C-139 BASIN VEGETABLE PRODUCTION DEMONSTRATION PROJECT

Annual progress report
Sept 2006
(Revised Nov 2006)

First year research results: Winter 2005 to Spring 2006

Farm 1
Farm 2
Farm 3a
Farm 3b

University of Florida/IFAS
Southwest Florida Research & Education Center
Immokalee, FL

Kent Cushman
Vegetable Specialist and Project leader

Gene McAvoy
Multi-County Extension Agent III

Kelly Morgan
Soil Scientist

Eric Simonne
Vegetable Specialist

Tom Obreza
Soil Scientist

Sponsored by
South Florida Water Management District
Florida Department of Agriculture and Consumer Services
Office of Agricultural Water Policy

Bill Donovan
Project Manager and Senior Engineer, SFWMD

Camilo Gaitán
Project Manager and Senior Water Resources Engineer, FDACS

This report represents research supported by a grant from the South Florida Water Management District. Information contained in this report has not been subjected to scientific peer review, nor has it yet been incorporated into IFAS recommendations.

Executive summary

This report presents first season results for the vegetable demonstration project completed in the C-139 Basin. The goal of the project was to demonstrate phosphorus (P) fertilization practices for vegetables based on soil testing. Four demonstration plantings: two tomato (Farms 1 & 3a), one eggplant (Farm 2), and one green bean (Farm 3b) were located on three large-scale commercial farms. For the two tomato and one eggplant plantings, demonstration plots of 0.4 acres or larger were installed with P fertilization treatments of zero, half, and full rates. The full rate was the farm rate and the zero rate was the IFAS recommended rate. For the green bean planting, demonstration plots of approximately 1 acre were installed with two P fertilization treatments of zero and full rates. The zero rate was the IFAS recommended rate and the farm rate. In three out of four plantings (Farms 1, 2 and 3b) treatments were replicated and this allowed for statistical analyses of data. All farms tested "very high" in extractable P and few differences were detected among the P treatments before applying fertilizer, during crop production, or after final harvest. Out of a total of 13 soil sample dates, only one detected significant differences among treatments. That sampling showed higher extractable P for the full rate compared to the zero rate.

Total tomato yield at one farm (Farm 1) was increased for the zero and half rates compared to the full rate. For the other three farms (Farms 2, 3a and 3b), there were few significant effects on yield due to P fertilization, although trends mostly showed small increases in yield with increasing P. In two out of four farms (Farms 3a and 3b), there was a trend of greater plant growth (plant biomass accumulation) with increasing P but these differences were not significant. Leaf tissue P concentrations were within or above sufficiency levels regardless of farm, crop, or time of sampling. Out of a total of nine sampling dates, only two detected significant differences in leaf tissue P concentration among treatments. The two samples came from one tomato farm (Farm 1) and showed increasing leaf tissue P concentration with increasing P.

In conclusion, extractable soil P was "very high" for each planting. With relatively high levels of P in the soil, it was difficult to detect differences due to P fertilization treatment regardless of the type of measurement recorded: yield, biomass, leaf tissue P concentration, or extractable soil P.

Project background

The C-139 Basin is a 170,000-acre agricultural basin in Hendry County that is tributary to the Everglades. The Everglades Forever Act (EFA) mandates that landowners within the C-139 Basin should not collectively exceed average annual historic total phosphorus (P) loading. In 2002, the C-139 Basin Regulatory Program was created to ensure that historic P levels are met based on mandatory implementation of Best Management Practices (BMPs), as defined in Rule 40E-63, F.A.C. The basin has been unable to meet historic P levels since the program's inception. BMP requirements are based on the annual assessment of compliance with historical P levels.

C-139 Basin agriculture has historically consisted of pasture, sugarcane and citrus. However, vegetable production has been increasing in the basin. On-farm projects intended to demonstrate optimum P fertilizer rates for vegetable producers have been identified as an opportunity for implementation of cost effective BMPs.

One method of optimizing P fertilizer rates is through the soil testing BMP that is defined in permits issued in accordance with 40E-63, F.A.C. Soil testing as an index of P availability for Florida vegetable production has existed for more than 30 years. A soil test allows the grower to accurately predict soil P availability and adjust P fertilizer rates.

In 2005, the C-139 Basin vegetable production demonstration project was funded by a grant from the South Florida Water Management District and the Florida Department of Agriculture and Consumer Services' Office of Agricultural Water Policy. A group from the University of Florida comprised of two horticulturists, two soil scientists, and one extension agent were awarded the contract to setup and implement the goals of the demonstration project. Briefly, the objectives of the demonstration project are as follows:

- Demonstrate soil test-based P fertilization application rate recommendations of commercial vegetables crops grown in the C-139 Basin
- Transfer soil test results and methodology to develop optimized P fertilization rates to vegetable farm managers
- Through education and extension services, reach 90% or more of commercial vegetable growers in the C-139 Basin to encourage them to base fertilizer application rates on soil test results
- Disseminate results of demonstration trials in the C-139 Basin to the region's growers using appropriate formats, such as workshops, field days, and publication of extension materials.
- Create on-farm areas within the C-139 Basin that have had no P applied to vegetable crops for a period of three years. This will provide sites of lowered soil P content for possible future study.

