. Cropping pattern LM-LM-LM provided some stability, but yields of southern pea decreased with successive plantings. A high degree of biological stability was

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[2]R. R. Harwood. 1974. Stability in cropping systems (mimeo). International Rice Research Institute, Los Banos, Philippines.

observed in cropping pattern HM-LM-MM although southern pea produced low yields.

Production costs and returns to management. Cropping pattern HM-HM-HM required the highest production costs of $8,580/ha, whereas cropping pattern LM-LM-LM required only $3,970/ha (Table 5). Cropping patterns HM-MM-LM and HM-LM-MM required similar production costs as the LM-LM-LM. In general, cash inputs for materials were higher than labor costs in the four cropping patterns. The low yields of most vegetable crops reduced harvest labor costs. Since total labor costs included harvest labor cost, total labor costs were lower than material costs. Gross income was highest with HM-HM-HM and lowest with HM-MM-LM (Table 5).

Crop management groupings significantly influenced relative returns to management. Total returns to management were highest with cropping pattern HM-HM-HM (Table 5). No significant differences in returns to management were calculated among cropping patterns LM-LM-LM, HM-MM-LM and HM-LM-MM. Growing low management crops was as profitable as growing a combination of low, medium, and high management crops.

Returns to production inputs. To assess profitability of cropping patterns, returns to production inputs such as fertilizer, cash, labor, and management were calculated in terms of dollar/dollar investment. In terms of dollar return per dollar invested in production inputs, cropping pattern HM-HM-HM was similar to both LM-LM-LM or HM-LM-MM (Table 6). Palada et al. (126) also reported that increasing production inputs such as fertilizer above recommended levels did not

Table 5. Production costs and returns to management of vegetable crops in four cropping patterns over two cropping cycles in the period 1977-79, Gainesville, FL.

Cropping pattern	Crop	Production inputs			Gross income	Returns to management[z]
		Material	Labor	Total		
		---------- Costs and returns, $/ha				
HM-HM-HM	Bulb onion	2,180	1,270	3,450	6,260	2,810
	Pole bean	730	1,010	1,740	1,010	-730
	Collard	2,510	880	3,390	5,890	2,500
	Total	5,420	3,160	8,580	13,160	4,580 a[y]
LM-LM-LM	English pea	760	920	1,690	3,050	1,360
	Southern pea	730	740	1,460	2,230	770
	Southern pea	520	300	820	1,210	390
	Total	2,010	1,960	3,970	6,490	2,520 b
HM-MM-LM	Bulb onion	1,290	530	1,820	2,460	640
	Squash	470	360	830	600	-230
	Southern pea	610	550	1,160	1,530	370
	Total	2,370	1,440	3,810	4,590	780 b
HM-LM-MM	Bulb onion	1,410	780	2,190	2,990	800
	Southern pea	460	540	1,000	1,330	330
	Mustard	780	460	1,240	2,600	1,360
	Total	2,650	1,780	4,430	6,920	2,490 b

[z] Returns to management = Gross income minus total costs.

[y] Mean separation of cropping pattern by Duncan's multiple range test, 5% level.

Table 6. Returns to fertilizer, cash, labor, and management of vegetable crops in four cropping patterns over two cropping cycles in the period 1977-79, Gainesville, FL.

Cropping pattern	Crop		Production inputs			
			Fertilizer	Cash	Labor	Management
			Returns, $/$			
HM-HM-HM	Bulb onion		15.40	2.30	3.20	0.80
	Pole bean		-1.40	0.00	0.30	-0.40
	Collard		10.70	2.00	3.90	0.70
		Total	9.70 ab[z]	1.90 a	2.50 ab	0.60 ab
LM-LM-LM	English pea		28.20	2.80	2.50	0.80
	Southern pea		16.40	2.10	2.10	0.50
	Southern pea		8.90	1,80	2.30	0.50
		Total	14.40 a	2.00 a	2.30 bc	0.50 ab
HM-MM-LM	Bulb onion		4.20	1.50	2.20	0.40
	Squash		-0.30	0.50	0.40	-0.30
	Southern pea		7.10	1.60	1.70	0.30
		Total	2.70 c	1.30 b	1.40 c	0.30 b
HM-LM-MM	Bulb onion		4.90	1.60	2.00	0.40
	Southern pea		9.10	1.70	1.60	0.30
	Mustard		8.30	2.70	3.90	1.10
		Total	7.70 bc	2.10 a	2.90 a	0.60 a

[z] Mean separation of cropping patterns within each column by Duncan's multiple range test, 5% level.

increase returns to management or to various production inputs in four cropping patterns.

Thus, growers with limited cash receive similar returns per dollar spent on production inputs as those growers with more available cash resource. Although both groups of growers assume risk during unfavorable cropping years, growers who grow high management crops will incur a much greater risk of loss than growers with limited cash. With limited cash, small-scale growers benefit from growing a sequence of low management crops because of low and efficient resource use and stable yields. Growers with available cash can grow low and high management crops and earn a greater gross income if they operate efficiently.

CHAPTER III

CROP AND FERTILIZER MANAGEMENT LEVELS IN FOUR SEQUENTIAL CROPPING PATTERNS INVOLVING VEGETABLES

Introduction

Many horticulturists working with small-scale vegetable growers in the tropics are concerned with improving crop production and profitability of year-round cropping systems (49, 107, 151). These cropping systems often involve the study of crops grown in numerous multiple cropping combinations ranging from single crops grown sequentially to crops grown together in various combinations (69). Productivity and profitability often depend on the management level utilized by farmers which depends on the type of vegetable crop, its market value (24, 105), and the capital, labor, and other production inputs that a farmer allocates to produce the crops (125). Generally, high value vegetable crops such as tomato are grown using high management levels, whereas low value crops such as mungbean are grown under low management levels (70).

Crop management in vegetable production is often limited to single crops grown in monoculture (31). However, small-scale farmers are often engaged in diversified production involving several crop and livestock enterprises (31, 68, 69, 70, 80, 118, 138). Therefore, a research approach that integrates the entire crop production enterprise with the farming system and the farmer's management skills is required to develop appropriate technologies for year-round vegetable cropping systems.

A conceptual model of the crop management approach in developing appropriate technologies for vegetable cropping systems is presented in

Fig. 3. Any vegetable cropping pattern involving a single, double or triple crop, or complex intercrop will interact with the biological, physical, and socio-economic factors and the type of available technology. The degree of interaction measured in terms of biological and economic productivity depends on the farmer's skill in integrating and manipulating these factors. The crop management approach seeks to integrate a cropping pattern with the available resources, production technologies, and skills which ultimately result in better nutrition, improved farm income, and a balanced ecology (68, 94).

In developing countries, fertilizers constitute a major cost in vegetable production for marginal farmers. Cost of high analysis fertilizer is often beyond their means (122). As chemical fertilizers become more expensive, researchers are developing methods to reduce rates of application through improved crop and soil management systems (71, 72, 75, 143). Increasing fertilizer use efficiency also can be achieved through efficient year-round cropping patterns (21, 33, 43, 52, 124). For example, squash, cucumber, carrot, lettuce, and onion required no additional fertilizer when planted after tomato on full-bed plastic mulch (21, 34, 43). Similarly, English pea and southern pea were not fertilized when planted after barley in a triple cropping pattern (51, 52).

This study was conducted to determine and evaluate the influence of crop and fertilizer management levels and their interactions on productivity, income, and soil nutrient stability in four vegetable cropping patterns, and to develop appropriate crop and fertilizer management practices for sequential cropping systems for North Florida.