Scope of Work

The University of Florida provides horticultural, soil and water science, and extension services to complete the tasks indicated below:

- Identify project participants, and enter into agreements with five C-139 Basin vegetable growers, with the intent to maintain a minimum of four cooperators fully engaged at any one time throughout the 3-year period.
- Conduct demonstration projects to evaluate soil test-based P fertilization recommendations,
- Coordinate individual project setup and implementation with participants,
- Collect soil and plant samples, determine crop-specific soil test values, and site-specific P fertilization rates based on University of Florida IFAS (UF-IFAS) standards,
- Evaluate plant P uptake during the season, and measure crop yield and quality at harvesting. Monitor indicators that may cause deviations from UF-IFAS standards,

- Provide verbal reports to participating growers and training when requested, and
- Produce technical reports, fact sheets, surveys and presentations for C-139 Basin growers and the District.

Deliverable 3.3: Annual Progress Report (this document)

The annual progress report includes the following: a list of grower participants, test site locations, treatment blocks acreages, crop type, relevant site characteristics, soil sample results, fertilizer recommendations and rationale for the recommendation, application rates, and resulting crop yield and quality. In addition, the annual progress report details preparations made for the next season's demonstrations. Other activities to be reported include on-site Soil Test BMP training.

Introduction

Phosphorus is considered a macronutrient and required by plants in relatively large amounts to sustain normal growth. Commercially available fertilizers are required by law to prominently display the fertilizer analysis on the bag or container. The three numbers most prominent are percent nitrogen (N), phosphorus (P), and potassium (K) expressed according to the following: N as an element, P as the oxide P_2O_5, and K as the oxide K_2O. A container of fertilizer that displays, for example, 5-10-15, is composed of materials that contain 5% N, 10% P_2O_5, and 15% K_2O.

Though this seems straightforward, it is not. Fertilizers do not contain P_2O_5. Expressing P content of fertilizer according to the oxide form is a convention of the fertilizer industry and subsequent government regulation. Regardless of the form of P in the fertilizer, it is the convention of the industry to express P in terms of the oxide P_2O_5.

In addition, soils and plants do not contain P_2O_5. Instead, plants acquire P in other forms (mostly PO_4^-) by root uptake from the soil. Soils may contain low to very high levels of P, but if P is present it is often in some form that is rather insoluble and immobile. This form is not directly available to plants. However, a small portion of insoluble P becomes soluble at a rate determined by many factors, such as temperature and pH. It is the soluble form of P that becomes available to plants and can be taken up by roots. From the roots, P travels in the vascular system of the plant to other locations such as leaves, flowers, and fruit. P is an essential component of organic compounds that are integral to cellular metabolism.

The University of Florida has determined crop nutrient requirements (CNR) for the most important vegetables and major soil types of the state. In all cases, no P fertilization is needed for mineral soils that test “high” or “very high” in Mehlich-1 extractable P. There are several types of extraction procedures, such as weak bray, strong bray, Mehlich-1, Mehlich-3, and Olson. Mehlich-1 is the only procedure widely used for the sandy soil types encountered in these trials despite the limitation that this procedure is not considered accurate at a pH of 7.3 or greater.

The purpose of soil testing is to provide reliable information to a grower about the quantity of nutrients in the soil that may be available to support plant growth. With this information, a grower can estimate the quantity of nutrients required in addition to that available in the soil to grow a crop. The grower can then supplement these soil-available nutrients with nutrients from fertilizer sources. To obtain soil test results, the area to be cropped is sampled, with several small samples combined into a composite sample, mixed, and sent to a soil testing laboratory for analysis. The laboratory then determines the amount of macronutrients (nitrogen, phosphorus, potassium, magnesium, calcium, and sulfur) and micronutrients (boron, iron, zinc, copper, manganese, and molybdenum) present in the soil, the amounts present are compared to the crop nutrient requirements (CNR), and recommendations are provided to correct any nutrient deficiencies. Deficiencies are corrected by addition of fertilizers to the soil that contain the desired elements. The soil test recommendations are based on crop yield response curves (the yield of a crop over time to different levels of individual nutrients) and nutrient price.

Methodology

Farms
There were four demonstration plantings installed in commercial vegetable production fields during the winter 2005 to spring 2006 growing season. The four plantings were located on three farms and labeled “Farm 1”(tomato), “Farm 2”(eggplant), “Farm 3a”(tomato), and “Farm 3b”(green bean).

Production practices for these crops are site specific, that is, every grower has their own method and procedure for establishing their crop and obtaining high yields of high quality produce. It is not the intent of this report to detail these production practices. Information about basic practices, shared in common with most growers, are found in the University of Florida publication “Vegetable Production Handbook for Florida 2006-2007”. The Handbook is updated every year, and individual chapters of the Handbook are available online at http://edis.ifas.ufl.edu/.

Rates
Rates of P fertilization were determined for each farm in the following manner. First, a soil analysis was completed to determine extractable P and the recommended fertilizer rate. For example, the soil from “Farm 1” tested “very high” in extractable P and the recommendation was to apply no P. Second, it was determined what the typical farm practice was. For “Farm 1” the typical practice was to apply 100 lb/acre P_2O_5. Finally, it was decided how many treatments to install. For “Farm 1” it was decided to install three P fertilization rates: (1) zero lb/acre P_2O_5, the recommended rate, (2) 50 lb/acre P_2O_5, considered an intermediate rate, and (3) 100 lb/acre P_2O_5, the typical farm practice. It was not known whether a difference of 100 lb/acre P_2O_5 between the zero and full farm rate would result in small or large effects on plant growth and crop productivity. Therefore, the intermediate rate, 50 lb/acre P_2O_5, was included in the study.

On “Farm 2”, the soil also tested “very high” in extractable P. However, the typical farm practice was to apply no P. In this case it was decided to install the same treatments as “Farm 1”, but the three P fertilization rates were described slightly differently: (1) zero lb/acre P_2O_5, the recommended rate *and* the typical farm practice, (2) 50 lb/acre P_2O_5, considered an intermediate high rate, and (3) 100 lb/acre P_2O_5, considered an arbitrary high rate.

“Farm 3a” was similar to “Farm 1”. The soil tested “very high” in extractable P and the recommendation was to apply no P. The typical farm practice was to apply 100 lb/acre P_2O_5. It was decided to install three P fertilization rates: (1) zero lb/acre P_2O_5, the recommended rate, (2) 50 lb/acre P_2O_5, an intermediate rate, and (3) 100 lb/acre P_2O_5, the typical farm practice.

On “Farm 3b”, the soil tested “very high” in extractable P. However, the typical farm practice at this site was to apply 39 lb/acre P_2O_5. It is a common practice at this farm to determine rate of P fertilization based on soil test results. At the demonstration site it was decided by the grower to apply 39 lb/acre P_2O_5 based on the farm’s recent soil test results. The two P fertilization rates were: (1) zero lb/acre P_2O_5, the IFAS recommended rate, and (2) 39 lb/acre P_2O_5, the typical farm practice. It was decided by the project leader to install only two treatments because an intermediate rate, at 19.5 lb/acre P_2O_5, was too small a difference compared to the zero and full rates. It was assumed that significant differences would not be detected with such small differences among rates.

Yield

Yield is an important measure of plant performance and is the measure that most attracts grower attention. Yield is a direct measure of plant productivity and an important indirect measure of how treatments affect overall plant growth. Yield is measured only for the portion of the crop that is removed from the field and sold for economic gain. For example, yield of a tomato crop is measured in terms of tomatoes and not in terms of plant size or biomass. There are several categories of yield. Total yield is a measure of everything the plant can produce, regardless of marketability. In the case of tomatoes, total yield is every tomato fruit the plants can produce. Marketable yield is that portion of total yield that is considered marketable. In the case of a tomato crop, these are tomato fruit with little or no defects. Unmarketable yield is that portion of total yield considered unmarketable. Unmarketable yield is composed of vegetables that are not harvested, discarded, or culled for any reason. For tomato, these are tomato fruit with defects considered to be unacceptable by the market. Defective fruit are "culled". The decision of what is marketable and unmarketable is made by the market and changes over time according to supply and demand. When tomatoes are plentiful in the market, even small defects on tomato fruit are considered unmarketable because there is a plentiful supply of perfect or nearly perfect tomato fruit. When tomatoes are not plentiful in the market, even the grossest of defects may be considered marketable because the supply of perfect or nearly perfect tomato fruit is limited. At times like this, a defective tomato fruit is better than none at all. Tomato fruit are delivered from the field to the packing shed and then sorted by marketability and size. The number of boxes that go to market is called the "pack out". A grower may talk in terms of a field producing a particular number of bins (crates that hold about 1000 pounds of tomatoes) and then say each bin "packed out" an average of 34 boxes. That means the tomatoes that filled 34 boxes were marketable and everything else was considered unmarketable and discarded. In summary: Total yield = Marketable yield + Unmarketable yield.

The two tomato crops in these studies were of the "large round" red type and grown for the "gas-green" market. Large rounds are slicing tomatoes and are not roma, cherry, or grape types. Large rounds average about 4 to 10 ounces per tomato depending on size category. Gas-green means the tomatoes are picked at the mature green stage and then sorted by size and quality in packing sheds. At the sheds, tomatoes are boxed according to size and quality and then gassed with the natural ripening compound ethylene. After several days of storage, depending on market demand, pallets of boxes are shipped by truck to distant markets. Mature green tomatoes have no pink or red color but are mature enough to ripen when exposed to ethylene. There are many yield categories for tomato. The traditional USDA size categories are medium, large, and extra large. These correspond to industry size categories of 6x7, 6x6, and 5x6 (pronounced "six by seven", "six by six", and "five by six"). The terms "6x7", "6x6", and "5x6" were established by the industry and have been developed according to how many of each category can fit in a box. However, boxes used by the industry change over time and these sizes may no longer represent what fits into a standard box. Currently, an industry box has inside dimensions of 14.75 inches long by 11.50 inches wide and 8.75 inches tall. These boxes hold 25 pounds of tomatoes regardless of size category.

It is not possible to assign economic value to each size category even though 5x6s frequently have greater value than 6x6s and, in turn, 6x6s frequently have greater value than 6x7s. At times, pricing for all size categories are similar. Pricing changes rapidly in the tomato business and it is difficult to obtain accurate data. Only the packing sheds know actual day-to-day prices. Pricing data published by the USDA should be considered a rough estimate of actual prices received by the industry. Growers care about size, but they are also highly interested in total yields regardless of size category.

Some tomato producers also harvest and sell “vine ripened” tomatoes. These are tomatoes harvested from the field that have some pink or red color but are still firm enough to handle and ship. For these demonstration plantings, mature green and vine ripe tomatoes were harvested together. In addition, marketable and unmarketable tomatoes were harvest together but then counted and weighed separately. Unmarketable tomatoes had defects that made them undesirable, such as being misshapen, scarred, diseased, bruised, wounded, or discolored. Yields reported in this document were combined totals of all marketable tomatoes, mature green and vine ripe. Unmarketable (or cull) yields were reported separate from marketable yields.

The one eggplant crop in this project was of the large, American type. This type produces a large plant and is supported on a taller stake than that used for the tomato plantings described above. Otherwise, many cultural practices are similar for tomato and eggplant. Eggplant is often grown and cropped for a longer period than that of tomato, about 180 days compared to about 120 days for tomato. Eggplant fruit is harvested and boxed in the field. Premium grade eggplant packs 16 to 18 excellent quality fruit per box, with lesser grades packing more per box. Boxes are palletized, refrigerated, and then shipped.