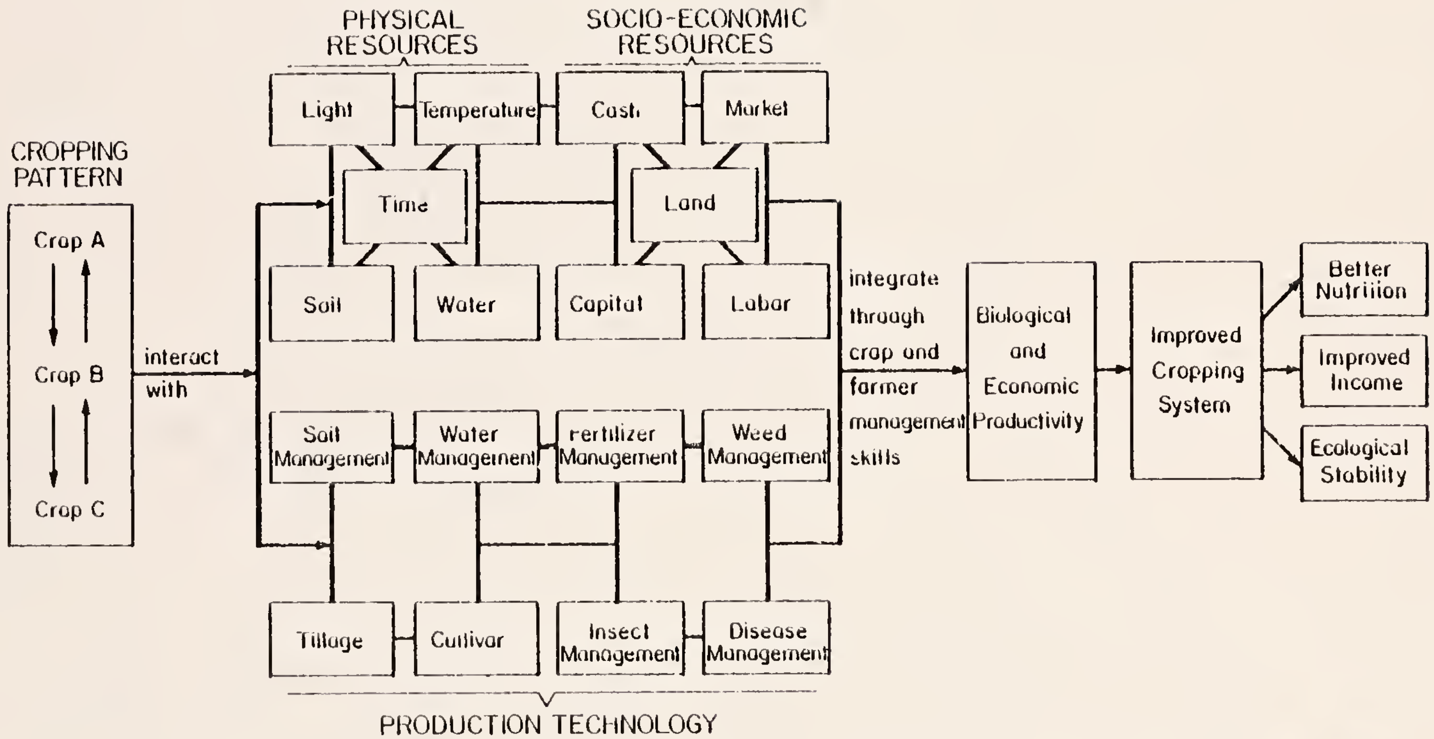

Fig. 3. A conceptual model of crop management approach to vegetable cropping systems research.

Materials and Methods

Experimental site. This 2-year study was conducted at the Horticultural Unit of the University of Florida at Gainesville (29° 45' N latitude, 82° 20' W longitude) beginning in October 1977, and terminating in October 1979. The climate is warm (average max 31°C; min 11°C) and humid (average 229 mm rainfall/month) from April to September, whereas October to March is cool (average max 24°C; min 0.55°C) and dry (average 76 mm rainfall/month).

Soil characteristics. The soil was classified as Kanapaha fine sand (loamy, siliceous, hyperthermic, Grossarenic Paleauquult) with 1% organic matter and a CEC of 2.52 meq/100 g (27). Initial soil chemical analysis resulted in a pH of 6.5, 0.04% N, 385 and 46 ppm of double-acid extractable P and K, respectively.

Classification of vegetable crops. Since vegetable crops require different levels of management, they were classified into three management groups: low (LM), medium (MM), and high (HM). These management groups were based on average costs of fertilizers, pesticides, cultural labor, and 5-year average harvesting costs for producing each vegetable crop in Florida (19). For example, HM crops such as pole bean and bulb onion required a production cost of $2,550/ha, whereas LM crops such as southern pea and English pea required only $790/ha. Labor and harvesting costs constitute the largest portion of the total production costs.

Selection of vegetable crops. Seven vegetable crops were selected based on total production costs and marketing potentials in North Florida.

High management crops included 'Texas Grano 502' bulb onion, 'Blue Lake' pole bean, and 'Morris Heading' collard. 'Early Golden Summer Crookneck' squash, and 'Florida Curled Leaf' mustard were selected as MM crops, whereas 'Wando' English pea and 'Zipper Cream' southern pea were classified as LM crops.

Design of cropping patterns. Based on crop management grouping, four basic cropping patterns were developed using combinations of three crops (Fig. 4). Cropping pattern HM-HM-HM (bulb onion-pole bean-collard) was designed to estimate the effect of HM crop sequence and fertilizer interactions on total productivity, profitability, and nutrient levels in soil. Within this pattern subsequent effects of HM crops on succeeding crops were observed. Similarly, cropping pattern LM-LM-LM (English pea-southern pea-southern pea) was designed to estimate the effects of LM crop sequence on the same parameters. Cropping patterns HM-MM-LM (bulb onion-squash-southern pea) and HM-LM-MM (bulb onion-southern pea-mustard) were designed to determine and estimate the effects of combination of LM, MM, and HM crops on the same parameters.

Levels of fertilizers. The crops were fertilized with low, medium, and high levels of N and K depending on crop management grouping (Table 7). These rates were based on several fertilizer and vegetable production studies conducted in Florida (20, 56, 59, 159). For each level, the combined N and K fertilizer treatments were considered as single treatments. Rate of P application was fixed depending on crop requirement. Basal fertilizer for each crop was applied and incorporated into the soil prior to planting. Depending on crop, the remaining

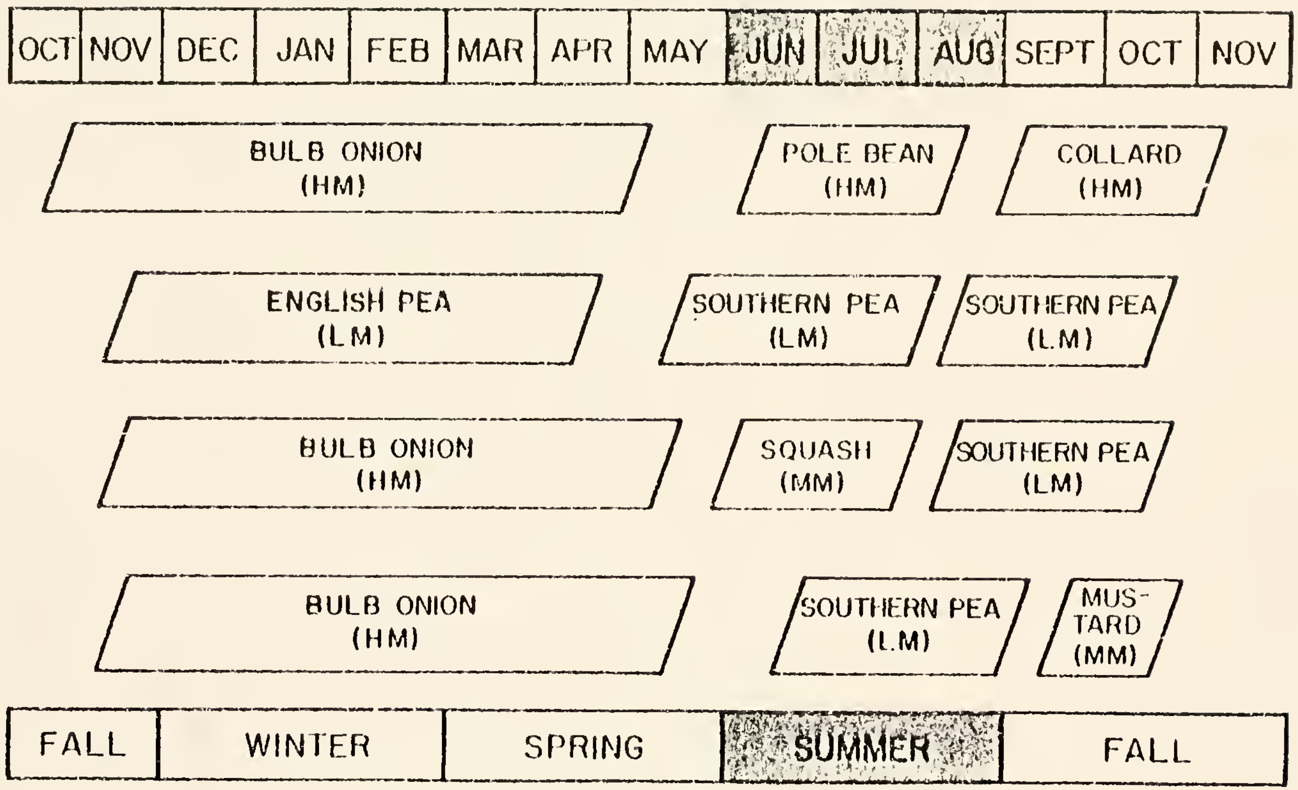

Fig. 4. Planting sequences of low, medium, and high management vegetable crops in four cropping patterns over two cropping cycles in the period 1977-79, Gainesville, FL.

Table 7. Nitrogen and potassium levels for low, medium, and high management crops, Gainesville, FL, 1977-79.

Fertilizer level[z]	Crop management level		
	Low	Medium	High
Low	0	1x	2x
Medium[y]	1x	2x	4x
High	2x	3x	6x

[z]Nitrogen and potassium increments (x) were 30 kg/ha and 40 kg/ha, respectively.

[y]Medium fertilizer level was regarded as recommended level for each crop.

amounts of fertilizer were side or topdressed once for LM and MM crops, but twice for HM crops during each crop cycle.