Green bean, or snapbean, can be hand picked or machine harvested. The grower in this project used mechanical combines that harvested four rows at a time (two rows of plants on each of two plant beds). Green beans are harvested when the beans that develop first on the plant are the correct size. This ensures that most of the rest of the beans on the plant are also ready to harvest. Bean plants must be healthy and strong enough to support the crop so that soil does not come in contact with the beans. This ensures a clean crop and prevents loses from disease and decay. Beans must be supported high enough in the canopy so that the combine can harvest the crop without picking up sand and debris. Plants must also be strong enough to withstand combining without shattering or pulling out of the ground. Marketable beans are mostly 4 to 6 inches long and straight or almost straight.

Biomass

Another measure of plant performance is biomass accumulation. This is simply dry weight of plant material. For this project, plant stems were cut at the soil surface and removed from the field. The entire shoot (the aboveground portion of the plant) was then dried in a drying oven until all water content was removed. The plant mass was then weighed. In general, plants produce the most biomass when they are grown under optimum conditions. When conditions are less than optimum, that is, when stressed in any way, biomass accumulation normally suffers. It is generally the case that unstressed plants grown under optimum conditions produce more biomass than stressed plants grown under less than optimum conditions. Biomass was determined at about 60-day intervals during the growth of the crop.

Biomass accumulation is sometimes a direct and sometimes an indirect measure of plant productivity. For leafy crops such as spinach, lettuce, and cabbage, the entire upper portion of the plant is harvested and sold. Biomass for these crops is a direct measure of plant productivity. For fruiting crops such as tomato, eggplant, and green bean, only a small portion of the plant is harvested and sold. For these crops, biomass accumulation is an indirect measure of plant productivity. It is assumed that larger plants produce higher yields, but this is only generally accurate. It is certain that small plants will not produce high yields, but sometimes even large plants do not produce high yields. The reasons for this are too varied to discuss here. Most important is that conditions for growth should be optimum so that plants can grow as large as possible while, at the same time, maintain high yields. It is not possible to have high yields without healthy plants, but it is possible to have healthy plants with low yields. This is yet another example of how biomass is an indirect measure of plant productivity with crops such as tomato, eggplant, and green bean.

Leaf tissue nutrient concentration
Plant nutrients accumulate in plant tissues at different rates and different concentrations depending on the nutrient, the plant tissue, and stage of growth. Nutrients accumulate in plant tissue according to how available the nutrients are to the plant. If not available in sufficient amounts, plant tissue will not contain nutrients in adequate concentrations and the nutrient or nutrients are then considered to be deficient. Deficiencies often lead to reduced growth and productivity. Tissue samples of tomato, eggplant, and green bean were taken at predetermined intervals throughout the growth of each crop to document that nutrient concentrations of P, and other elements, were present in adequate concentrations.

Sufficiency ranges for nutrients have been determined for vegetables. The plant tissue most often used to determine nutrient sufficiency is the "most recently mature" leaf. This is a leaf about four to six leaves down from the apex of the plant that has reached its final size and will not expand further. It is the youngest leaf on the plant or shoot that has reached final size. Sufficiency ranges for the crops in these plantings are as follows:

Crop	*Stage of growth*	*Sufficiency range (% P on dry weight basis)*
Tomato [z]	5-leaf stage	0.3 to 0.6
	First flower	0.2 to 0.4
	Early fruit set	0.2 to 0.4
	First ripe fruit	0.2 to 0.4
	During harvest period	0.2 to 0.4
Eggplant	Early fruit set	0.3 to 0.6
Green bean	First bloom	0.3 to 0.4

[z]Hochmuth, Maynard, Vavrina, Hanlon, and Simonne. 2004. Plant tissue analysis and interpretation for vegetable crops in Florida. UF/IFAS

Values for sufficiency ranges are accurate only for the stage or stages of growth listed above. It is well recognized by plant scientists and horticulturists that nutrient concentrations in leaf tissue decrease as the entire plant matures, even when the same type of leaf, the most recently mature leaf, is sampled throughout growth. For example, tomato plants at first flower or first harvest have lower levels of N in leaf tissue compared to young plants at the three or five leaf stage of growth. Older plants have lower levers of N in leaf tissue compared to plants at first flower or first harvest. This is common for most nutrients that accumulate in leaves. Sometimes it is difficult to obtain accurate values of nutrients concentration because of the chemicals applied to plants under production. Growers apply pest control chemicals that contain high concentrations of iron, copper, and manganese and they often apply nutritional compounds that contain many other nutrients. These elements become imbedded in the leaf tissue, cannot be washed off, and can cause erroneous values for nutrient concentrations of the leaf tissue.

Other nutrients besides P are reported in this document. It is important to document the effect of treatments on other nutrients besides P because they may influence or interact with P uptake and to establish they were present in adequate and rather equal amounts among all treatments. It was expected that P would be the only nutrient that may have been significantly different among treatments. At times other nutrients are found to be significantly different among treatments even though there seems no reason for them to be different. At times this is explained by differences being significant but not practical. For example, in Table 6 the value of iron (Fe) in the leaf tissue at 60 DAT was 75 ppm for the zero P treatment. This was significantly less than 81 ppm for the half rate. This difference of 6 ppm was significant but not practical. It is almost certain that a 6 ppm difference in Fe concentration would not lead to changes in plant growth or productivity. At other times, significant differences among treatments are significant and must be taken seriously. However, given the experimental design—with its focus on P fertilization—these differences cannot always be explained. There is simply a lack of information about how these differences occurred. See the section below about "Statistical significance" for further discussion of this topic.

Extractable soil nutrients

Availability of plant nutrients in the soil are estimated by laboratory analyses. To estimate nutrient availability for many Florida soils, the Mehlich-1 test is used. For the plantings in these trials, soil analyses of all nutrients commonly tested for vegetable production were conducted for all samples and for all farms. In addition to the effect of treatments on extractable P, it was considered important to document the effect of treatments on other nutrients, such as Ca, that may influence or interact with P uptake. As explained above for leaf tissue analyses, it is important to establish that other plant nutrients were present in adequate and rather equal amounts among all treatments. It was expected that P would be the only nutrient that may have been significantly different among treatments.

Other soil measurements include pH, which is a measure of soil acidity or alkalinity, and CEC, or cation exchange capacity. The preferred soil pH for vegetables is about 5.5 to 7.5, but many soils in the C-139 basin are between 7.0 to 8.0 and at times even higher. Growers control soil pH with the types of fertilizers they use, lime or dolomite to raise pH or sulfur to lower pH. Some soil testing laboratories report pH according to the solution used to extract from the soil sample. If just water is used, then it is reported as pH_w. If buffered solution is used, then it is reported as pH_g and these values are used to determine liming requirements. For the purposes of this report, values of pH_w are adequate and sufficient. CEC is a measure of the ability of soils to interact with charged particles, or ions, in the soil solution. CEC is always low in sandy soils unless a relatively high level of organic matter is present.

Other
Yield, plant biomass accumulation, leaf tissue nutrient concentration, and soil nutrient content were the only measurements recorded at Farms 1, 2, 3a and 3b. Rainfall and soil moisture content were not recorded as each of these varies widely from farm to farm and from the beginning to end of the cropping cycle, from bed preparation to planting or seeding to harvest and, finally, to crop destruction.

It was decided by the project leader and co-investigators to record measurements every 60 days for the high-value and long-lived crops of tomato and eggplant and every 30 days for the short-lived crop of green bean. Soil samples were taken before bed preparation and called in the following tables “zero days after transplant” or “0 DAT”. Regardless of when soil samples were taken or how many days before transplant, these samples were referred to as “0 DAT”.

The first demonstration project to be established was at Farm 1 (tomato). Procedures for sampling had not yet been established and, at the same time, an assistant had just been hired to work with the project. The assistant stayed in the position only a few months and then left. As a result, soil samples, biomass accumulation, and leaf tissue samples were not taken or not recorded at regular intervals. Soil samples were taken at 0, 60, and 150 DAT instead of 0, 60, and 120 DAT. Biomass was recorded at 75 DAT instead of 60 and 120 DAT. Leaf tissue samples were taken at 30, 60, and 150 DAT instead of 60 and 120 DAT. The tomato crop was destroyed soon after 150 DAT.

Farm 2 (eggplant) was more organized. Soil samples were taken at 0, 60, 120 and 180 DAT. Biomass was recorded at 60, 120, and 180 DAT. Leaf tissue samples were taken at 60 and 120 DAT. Leaf tissue samples were not taken at 180 DAT because the crop was at the end of the cropping cycle and had stopped growing. It was thought leaf tissue samples taken at this time would not represent the nutritional status of the crop. There is no reason to sample nutritional status of crops at the very end of the cropping cycle, that is, for crops that are soon to be destroyed. As a result, there is little or no data from past research about nutritional status of plants at the end of the cropping cycle. The eggplant crop was destroyed soon after 180 DAT.

Soil samples at Farm 3a (tomato) were taken at 0, 60, and 120 DAT. Biomass was recorded at 60 and 120 DAT. Leaf tissue samples were taken at 60 and 120 DAT. The tomato crop was destroyed soon after 120 DAT.

Soil samples at Farm 3ab (green bean) were taken at 0, 30, and 60 DAT. Biomass was recorded at 30 and 60 DAT. Leaf tissue samples were taken at 30 and 60 DAT. The green bean crop was harvested soon at 60 DAT.

Statistical significance
Agricultural experiments are often designed in such a way that data that results from the experiment can be statistically analyzed. Experimental designs and statistical analyses are as varied as the experiments themselves, but what is common to most experiments is the ability to test for statistically significant differences. When confronted with numbers that have different values, researchers often ask the question, “Are these differences real?” this is the same as

asking, “Are the differences significant?” Statistical analyses allow researchers to answer these questions. Statistical analyses require that experiments have appropriate experimental designs and replication of treatments. In the demonstration plantings reported here, the experimental design used was a randomized complete block, also known as a “RCB design”. This is a common experimental design used in agriculture. Treatments must also be replicated for analysis to be possible. There must be at least two replications of treatments but three or four replications are preferred. When reporting results from these experiments, differences among treatments are considered statistically significant at levels of probability of “*0.050*” or less. This is the most common threshold of significance used in agricultural research and means there is a 95% probability that the values being reported are truly different. This means the values are highly likely they come from at least two different populations of numbers and there is only a 5% probability the values come from the same population of numbers. Values reported in tables are traditionally labeled with lettering such as “a”, “ab”, and “b” to designate significant differences among treatments. Values that have letters in common are not significantly different. For example, values labeled “a” are statistically similar to values labeled “ab” but are significantly different than values labeled “b”. Values without lettering are not significantly different at the 0.050 level. When possible, significance levels are reported in the tables used in this report. The way to read these significance levels is as follows: if the significance level is 0.20 this means there is an 80% probability that the values being reported are truly different and that the values come from at least two different populations of numbers. There is 20% probability the values come from the same population of numbers. Whoever reads the report may decide for themselves that this is a “significant difference” or not. For research purposes, as already mentioned, significance differences are traditionally accepted at the 95% level or greater. Some in the business community often accept levels less than 95% at which differences are considered “significantly different”.