Experimental design. A randomized block design with a split-plot arrangement and four replications was used. The four cropping patterns were main plots within each block and the three fertilizer levels were subplots. Each subplot measured 4 x 7 m and consisted of three beds, 40 cm wide and 15 cm high, spaced 1.10 m apart. Land preparation, planting practices, and pest and disease control were based on recommended practices and methods reported by Palada et al. (125).

Data collection. Yields were harvested from a 5-m section of the center bed. Bulb onion was hand-pulled, oven-dried at 80°C for 48 hours, and graded to sizes of large (diameter greater than 7 cm), medium (5 to 7 cm), and small (less than 5 cm). Mature green marketable pods of pole bean, southern pea, and English pea were picked two to four times during each crop season. Marketable squash were harvested three times during the crop season. Tender leaves from the base of collard plants were stripped four times during each season, whereas mustard plants were cut slightly above the ground 38 days after seeding.

Production costs and returns to management were based on 2-year average prices of production inputs and market prices (150) at the time of harvest. Return to management was calculated by subtracting total production costs from gross returns. Rates of return to labor, cash, and fertilizer were calculated by deducting either labor, material, or fertilizer costs from gross returns and dividing the difference by either labor, material, or fertilizer costs. For example, rates of return to labor were calculated as follows:

$$\text{Return to labor (\$/\$)} = \frac{\text{Gross return - Material cost}}{\text{Labor cost}}$$

Similarly, return to material cash was calculated:

$$\text{Return to cash (\$/\$)} = \frac{\text{Gross return - Labor cost}}{\text{Material cost}}$$

Production costs and market prices (46, 108, 150) were compared with 5-year averages (19) to determine long-term profitability.

Soil sampling and chemical analyses. Soils were sampled from the top center of each bed to a depth of 15 cm. Samples were oven-dried at 70°C for 48 hours, screened to pass a 25-mesh sieve, and analyzed for organic matter (OM) content, total soluble salts (TSS), pH, nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N), and K. Equal volumes of soil and water were prepared as suspensions for determination of pH and total soluble salts. Soil pH was measured using a combination pH electrode. Total soluble salts were determined from soil solution conductivity readings using a solubridge. Organic matter was analyzed by the method of Walkley and Black as outlined by Allison (4). Nitrate and ammonium were determined by steam distillation (18). Potassium was analyzed at the Soil Testing Laboratory of Soil Science Department using a double-acid extractant (130).

Statistical analysis of data. Analyses of variance on marketable yields and soil test results were run by computer using programs from the Statistical Analysis System (11). Treatment means of marketable yields and costs and returns from each crop were compared using Duncan's multiple range test, whereas treatment means from interactions between crop and fertilizer management levels were compared using least significant difference. Except for marketable yields, all data were analyzed and treatment means compared using the statistical model for split-plot design.

Results and Discussion

Shifts in Soil Properties

Total soluble salts. Cropping pattern HM-HM-HM resulted in higher TSS among the four cropping patterns (Fig. 5). In cropping pattern HM-HM-HM, application of medium to high levels of fertilizer resulted in significant increase in TSS (Fig. 5), whereas no significant differences in TSS were found after harvest of the first crops in the other cropping patterns.

High soluble salts after pole bean and collard can be attributed to fertilizer level and crop duration. Pole bean and collard are short maturing crops compared to bulb onion. The low TSS after bulb onion might have been the result of long and extended crop duration which enhanced more leaching and absorption of fertilizer salts. Sequential planting of HM crops increased soluble salt accumulation, whereas sequential planting of LM, MM, and HM crops in combination stabilized soluble salt levels. Previous studies (34, 73, 103, 161) showed that large fertilizer applications to HM crops such as tomato, cabbage, and celery resulted in high residual soluble salts at harvest.

Soil reaction. Soil reaction (pH) was lowest after harvest of second and third crops (Table 8). Differences in soil pH after harvest

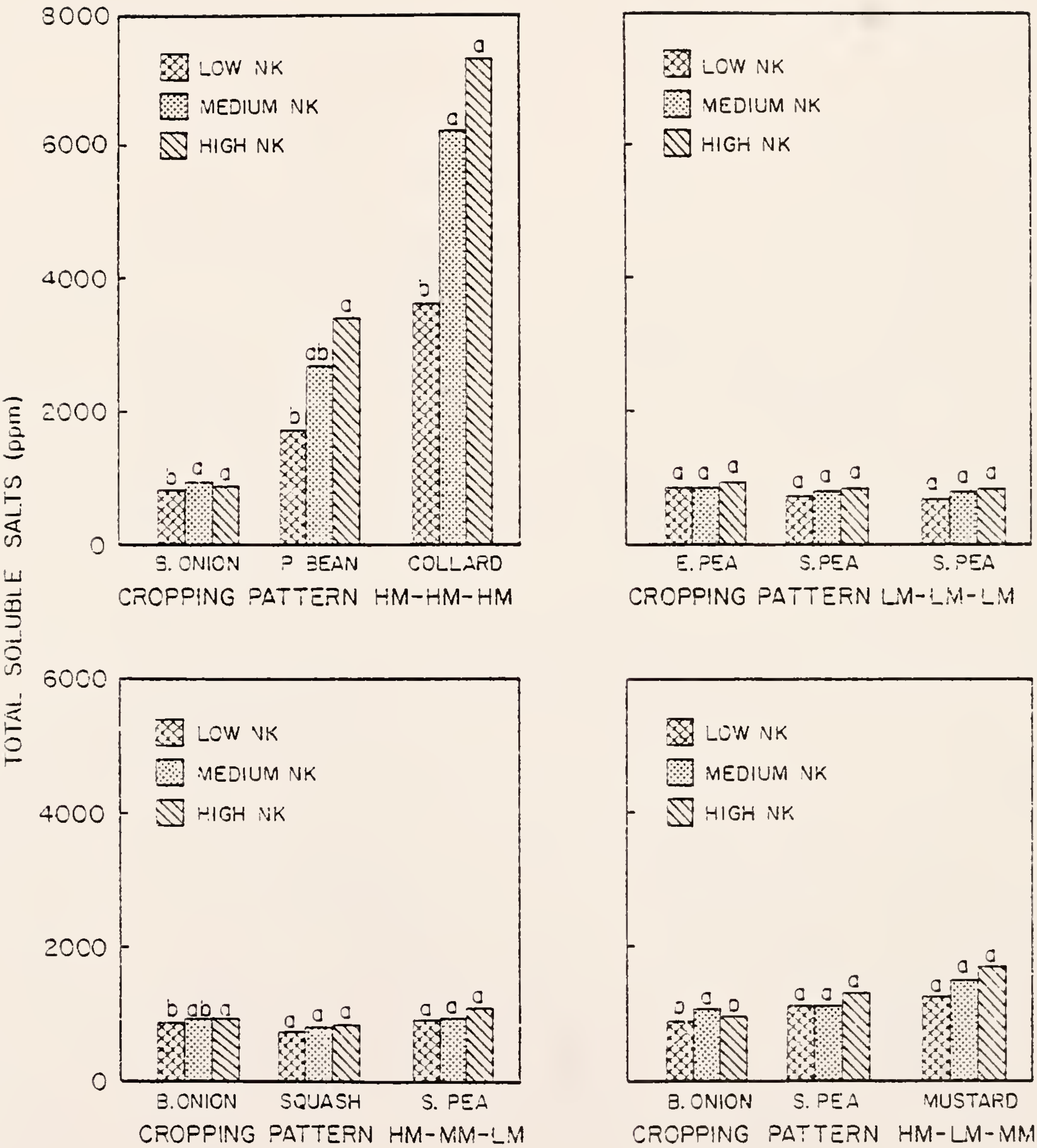

Fig. 5. Total soluble salts after harvest of each crop as influenced by crop and fertilizer management levels over two cropping cycles in the period 1977-79, Gainesville, FL. Letters on the bars indicate mean separation among fertilizer levels within each crop by least significant difference, 5% level.

of first and third crops were greater in cropping patterns HM-HM-HM, HM-MM-LM, and HM-LM-MM than in LM-LM-LM. Cropping pattern LM-LM-LM resulted in pH above 6.0 after the third crop, whereas cropping patterns involving combinations with HM crops resulted in pH below 6.0 (Table 8). In all cropping patterns, soil pH tended to equilibrate to its initial level after each year of cropping. The low soil pH in HM-HM-HM can be attributed to replacement of H^+ on the exchange complex and by hydrolysis of exchangeable Al^{3+} and hydroxy Al resulting from high management fertilizer application rates.

Soil organic matter. Soil OM content decreased with successive cropping in all cropping patterns except for cropping pattern LM-LM-LM (Table 9). Average reductions in soil OM content were greater with cropping pattern HM-HM-HM than other cropping patterns. In contrast, cropping pattern LM-LM-LM resulted in increased soil OM content from 0.86 to 0.94% after harvest of third crops. After harvest of third crops, cropping pattern HM-HM-HM resulted in significantly lower OM content among the four cropping patterns (Table 9). For each cropping pattern, the effect of high fertilizer levels generally resulted in greater OM contents after harvest of second and third crops (Table 9). These data are consistent with other studies (1, 12, 40, 41, 111, 135, 166), and suggest that OM stability can be achieved by including vegetable legumes in sequential cropping patterns.

Soil nitrogen. Except for collard, fertilizer levels had no significant influence on soil N measured as NH_4-N and NO_3-N (Fig. 6). In cropping pattern HM-HM-HM, high soil N after collard was caused by high levels of fertilizer. In addition, residual fertilizer from

Table 8. Soil pH after harvest of each crop as influenced by crop and fertilizer management levels over two cropping cycles in the period 1977-79, Gainesville, FL.

Cropping pattern	Fertilizer level	Crop		
		First	Second	Third
		pH		
		B. Onion	P. Bean	Collard
HM-HM-HM	Low	6.4 a[z]	6.4 a	5.7 a
	Medium	6.4 a	6.4 a	5.6 a
	High	6.5 a	6.3 a	5.7 a
	Mean	6.4 B	6.4 A	5.6 B
		E. Pea	S. Pea	S. Pea
LM-LM-LM	Low	6.7 a	6.4 a	6.5 a
	Medium	6.8 a	6.4 a	6.5 a
	High	6.8 a	6.5 a	6.4 a
	Mean	6.8 A	6.5 A	6.5 A
		B. Onion	Squash	S. Pea
HM-MM-LM	Low	6.4 a	6.3 a	5.9 b
	Medium	6.5 a	6.3 a	5.9 b
	High	6.5 a	6.3 a	6.0 a
	Mean	6.5 B	6.3 A	5.9 B
		B. Onion	S. Pea	Mustard
HM-LM-MM	Low	6.5 a	6.3 a	6.0 a
	Medium	6.6 a	6.4 a	5.9 ab
	High	6.6 a	6.4 a	5.7 b
	Mean	6.6 B	6.4 A	5.9 B

[z]Mean separation in columns within crops by least significant difference at 5% level. Fertilizer means (lower case letters), cropping pattern means (upper case letters).

Table 9. Soil organic matter content after harvest of each crop as influenced by crop and fertilizer management levels over two cropping cycles in the period 1977-79, Gainesville, FL.

Cropping pattern	Fertilizer level	Crop: First	Second	Third
		----------	%	----------
		B. Onion	P. Bean	Collard
HM-HM-HM	Low	0.88 a[z]	0.76 b	0.60 a
	Medium	0.88 a	0.75 b	0.45 c
	High	0.95 a	0.82 a	0.58 b
	Mean	0.90 A	0.78 A	0.54 C
		E. Pea	S. Pea	S. Pea
LM-LM-LM	Low	0.84 a	0.82 b	0.99 a
	Medium	0.88 a	0.88 a	0.88 b
	High	0.85 a	0.91 a	0.96 a
	Mean	0.86 A	0.87 A	0.94 A
		B. Onion	Squash	S. Pea
HM-MM-LM	Low	0.92 a	0.77 c	0.86 a
	Medium	0.91 a	0.85 b	0.79 b
	High	0.96 a	0.93 a	0.86 a
	Mean	0.93 A	0.85 A	0.84 B
		B. Onion	S. Pea	Mustard
HM-LM-MM	Low	0.90 a	0.88 b	0.84 b
	Medium	0.93 a	0.80 c	0.78 c
	High	0.95 a	0.97 a	0.90 a
	Mean	0.93 A	0.88 A	0.84 B

[z]Mean separation in columns within crops by least significant difference, 5% level. Fertilizer means (lower case letters), cropping pattern means (upper case letters).

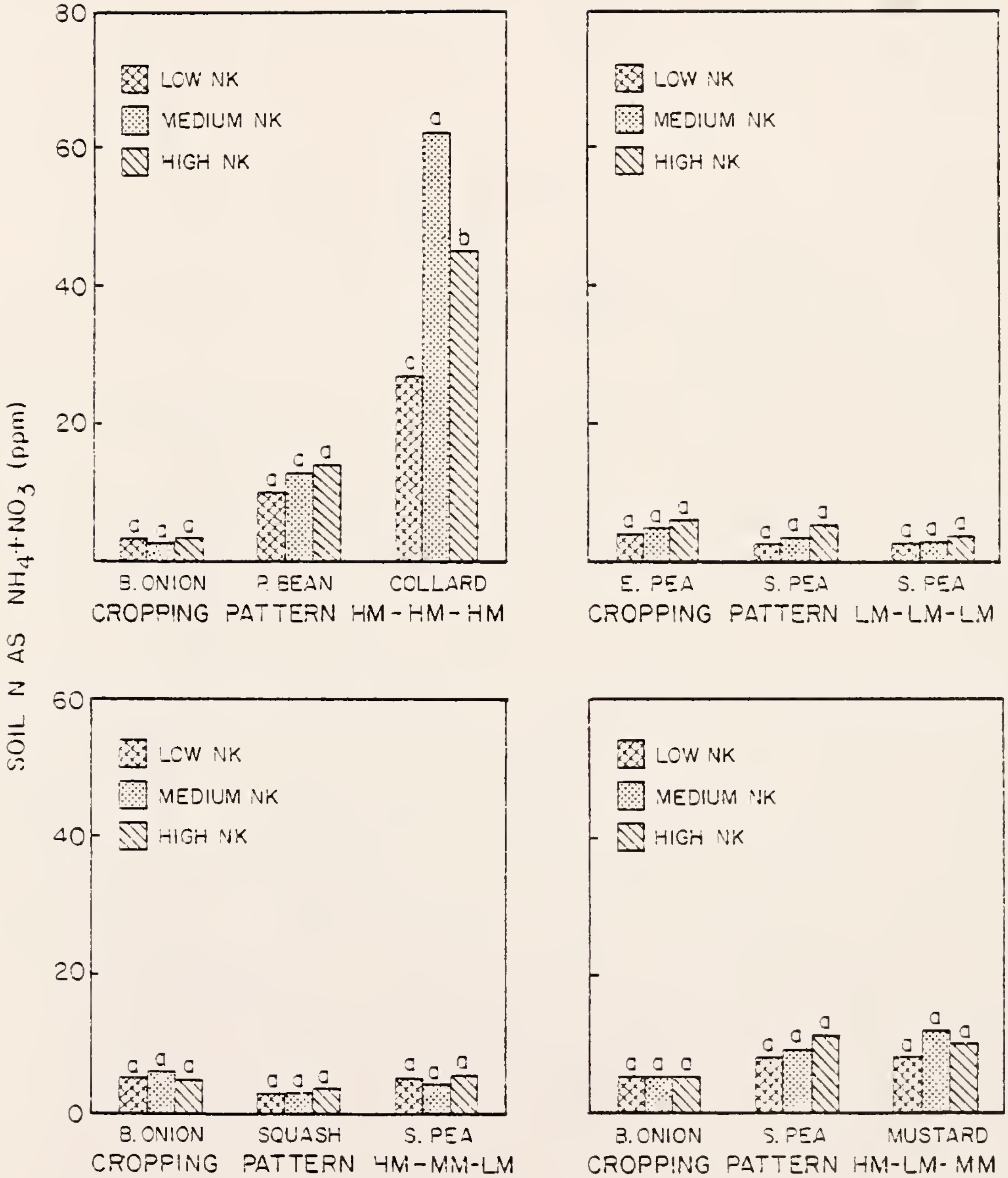

Fig. 6. Soil nitrogen after harvest of each crop as influenced by crop and fertilizer management levels over two cropping cycles in the period 1977-79, Gainesville, FL. Letters on the bars indicate mean separation among fertilizer levels within each crop by least significant difference, 5% level.

previous bulb onion and pole bean significantly contributed to higher soil N. These results agree with Rao and Sharma (135) who reported that soil N decreased at low fertilizer levels after each crop in six cropping patterns, whereas soil N increased at high fertilizer levels.

Soil potassium. A consistent increase in double-acid extractable soil K was observed with successive cropping in HM-HM-HM but not with the other three cropping patterns (Fig. 7). For each cropping pattern, high fertilizer levels increased soil K except the third crop in the HM cropping pattern (Fig. 7). However, residual soil K remained almost constant with successive crops in all cropping patterns except the HM cropping pattern (Fig. 7).

In general, residual K was higher than applied K for the LM cropping pattern, whereas HM and MM vegetable crops required supplemental applications of about 40 to 80 kg/ha K. Results from this study do not agree with Biswas et al. (14), and Rao and Sharma (135) who reported that soil K remained low after two cycles and after harvest of different crops at various fertilizer levels.