C-139 Basin Vegetable Production Demonstration Project
Annual summary report

Farm 1 -Tomatoes
Winter 2005 to Spring 2006

C-139 Basin Vegetable Production Demonstration Project
Annual summary report

Farm 1 -Tomatoes

"Farm 1" produced large round tomatoes for the gas-green market. Vegetable beds were installed at Farm 1 on 5 Nov. 2005. Phosphorus (P) fertilization treatments were applied immediately before bedding by using preplant fertilizer mixes that contained 0%, 5%, or 10% P_2O_5. Nitrogen (N) and potassium (K) rates were the same for all treatments. Treatments were defined by P fertilization:

(1) Zero rate – no soil-applied P, IFAS recommended rate
(2) Half rate – 50 lb/acre P_2O_5
(3) Full rate – 100 lb/acre P_2O_5, Grower rate

Two types of preplant fertilizer were used. The "bottom mix" was applied before bedding and was incorporated in the soil during the pre-bedding and bedding operation. Treatments were applied by adjusting the P content of the bottom mix as described above. The "top mix" was applied in grooves on the right and left shoulders of plant beds as they were formed. The top mix did not contain P. After transplanting seedlings, starter solution that contained P was applied to all plants in all treatments. This was a normal practice for this farm. In addition, foliar-applied fertilizers that contained P were applied on a regular basis to the crop during the growing season at the same time pesticides were applied. This also was a normal practice for this farm. Together, these extra sources of P probably did not contribute a significant amount of P to the crop.

Tomato seedlings were transplanted 18 Nov. 2005 to establish a winter-to-spring crop. The experimental design was a randomized complete block with three replications. Each plot was 6 rows wide (a typical "land" of two sets of three rows with a drive row between) and 500 to 700 ft long. Two 10-plant subsample plots within each replication were harvested for yield determinations. Harvests were made by hand and fruit were sorted and weighed in the field. Harvests of all subsample areas were made on 27 Feb., 10 and 27 Mar., and 13 Apr. 2006; and were made one to three days before commercial harvest each time. Soil within the plastic-mulched bed was sampled 0, 60, and 150 days after transplant, leaf tissue was sampled 30, 60, and 150 days after transplant, and plant biomass accumulation was determined 75 days after transplant.

Results

For the 5x6 size category, P fertilization did not affect marketable yield, average fruit weight, or unmarketable yield during any harvest or for total yield (Table 1).

For the 6x6 size category, P fertilization affected marketable yield during the third and fourth harvests and for total yield (Table 1). P fertilization also affected average fruit weight and unmarketable yield during the fourth harvest and unmarketable yield for total harvest in this size category. In every case except one, the zero and half rates produced higher values than full rate. During the third harvest the half rate was equal to the full rate.

For the 6x7 size category, P fertilization had little affect on marketable yield, average fruit weight, or unmarketable yield (Table 1). The only exception was during the fourth harvest when marketable yield was higher for the zero and half rates compared to the full rate.

P fertilization did not affect total average fruit weight or total unmarketable yield. As mentioned in the introduction, unmarketable tomatoes were considered undesirable due to blemish, poor color or shape, or damage. P fertilization affected marketable yield for the third and fourth harvest and for the grand total of all harvests (Table 1). P fertilization affected average fruit weight of all size categories combined (Table 1). In each case, the zero rate produced higher values than the full rate. The half rate was equal to the zero rate except during the third harvest.

P fertilization did not affect plant biomass accumulation 75 days after transplant (Table 2).

Extractable soil P ranged from a low of 137 ppm to a high of 197 ppm during the experiment (Table 2). Increasing P rate significantly increased extractable soil P at 60 days after transplant. None of the other soil elements were affected by P fertilization. P fertilization did not affect extractable soil P at 0 or 150 days. Values for pH significantly decreased from 6.3 to 5.9 at 60 days after transplant as P rate increased from zero to full rate. Despite variability in values of soil K, Mg, Ca, pH_w, pH_g and CEC before transplant, during crop production, and after harvest, these values appeared unaffected by P fertilization and variability among these values was not great enough to affect plant growth or productivity.

P fertilization affected leaf tissue elemental concentrations (Table 3). Increasing P fertilization significantly increased P tissue concentration. Differences were statistically significant at 30 and 150 DAT but not at 60 days. The trend of increasing P concentration with increasing P fertilization was present for 30, 60, and 150 DAT. However, the trend appeared significant only for 30 and 150 DAT. This indicates that P fertilization probably affected tissue P concentration, but all values were above sufficient levels and probably did not affect plant growth or productivity. Other significant differences occurred with N, Mg, and S concentrations at 30 DAT and S and Zn at 150 DAT. In each case except N, the zero rate produced values lower than the full rate. The half rate was sometimes statistically equal to the zero rate or the full rate for these elements. It is not known how these essential elements were lower for the zero rate compared to the full rate, but as with P concentration, these concentrations were above sufficiency levels and probably did not affect plant growth or productivity. It is important to measure all nutrients, not just P, so that differences in plant growth or productivity can be attributed solely to P fertilization. If other elements are not held constant, then the effects of P fertilization may be confounded by other factors.