Effects of Crop and Fertilizer Management Levels on Marketable Yields

Cropping pattern HM-HM-HM. Marketable yield of bulb onion was generally high because of early planting date (Table 10). Onion fertilized with the medium level of fertilizer (120 kg/ha N, and 160 kg/ha K) yielded significantly higher than onion fertilized with low level (Table 10). Application of a high fertilizer level resulted in no significant yield increase (Table 10). Marketable yield of pole bean was generally low because of late spring planting which subjected the crop

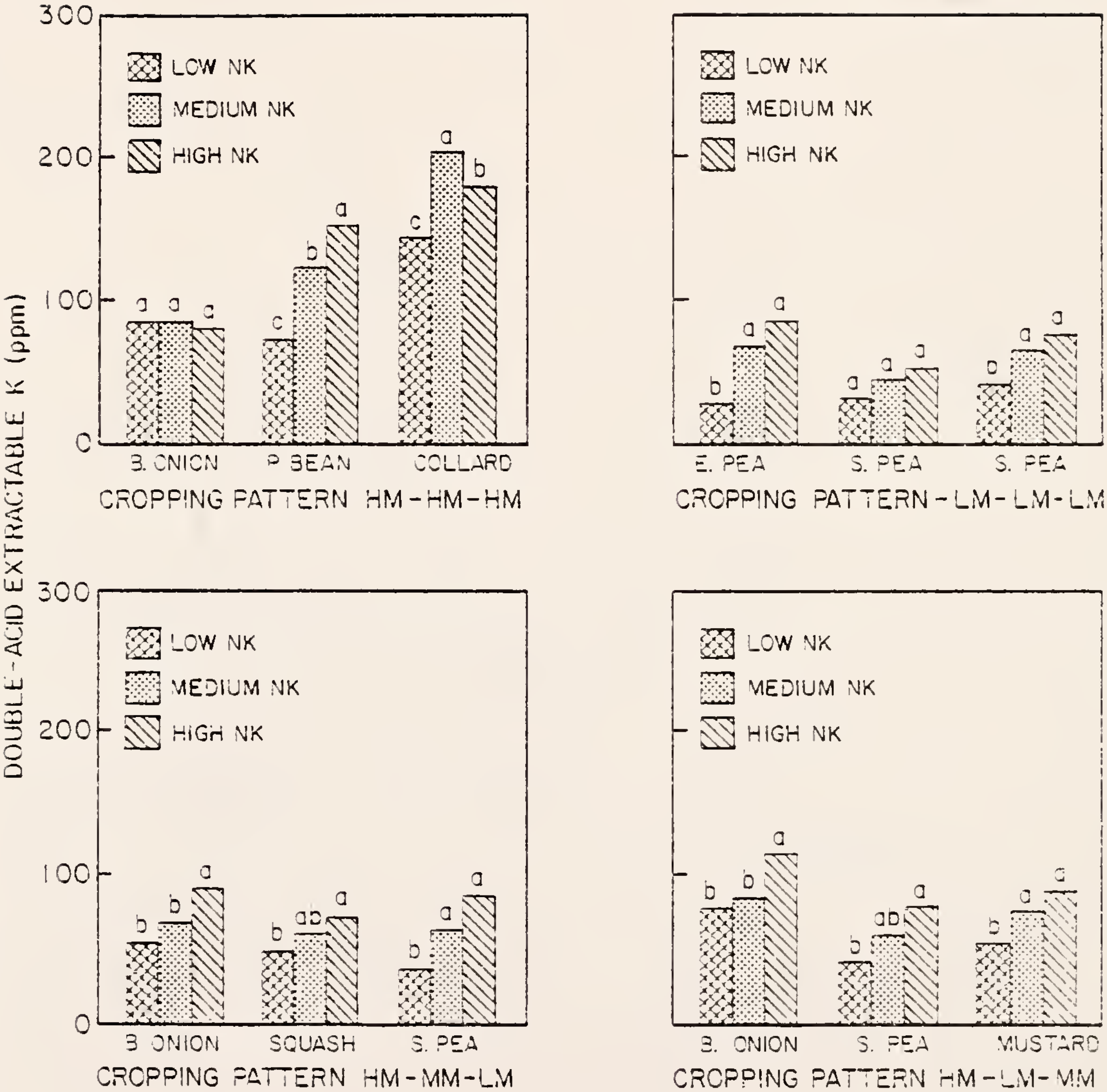

Fig. 7. Soil potassium after harvest of each crop as influenced by crop and fertilizer management levels over two cropping cycles in the period 1977-79, Gainesville, FL. Letters on the bars indicate mean separation among fertilizer levels within each crop by least significant difference, 5% level.

to high rainfall and temperature (Table 10). Fertilizer levels did not influence pole bean yield. Leafy vegetable collard responded equally to all levels of fertilizer (Table 10).

Cropping pattern LM-LM-LM. Only English pea produced a low yield at the low fertilizer level (Table 10). Successive plantings of vegetable legumes resulted in low yield of the third crop southern pea (Table 10). This result was consistent with previous studies (83, 84). Fertilizer levels did not influence yields of southern pea which support the data reported from previous investigations (17, 59, 128, 155, 156, 174).

Cropping pattern HM-MM-LM. Low yield of bulb onion was due to late fall planting (Table 10). Combined effects of previous southern pea residue and low residual nutrients in soil contributed also to low yields. Late planting predisposed onion seedlings to freezing temperatures, whereas pea residue reduced germination and seedling survival. Squash productivity was low when planted in June because of high temperature and humidity (Table 10). The high management fertilizer level did not result in significant yield increase (Table 10). Southern pea produced satisfactory yields after squash; however, low yield was obtained without fertilizer application (Table 10).

Cropping pattern HM-LM-MM. No significant differences in yield of bulb onion were observed as a result of fertilizer levels (Table 10). These yields, however, were generally lower than yields obtained from cropping pattern HM-HM-HM. Low yield was the result of late planting in November. A low yield of second crop southern pea was caused by late

Table 10. Marketable yields of component vegetable crops in four cropping patterns as influenced by crop and fertilizer management levels over two cropping cycles in the period 1977-79, Gainesville, FL.

Cropping pattern	Fertilizer level	Crop		
		First	Second	Third
		----------------	MT/ha	----------------
		B. Onion	P. Bean	Collard
HM-HM-HM	Low	18.5 b[z]	0.8 a	10.0 a
	Medium	24.2 a	1.5 a	10.7 a
	High	22.3 ab	0.9 a	10.0 a
		E. Pea	S. Pea	S. Pea
LM-LM-LM	Low	4.6 b	3.4 a	2.0 a
	Medium	5.2 a	4.0 a	2.0 a
	High	5.3 a	3.8 a	1.9 a
		B. Onion	Squash	S. Pea
HM-MM-LM	Low	10.0 a	0.6 b	2.7 b
	Medium	9.8 a	2.1 a	3.5 a
	High	8.5 a	3.1 a	3.5 a
		B. Onion	S. Pea	Mustard
HM-LM-MM	Low	11.7 a	2.0 a	4.6 a
	Medium	11.9 a	1.9 a	5.3 a
	High	12.6 a	1.8 a	4.3 a

[z]Mean separation in columns within each crop by Duncan's multiple range test, 5% level.

planting in June which subjected the crop to high rainfall and temperature. Mustard responded equally to fertilizer levels (Table 10).

Resource Utilization of Cropping Patterns

Labor profile. Cropping pattern HM-HM-HM was characterized by three labor peaks (Fig. 8). Planting and harvesting constituted 30 and 50%, respectively, of the total labor requirements. The high labor required for planting and harvesting was due to many hours required for transplanting collard, handseeding pole bean, and multiple harvests of both crops.

Cropping patterns LM-LM-LM, HM-MM-LM, and HM-LM-MM were characterized by only one labor peak for harvesting (Fig. 8). However, labor required for harvesting in cropping pattern LM-LM-LM was equal to HM-HM-HM because of multiple harvests of three successive vegetable legume crops.

Vegetable growers who have limited year-round labor resources should grow a combination of LM, MM, and HM crops where labor demands are low and evenly distributed throughout the year. Growers who have abundant labor and cash can probably benefit by growing HM vegetable crops in their year-round cropping patterns. Growers who have abundant labor but are limited in cash resource may have an advantage by growing a sequence of LM vegetable crops.

Production costs. For each cropping pattern, fertilizer levels had no influence on production costs (Table 11). Therefore, cropping patterns were compared based on mean production cost across fertilizer levels. Cropping pattern HM-HM-HM required the highest total mean

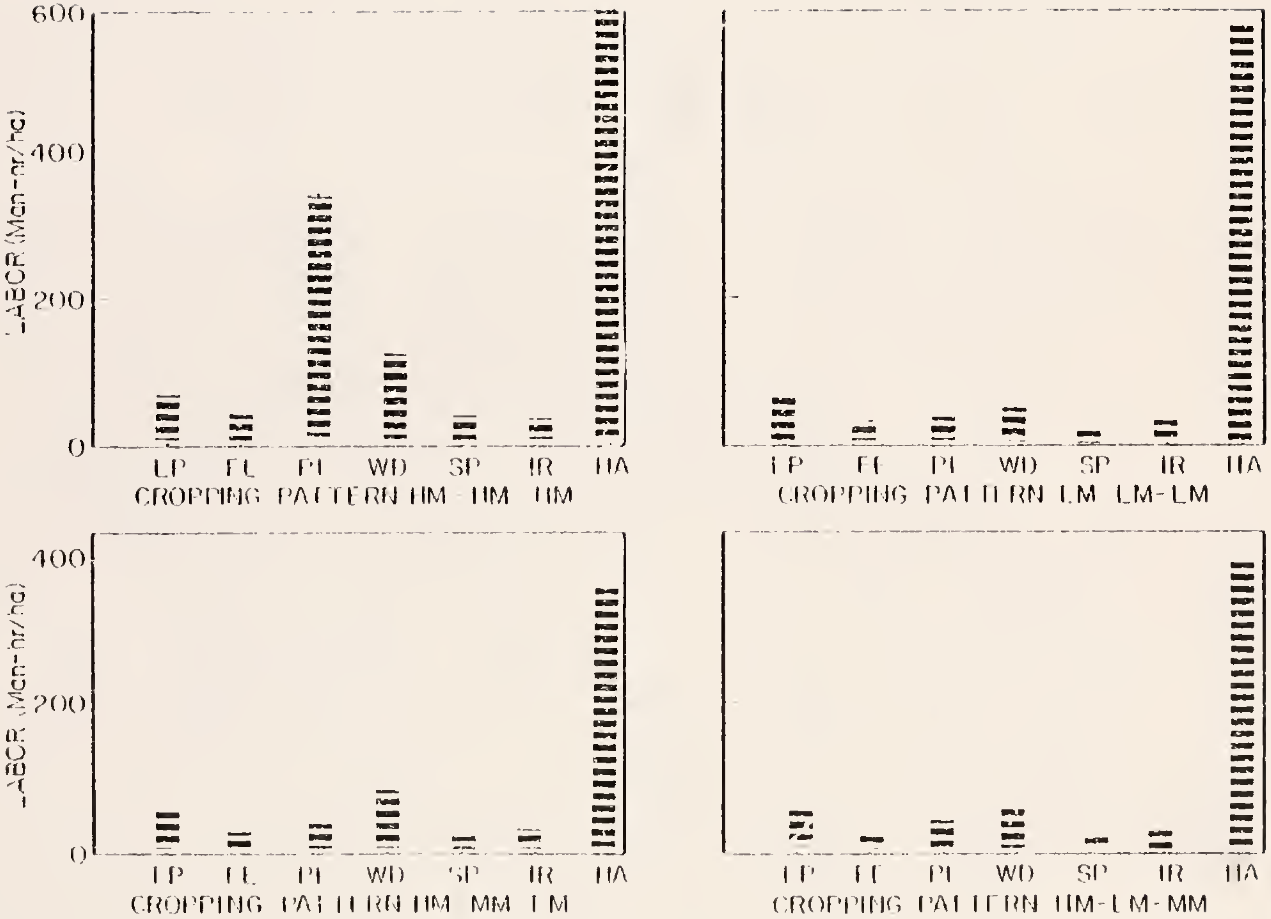

Fig. 8. Labor profile of four vegetable cropping patterns as influenced by crop management levels over two cropping cycles in the period 1977-79, Gainesville, FL. LP-land preparation; FE-fertilization; PL-planting; WD-weeding; SP-spraying; IR-irrigating; HA-harvesting.

production cost of $7,630/ha which was significantly different from the other three cropping patterns (Table 11). Except for material cost, cropping patterns LM-LM-LM, HM-MM-LM, and HM-LM-MM were similar in cultural and harvest labor costs (Table 11). In terms of harvest labor cost, the four cropping patterns were similar although cropping patterns HM-HM-HM and LM-LM-LM required more harvest labor.

In general, production cost data indicated that planting HM vegetable crops in year-round cropping patterns required high cash and labor inputs, but planting a combination of LM, MM, and HM reduced total production costs by about 50%.

Income and Returns to Production Inputs

Gross and net income. Gross and net incomes were significantly higher in cropping pattern HM-HM-HM than the other three cropping patterns (12). Cropping patterns LM-LM-LM, HM-MM-LM, and HM-LM-MM resulted in statistically similar gross income, although cropping pattern HM-MM-LM produced the lowest gross income (Table 12). The low gross income from pattern HM-MM-LM was caused by low marketable yields of bulb onion and squash.

Regardless of fertilizer levels, the best pattern seemed to be HM-HM-HM if growers consider total net income as the criterion for profitability. However, this pattern required the highest total costs and labor inputs (Table 12). Cropping pattern HM-LM-MM netted $3000/ha income, but total production costs were lower than HM-HM-HM, and yields were stable than the other cropping patterns.

Table 11. Production costs of four vegetable cropping patterns as influenced by crop and fertilizer management levels over two cropping cycles in the period 1977-79, Gainesville, FL.

Cropping pattern	Fertilizer level	Production inputs			Total cost
		Material	Cultural labor	Harvest labor	
		-------- Costs, $/ha	----------	----------	----------
HM-HM-HM	Low	2,990 a[z]	1,430 a	1,440 a	5,860 a
	Medium	5,420 a	1,430 a	1,720 a	8,570 a
	High	5,400 a	1,430 a	1,640 a	8,470 a
	Mean	4,600 A	1,430 A	1,600 A	7,630 A
LM-LM-LM	Low	1,840 a	400 a	1,520 a	3,760 a
	Medium	2,010 a	400 a	1,560 a	3,970 a
	High	2,070 a	400 a	1,700 a	4,170 a
	Mean	1,970 C	400 B	1,590 A	3,950 B
HM-MM-LM	Low	1,890 a	750 a	800 a	3,440 a
	Medium	2,370 a	520 a	930 a	3,820 a
	High	2,210 a	800 a	970 a	3,930 a
	Mean	2,160 B	690 B	900 A	3,730 B
HM-LM-MM	Low	2,420 a	560 a	1,060 a	4,040 a
	Medium	2,660 a	560 a	1,230 a	4,450 a
	High	3,040 a	560 a	990 a	4,590 a
	Mean	2,710 B	560 B	1,090 A	4,360 B

[z]Mean separation in columns within each cropping pattern by least significant difference, 5% level. Fertilizer means (lower case letters), cropping pattern means (upper case letters).

Table 12. Gross and net incomes of four vegetable cropping patterns as influenced by crop and fertilizer management levels over two cropping cycles in the period 1977-79, Gainesville, FL.

Cropping pattern	Fertilizer level	Total cost	Income	
			Gross	Net
		------------- $/ha	--------------------	
HM-HM-HM	Low	5,860 a[z]	10,990 b	5,130 a
	Medium	8,570 a	13,440 a	4,870 a
	High	8,470 a	11,920 a	3,450 a
	Mean	7,630 A	12,120 A	4,490 A
LM-LM-LM	Low	3,760 a	5,830 a	2,070 a
	Medium	3,970 a	5,890 a	1,920 a
	High	4,170 a	6,500 a	2,300 a
	Mean	3,950 B	6,070 B	2,120 BC
HM-MM-LM	Low	3,440 a	3,920 a	480 a
	Medium	3,810 a	5,110 a	1,300 a
	High	3,930 a	4,410 a	480 a
	Mean	3,730 B	4,480 B	750 C
HM-LM-MM	Low	4,040 a	6,940 a	2,900 a
	Medium	4,450 a	7,030 a	2,580 a
	High	4,590 a	7,990 a	3,400 a
	Mean	4,360 B	7,320 B	2,960 B

[z] Mean separation in columns within each cropping pattern by least significant difference, 5% level. Fertilizer means (lower case letters), cropping pattern means (upper case letters).

Returns to production inputs. Except for cash, returns to fertilizer, labor and management on a dollar/ha basis were not significantly influenced by fertilizer levels (Table 13). Comparing returns to fertilizer, cash, and labor on the basis of total mean, indicated that cropping pattern HM-HM-HM produced a higher return to production inputs (Table 13). Cropping pattern HM-MM-LM resulted in lowest returns to fertilizer, cash, labor, and management (Table 13).

Rates of return to production inputs. Rate of return to production inputs expressed in terms of dollar/dollar is a measure of return per unit investment of production inputs. This provides a measure of resource use efficiency for each cropping pattern and is useful in comparing economic performance of cropping patterns. Rates of return to fertilizer were influenced by fertilizer levels in cropping pattern HM-HM-HM and LM-LM-LM but not in HM-MM-LM and HM-LM-MM (Table 14). Rates of return to fertilizer decreased with increasing fertilizer levels for each cropping pattern. Among cropping pattern means, rates of return to fertilizer were significantly higher with LM-LM-LM than the other three patterns. This suggested that growers with limited fertilizer input can make more efficient use of this limiting resource by growing a sequence of LM crops, whereas growers who adopt cropping patterns HM-HM-HM and HM-LM-MM can profit by reducing fertilizer application.

Although cropping pattern HM-HM-HM produced high return to cash on a dollar/ha basis (Table 13), rates of return to cash on a dollar/dollar basis did not differ with pattern LM-LM-LM (Table 14). For every dollar spent on cash input, pattern HM-HM-HM resulted in $2.50,

Table 13. Returns to production inputs of four vegetable cropping patterns as influenced by crop and fertilizer management levels over two cropping cycles in the period 1977-79, Gainesville, FL.