Conclusions

P fertilization was not expected to affect tomato production during the first season of this demonstration project. In previous research with green bean, experimental plots receiving no P fertilization showed no negative effects until the sixth year of the study when extractable P was reduced to values of 30 ppm, a level intermediate between “medium” and “high” (Gene McAvoy, oral presentation, Immokalee, FL, 20 Sep 2006). The tomato crop grown on this farm, however, showed an immediate effect of P fertilization on some yield components as well as on some soil and tissue elemental concentrations, with the zero rate increasing particular yield components compared to the full rate. Increasing P fertilization increased leaf tissue P concentration, but all levels were above that considered sufficient and, in some cases, were far above that considered sufficient. The observed decrease in yield at the full rate of P fertilization was unexpected because the soils on this farm tested relatively low for extractable soil P (although still testing “very high” for P) compared to some of the other farms in this study. Phosphorus fertilization was expected to have a positive or neutral affect on yield, not a decrease in yield.

This report represents research supported by a grant from the South Florida Water Management District. Information contained in this report has not been subjected to scientific peer review, nor has it yet been incorporated into IFAS recommendations.

Table 1. Tomato yields. Yields determined by harvest of two 10-plant subsample areas within each treatment. There were four harvests. Size categories are 5x6 (extra large), 6x6 (large), 6x7 (medium). Yields are reported in units of 25-lb boxes/acre. Cull fruit were considered unmarketable. Values in bold followed by the letter "a" are significantly different ($P \leq 0.05$) then those followed by the letter "b".

	5x6			6x6			6x7			Total marketable		
P fertilizer rate	Marketable Yield (boxes/ac)	Avg Wt (oz/fruit)	Unmarketable yield (boxes/ac)	Marketable yield (boxes/ac)	Avg Wt (oz/fruit)	Unmarketable yield (boxes/ac)	Marketable yield (boxes/ac)	Avg Wt (oz/fruit)	Unmarketable yield (boxes/ac)	Marketable yield (boxes/ac)	Avg Wt (oz/fruit)	Unmarketable yield (boxes/ac)
					First harvest							
Zero	651	7.9	89	204	5.7	17	53	4.6	10	908	7.0	116
Half	722	7.9	105	210	5.6	28	53	4.7	11	985	7.1	144
Full	694	7.9	86	183	5.6	16	44	4.8	8	921	7.1	109
Significance	*0.444*	*0.868*	*0.621*	*0.066*	*0.881*	*0.117*	*0.741*	*0.808*	*0.572*	*0.451*	*0.707*	*0.268*
					Second harvest							
Zero	298	7.0	46	273	5.4	35	243	4.4	32	814	5.5	113
Half	318	7.0	36	271	5.4	34	208	4.3	26	796	5.5	96
Full	275	6.9	44	265	5.3	22	205	4.4	21	745	5.5	86
Significance	*0.652*	*0.258*	*0.783*	*0.932*	*0.779*	*0.282*	*0.274*	*0.330*	*0.570*	*0.563*	*0.913*	*0.380*
					Third harvest							
Zero	354	6.9	49	**371 a**	5.3	44	379	4.3	41	**1105 a**	5.3	134
Half	305	6.8	58	**316 b**	5.3	47	312	4.2	52	**932 b**	5.2	158
Full	313	6.9	35	**322 b**	5.3	38	350	4.2	56	**985 b**	5.2	130
Significance	*0.467*	*0.513*	*0.608*	*0.024*	*0.680*	*0.620*	*0.136*	*0.668*	*0.456*	*0.013*	*0.942*	*0.454*
					Fourth harvest							
Zero	86	6.6	18	**201 a**	**5.2 a**	**40 a**	**472 a**	4.0	100	**759 a**	4.4	159
Half	114	6.5	31	**242 a**	**5.2 a**	**42 a**	**485 a**	4.0	99	**841 a**	4.5	172
Full	40	6.9	20	**138 b**	**5.1 b**	**23 b**	**331 b**	3.9	68	**508 b**	4.3	112
Significance	*0.065*	*0.534*	*0.269*	*0.010*	*0.003*	*0.019*	*0.040*	*0.750*	*0.284*	*0.019*	*0.209*	*0.155*
					Total marketable							
Zero	1390	7.4	201	**1050 a**	5.4	**136 a**	1150	4.2	183	**3590 a**	5.4	521
Half	1460	7.4	231	**1040 a**	5.4	**150 a**	1060	4.2	189	**3550 a**	5.5	570
Full	1320	7.4	185	**907 b**	5.4	**98 b**	930	4.2	153	**3160 b**	5.5	436
Significance	*0.497*	*0.984*	*0.385*	*0.028*	*0.900*	*0.009*	*0.064*	*0.809*	*0.591*	*0.014*	*0.722*	*0.127*

Table 2. Tomato biomass and extractable soil nutrients. Plant biomass accumulation was determined by harvest of four individual plants at separate locations throughout each plot. Plant tissue was then dried to remove water content. Soil samples were taken with a ¾ inch diameter probe inserted in the center of the plant bed, halfway between bed shoulders, and to a depth of 6 to 10 inches. Ten to twelve individual cores were taken throughout each plot and then combined. Differences among treatments are statistically significant at levels of "*0.050*" or less and are marked with lettering "a", "ab" or "b". Values that have letters in common are not significantly different.