Cropping pattern	Fertilizer level	Production inputs			
		Fertilizer	Cash	Labor	Management
		Returns, $/ha			
HM-HM-HM	Low	5,650 a[z]	8,120 b	8,010 a	5,130 a
	Medium	5,440 a	10,290 a	8,020 a	4,870 a
	High	4,880 a	4,240 b	6,900 a	3,450 a
	Mean	5,320 A	7,550 A	7,640 A	4,490 A
LM-LM-LM	Low	2,120 a	3,860 a	3,890 a	2,070 a
	Medium	2,170 a	4,010 a	3,980 a	1,920 a
	High	2,630 a	4,400 a	4,430 a	2,330 a
	Mean	2,310 BC	4,090 BC	4,100 B	2,120 BC
HM-MM-LM	Low	1,160 a	2,370 a	2,040 a	480 a
	Medium	1,170 a	3,110 a	2,240 a	1,300 a
	High	1,040 a	2,720 a	2,270 a	480 a
	Mean	1,120 C	2,730 C	2,180 C	750 C
HM-LM-MM	Low	2,480 a	4,430 b	4,520 a	2,900 a
	Medium	3,290 a	5,240 ab	4,360 a	2,580 a
	High	3,470 a	5,970 a	4,960 a	3,400 a
	Mean	3,080 B	5,210 B	4,610 B	2,960 B

[z]Mean separation in columns within each cropping pattern by least significant difference, 5% level. Fertilizer means (lower case letters), cropping pattern means (upper case letters).

Table 14. Rates of return to production inputs of four vegetable cropping patterns as influenced by crop and fertilizer management levels over two cropping cycles in the period 1977-79, Gainesville, FL.

Cropping pattern	Fertilizer level	Production inputs			
		Fertilizer	Cash	Labor	Management
		Returns, $/$			
HM-HM-HM	Low	11.80 a[z]	2.90 a	2.90 a	1.00 a
	Medium	9.70 a	3.10 a	2.50 b	0.60 b
	High	5.20 b	1.60 a	2.10 c	0.40 c
	Mean	8.90 B	2.50 A	2.50 A	0.70 A
LM-LM-LM	Low	20.80 a	2.10 a	2.00 b	0.60 a
	Medium	14.40 b	2.00 a	2.00 b	0.50 a
	High	8.70 c	2.10 a	2.50 a	0.50 a
	Mean	14.60 A	2.10 AB	2.20 A	0.50 A
HM-MM-LM	Low	2.50 a	1.30 a	1.90 a	0.10 a
	Medium	2.70 a	1.20 a	1.40 a	0.30 a
	High	1.90 a	1.10 a	1.80 a	0.10 a
	Mean	2.40 C	1.20 C	1.70 A	0.20 B
HM-LM-MM	Low	7.90 a	1.90 a	2.30 bc	0.70 a
	Medium	7.70 a	1.90 a	2.50 b	0.60 a
	High	6.50 a	1.90 a	3.20 a	0.70 a
	Mean	7.30 B	1.90 B	2.60 A	0.70 A

[z]Mean separation in columns within each cropping pattern by least significant difference, 5% level. Fertilizer means (lower case letters), cropping pattern means (upper case letters).

whereas rate for LM-LM-LM was $2.10 (Table 14). Rates of return to cash were similar for cropping patterns LM-LM-LM and HM-LM-MM, whereas HM-MM-LM provided the lowest rate of return to cash input. Growers with limited cash often adopt cropping patterns with high cash returns.

Except for cropping pattern HM-MM-LM, rates of return to labor were influenced by fertilizer levels within cropping pattern but not among cropping patterns (Table 14). In cropping pattern HM-HM-HM, increasing fertilizer levels significantly decreased rates of return to labor, whereas the reverse was true in cropping pattern LM-LM-LM and HM-LM-MM. Thus, it pays to increase fertilizer levels when labor is limited for cropping patterns involving LM and a combination of LM, MM, and HM vegetable crops.

Except for cropping pattern HM-HM-HM, fertilizer levels did not affect rates of return to management (Table 14). In cropping pattern HM-HM-HM, increasing fertilizer levels decreased rates of return to management. Thus, growers who face constraints to management can make more efficient use of their management skills by reducing rates of fertilizer if they grow a sequence of HM vegetable crops. Among cropping patterns, HM-HM-HM, LM-LM-LM, and HM-LM-MM, average rates of return to management were similar (Table 14). This implies that low-labor and low-cash requiring cropping patterns are as efficient and profitable as cropping patterns requiring high labor and high cash inputs. Therefore, growers with limited resources can grow a sequence of LM or a combination of LM, MM, and HM vegetable crops and obtain profitable economic returns without necessarily increasing production inputs such as fertilizer.

Economic Implications

Economic evaluation of four cropping patterns based on costs and returns analysis indicated that resource use, income, and returns to production inputs were influenced by management level associated with crop grouping and levels of component technology within each group. Although levels of component technology such as fertilizer management did not cause significant differences in marketable yields, resource use in terms of production costs and rates of return to production inputs for cropping patterns were affected by fertilizer levels. This implies that insignificant difference in agronomic yields may sometimes be misinterpreted in economic terms, especially when the grower bases production decisions on economic criteria.

Cropping patterns involving HM vegetable crops are highly productive and profitable but may not be more efficient in terms of resource use and rates of return to production inputs than cropping patterns involving LM and a combination of HM, MM, and LM vegetable crops. This was shown by high total marketable yield and gross and net incomes, but non-significant rates of return to fertilizer, cash, labor, and management in cropping pattern HM-HM-HM. With increasing costs of production inputs, vegetable growers with limited cash for purchasing these inputs will have an advantage by planting either a sequence of LM or a combination of LM, MM, and HM crops for year-round cropping patterns. Growers who have available production resources can benefit more by reducing levels of production inputs such as fertilizer if they grow a sequence of HM vegetable crops.

This study showed that crop and fertilizer management levels can influence productivity, profitability, and income in year-round cropping systems involving vegetables. Thus, economic returns are a function of farmer's integration and manipulation of component technology levels and their interaction with biological, physical, and socio-economic factors. In understanding and improving management of vegetables in year-round cropping systems, horticulturists can study other aspects of component technologies such as insect pest, disease, weed, and water management through joint effort with entomologists, plant pathologists, weed scientists, and economists. Through joint research efforts, technologies can be developed and become more relevant and appropriate for small-scale vegetable farmers.

SUMMARY AND CONCLUSIONS

A 2-year study on four vegetable cropping patterns was conducted at the Horticultural Unit of the University of Florida, Gainesville, in 1977 to 1979. The objectives of this study were to evaluate productivity, resource use, and profitability of several vegetable crops planted in four year-round cropping patterns for North Florida, to determine and evaluate the influence of crop and fertilizer management levels on productivity, income, and nutrient levels in soil from four vegetable cropping patterns, and to develop appropriate crop and fertilizer management practices for sequential vegetable cropping systems.

To achieve the first objective, seven vegetable crops including bulb onion, pole bean, collard, crookneck squash, English pea, mustard, and southern pea were classified into low (LM), medium (MM), and high (HM) management groups. These management groups were based on average costs of fertilizers, pesticides, cultural labor, and a 5-year average harvesting costs for producing each vegetable crop.

Four basic cropping patterns were developed using combinations of seven vegetable crops. Two cropping patterns were three HM crops planted in sequence (bulb onion-pole bean-collard), and three LM crops planted in sequence (English pea-southern pea-southern pea). The other two cropping patterns were a combination of LM, MM, and HM crops planted in sequence as follows: HM-MM-LM (bulb onion-squash-southern pea) and HM-LM-MM (bulb onion-southern pea-mustard). The four cropping patterns were arranged in a randomized block design with four replications. To achieve the second and third objectives, three levels of fertilizer N and K (low, medium, and high) were superimposed on each of the four cropping pattern main plots.

The longest cropping duration was 322 days in cropping pattern HM-HM-HM, while the shortest duration of 300 days was observed in cropping patterns LM-LM-LM and HM-LM-MM. Crops grown during winter had prolonged growing periods which delayed the planting of second crops in cropping patterns involving bulb onion.

In general, marketable yields of vegetables were affected by planting dates. Cropping patterns involving bulb onion resulted in late planting and reduced yields of second crops. Cropping patterns involving large crop residues also delayed planting of succeeding crops. Bulb onion produced lower yield when planted after southern pea where large crop residue remained in the soil than onion planted after collard and mustard.

High rainfall and temperature at flowering and pod set resulted in low yields of pole bean in both years. Marketable yield averaged only 1.7 metric tons/ha in 1977-78 and 1.5 metric tons/ha in 1978-79. These yields were lower than those obtained from normal spring planting in Florida.

Marketable yields of English pea were lower in 1977-78 than in 1978-79 because prolonged low temperature severely retarded early growth which predisposed some plants to killing frost in January and February.

Yields of southern pea were not significantly different between years except in cropping pattern HM-MM-LM. High residual nutrient level in soil from previous squash and early planting dates contributed to increased yields in 1977-78 than in 1978-79. In general, the third crop of southern pea produced low yields.

Cropping pattern LM-LM-LM provided some biological stability but yields of southern pea decreased with successive plantings. A high degree of biological stability was observed in cropping pattern HM-LM-MM. In cropping patterns HM-HM-HM and HM-MM-LM, inclusion of pole bean and squash resulted in unstable yields due to improper time of planting.

Crop and fertilizer management levels significantly influenced total soluble salts (TSS). Cropping pattern HM-HM-HM resulted in higher TSS among the four cropping patterns. Differences were apparent after harvest of second and third crops. Fertilizer levels significantly affected TSS only in cropping pattern HM-HM-HM, where high levels of fertilizer were applied. High TSS was due to high rates of fertilizer and crop duration in pattern HM-HM-HM. The shorter the crop duration, the higher the TSS content.

In general, soil pH decreased after harvest of second and third crops. Differences in soil pH after first and third crops were higher in all cropping patterns except LM-LM-LM. Cropping pattern LM-LM-LM maintained soil pH above 6.0, whereas cropping patterns involving HM and a combination of HM, MM, and LM crops resulted in pH below 6.0 after the third crop. Fertilizer levels significantly affected soil pH only after the harvest of third crops, but there was no tendency for pH to decrease or increase with increasing fertilizer levels.

Soil organic matter (OM) content decreased with successive cropping in all cropping patterns except for LM-LM-LM. Differences among cropping patterns were significant after harvest of third crops. Soil OM decreased from 0.90 to 0.54% between the first and third crops in

HM-HM-HM, whereas soil OM increased from 0.86 to 0.94% in LM-LM-LM. High OM content in pattern LM-LM-LM was probably due to large amount of crop residues from southern peas. Effect of fertilizer levels on soil OM was apparent after harvest of second and third crops in all cropping patterns. After harvest of second crops, soil OM content was significantly higher at high than at low fertilizer level, but this trend was not consistent at harvest of third crops.

Significant differences in soil nitrogen (N) were observed among cropping patterns after harvest of second and third crops. Cropping patterns HM-HM-HM and HM-LM-MM resulted in significantly higher soil N than LM-LM-LM and HM-MM-LM after harvest of second crops. After harvest of third crops, highest soil N (95 ppm) was measured in HM-HM-HM. Low soil N was observed in cropping patterns HM-MM-LM, HM-LM-MM, and LM-LM-LM even after harvest of third crops. Differences in soil N were only observed after collard in HM-HM-HM. Application of low, medium, or high fertilizer level resulted in similar soil N after each crop in cropping patterns LM-LM-LM, and HM-LM-MM.

A consistent increase in soil K was observed with successive cropping in HM-HM-HM, but not with the other cropping patterns. Soil K increased from 84 ppm after bulb onion to 176 ppm after collard. In general, soil K was lowest with LM-LM-LM where low levels of fertilizer were applied, but after harvest of second and third crops, soil K was not different between cropping patterns LM-LM-LM and HM-MM-LM. Soil K was influenced by fertilizer levels, in that, increasing fertilizer level increased soil K for each crop in all cropping patterns. Application of medium to high levels of fertilizer usually resulted in higher soil K than low fertilizer level. The residual soil K levels from all fertilizer treatments were higher than applied K indicating that K fertilizer is less limiting compared to N fertilizer in sequential cropping.

The overall effects of fertilizer levels on marketable yields of vegetable crops in four cropping patterns indicated that more responses were observed on first crops than on second and third crops. Differences in yield responses due to fertilizer levels were not consistent with differences in soil test values for N and K. Improved yields of crops in four cropping patterns were achieved at medium fertilizer level although most yields obtained from this level were not significantly higher than yields at low fertilizer level. Application of high fertilizer rate beyond the medium level resulted in no additional yield increase for most crops.

Labor requirement and total production costs were significantly higher in cropping pattern HM-HM-HM than LM-LM-LM, HM-MM-LM, and HM-LM-MM at all fertilizer levels. For each cropping pattern, increasing level of fertilizer did not significantly increase total production costs.

In general, cropping pattern HM-HM-HM produced high gross and net income and returns to production inputs. Except for cash, returns to fertilizer, labor, and management were not influenced by fertilizer levels for each cropping pattern. Although cropping pattern HM-HM-HM produced high gross and net incomes, and returns to production inputs on a dollar/dollar basis, rates of returns to fertilizer, cash, labor, and management did not differ with patterns LM-LM-LM and HM-LM-MM. Rates of return to fertilizer decreased with increasing fertilizer level for each cropping pattern.

Rates of return to cash were not influenced by fertilizer levels within each cropping pattern, but among cropping patterns, rates of return to cash were significantly different. Cropping pattern HM-HM-HM had similar rates of return to cash as the LM-LM-LM.

Rates of return to labor were influenced by fertilizer levels within each cropping pattern, but not among cropping patterns. In cropping pattern HM-HM-HM, increasing fertilizer level significantly decreased rates of return to labor. In cropping patterns LM-LM-LM and HM-LM-MM, high fertilizer level resulted in higher rate of return to labor than medium and low levels.

Rates of return to management were not affected by fertilizer levels except for cropping pattern HM-HM-HM, where increasing fertilizer levels decreased rates of return to management.

Based on the results obtained from this study, the following conclusions can be drawn:

1. Classifying vegetables according to low, medium, and high management groups and growing them in sequential cropping patterns influenced productivity and relative economic returns.

2. In this study, the sequence of HM vegetable crops increased total soluble salts, soil N and K, but decreased soil pH and OM content. This suggested that additional fertilizer applications might not have been required for succeeding crops in cropping patterns involving HM crops.

3. Increasing fertilizer application above the recommended levels did not increase marketable yields of vegetable crops in this study. Vegetable crops that belong to any of the management groups did not respond to high levels of applied fertilizer when grown in sequential

cropping patterns.

4. In this study, applications of the same rate of fertilizers to each crop in sequential cropping patterns with HM vegetable crops were not profitable. Residual fertilizer from previous crops should be considered in formulating fertilizer rates for succeeding crops.

5. Successive plantings of related LM crops such as English pea and southern pea in a year-round cropping pattern resulted in low yields of successive crops.

6. Cropping patterns involving HM vegetable crops were highly productive and profitable, but were not more efficient than cropping patterns involving LM and a combination of HM, MM, and LM vegetable crops in terms of resource use and rates of return to production inputs.

7. The low-labor and low-cash requiring cropping patterns were as efficient and profitable as cropping patterns requiring high labor and cash inputs. Therefore, vegetable growers with limited resources can grow a sequence of LM or a combination of HM, MM, and LM crops and improve their income without additional production costs.

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BIOGRAPHICAL SKETCH

The author, Manuel Celiz Palada, was born on 26 September 1944, in Bacolod City, Philippines. He received his elementary education from Bacolod North Elementary School and graduated from Negros Occidental High School in 1961 as salutatorian. He studied for 2 years at La Salle College, Bacolod City, and took basic mathematics and science courses preparatory to the Bachelor of Science degree. In 1966, he received the Bachelor of Science in Agriculture (B.S.A.) degree major in agronomy from Central Philippine University, Iloilo City, Philippines. From 1967 to 1968, he served as Instructor in agronomy at the College of Agriculture, Central Philippine University. From November 1968 to December 1970, he studied at the University of the Philippines at Los Banos and took graduate courses leading to the Master of Science in agronomy under the International Rice Research Institute (IRRI) scholarship program. He received the M. S. in agronomy degree from the University of the Philippines at Los Banos in January 1971. Immediately, he was appointed Assistant Professor and Plant Science Research Coordinator, College of Agriculture, Central Philippine University from 1971 to January 1973. He moved back to Los Banos and worked as Instructor II in the Agronomy Department, University of the Philippines, from February to April 1973. From May 1973 to January 1974, he was employed by the Multiple Cropping Department, IRRI as Research Assistant, organized and coordinated a 6-month multiple cropping training course participated by trainees from Southeast Asian countries. In 1975, he was promoted to Senior Research Assistant and was assigned to Iloilo province as Site Coordinator for IRRI-BPI (Bureau of Plant Industry) Cropping Systems

Project covering two townships and eight villages. While working with IRRI, he had a chance to visit Taiwan in October 1974 and participated in a 2-week Multiple Cropping Training Course sponsored by Food and Fertilizer Technology Center (FFTC) of the Asian Pacific region (ASPAC).

In September 1976, he entered the Graduate School of the University of Florida with a Rockefeller Foundation graduate fellowship for the degree of Doctor of Philosophy in horticulture with major interest in vegetable cropping systems.

Mr. Palada has been a member of the Crop Science Society of the Philippines, Weed Science Society of the Philippines, and Biology Teachers Association of the Philippines. He is a member of American Society for Horticultural Science, American Society for Horticultural Science Tropical Region, Florida State Horticultural Society, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

He is happily married to Elisa Hortelano, and they have two children, Daffodil and Ted Peter.

The author has accepted a 1-year post-doctoral fellowship with the Organic Gardening and Farming Research Center in Kutztown, Pennsylvania to work on low-energy input farming systems with emphasis on small farms.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Donald N. Maynard, Chairman
Professor of Horticultural Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

William G. Blue
Professor of Soil Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Gordon M. Prine
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Lawrence H. Halsey
Associate Professor of Horticultural Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Stephen R. Kostewicz
Associate Professor of Horticultural Science

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

March 1980

Dean, College of Agriculture

Dean, Graduate School