P fertilizer rate	Plant biomass[z] (g)	Soil P (ppm)	Soil K (ppm)	Soil Mg (ppm)	Soil Ca (ppm)	Soil pHw	Soil pHg	Soil CEC
Before transplant								
Zero	--	137	4.8	47	803	7.2	8.0	4.8
Half	--	152	7.0	52	816	7.1	8.0	4.9
Full	--	137	5.5	43	761	7.1	8.0	4.6
Significance	--	*0.558*	*0.263*	*0.708*	*0.827*	*0.538*	--	*0.805*
60 days after transplant								
Zero	217	142 b	110	104	871	6.3 a	8.0	5.9
Half	209	171 ab	55	90	811	6.0 b	8.0	5.3
Full	206	197 a	114	121	805	5.9 b	8.0	5.7
Significance	*0.676*	*0.031*	*0.130*	*0.430*	*0.679*	*0.012*	--	*0.656*
150 days after transplant								
Zero	--	168	26	92	843	8.0	8.0	5.4
Half	--	141	26	89	844	8.1	7.9	5.6
Full	--	168	28	116	819	7.9	8.0	5.5
Significance	--	*0.175*	*0.940*	*0.558*	*0.952*	*0.801*	*0.444*	*0.976*

[z] Plant biomass sampled 75 days after transplant.

Table 3. Tomato leaf tissue elemental concentrations. Ten to fifteen leaves were removed at separate locations throughout each plot and then combined into one composite sample per plot. Youngest fully expanded leaves were selected and were generally the fifth unfurled leaf from the tip of a dominate shoot. Values are based on dry weight. Differences among treatments are statistically significant at levels of "*0.050*" or less and are marked with lettering "a", "ab" or "b". Values that have letters in common are not significantly different. For example, values labeled "a" are statistically similar to values labeled "ab" but are significantly different than values labeled "b". For further information, see Methodology section at the beginning of this document.

P fertilizer rate	N (%)	P [z] (%)	K (%)	Mg [y] (%)	Ca (%)	S [y] (%)	B (ppm)	Zn [y] (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
					30 days after transplant						
Zero	6.1 b	0.78 b	4.4	0.42 b	2.12	1.24 b	74	166	237	89	564
Half	6.5 a	0.88 ab	4.2	0.41 b	2.18	1.29 b	69	165	246	101	664
Full	6.0 b	0.94 a	4.5	0.49 a	2.22	1.39 a	73	179	252	91	642
Significance	*0.043*	*0.027*	*0.557*	*0.025*	*0.611*	*0.012*	*0.839*	*0.484*	*0.747*	*0.096*	*0.358*
					60 days after transplant						
Zero	5.2	0.70	5.5	0.47	2.10	2.43	89	114	242	109	657
Half	5.5	0.77	5.3	0.46	2.05	2.43	71	116	241	105	692
Full	5.4	0.80	5.3	0.49	2.15	1.17	96	103	253	106	729
Significance	*0.378*	*0.211*	*0.796*	*0.608*	*0.604*	*0.501*	*0.130*	*0.091*	*0.906*	*0.532*	*0.423*
					150 days after transplant						
Zero	3.4	0.44 b	3.3	0.51	1.77	0.33 b	79	36 b	134	79	357
Half	3.4	0.48 a	3.6	0.56	1.88	0.34 b	68	43 a	129	80	373
Full	3.1	0.51 a	3.5	0.61	2.07	0.43 a	82	45 a	142	78	449
Significance	*0.056*	*0.009*	*0.153*	*0.107*	*0.071*	*0.047*	*0.231*	*0.033*	*0.505*	*0.946*	*0.495*

[z] Values of 0.2% to 0.4% are considered adequate concentrations of P in leaf tissue of tomato from time of first flower (about 30 days after transplant) through harvest period (about 70 to 150 days after transplant).

[y] See discussion of leaf tissue concentration in Methodology section at beginning of document on page 10 concerning differences that are at times significant but not practical.

C-139 Basin Vegetable Production Demonstration Project
Annual summary report

Farm 2 - Eggplant
Winter 2005 to Spring 2006

C-139 Basin Vegetable Production Demonstration Project
Annual summary report

Farm 2 – Eggplant

Phosphorus (P) fertilization treatments were applied on Farm 2 at bedding by using preplant fertilizer mixes that contained 0%, 5%, or 10% P_2O_5. Nitrogen (N) and potassium (K) rates were the same for all P treatments. Treatments were defined by P fertilization:

(1) Zero rate – no soil-applied P, IFAS recommended rate
(2) Half rate – 50 lb/acre P_2O_5
(3) Full rate – 100 lb/acre P_2O_5, Grower rate

Two types of preplant fertilizer were used. The "bottom mix" was applied before bedding and was incorporated in the soil during the pre-bedding and bedding operation. Treatments were applied by adjusting the P content of the bottom mix as described above. The "top mix" was applied in grooves on the right and left shoulders of plant beds as they were formed. The top mix did not contain P. For this farm, it is not known how much, if any, starter solution may have been applied to the eggplant seedlings after transplant. It is also not known how much, if any, foliar-applied fertilizers were used on the crop during the growing season.

Eggplant seedlings were transplanted 5 Dec. 2005 to establish a winter-to-spring crop. The experimental design was a randomized complete block with three replications. Each plot was 7 rows wide and about 900 ft long. Two 10-plant subsample plots within each replication were harvested for yield determinations. Harvests were made by hand and fruit were sorted and weighed in the field. Harvest of all subsample areas were made about once a week beginning 10 Mar. 2006 and ending 1 June for a total of 14 harvests. Yield data was analyzed and tabulated by categories of early-, mid-, or late-season harvest. Commercial harvest of the field occurred randomly and little effort was made to synchronize with on-farm harvest operations. Soil was sampled at 0, 60, 120, and 180 days after transplant, leaf tissue was sampled 60 and 120 days after transplant, and plant biomass accumulation was determined 60, 120, and 180 days after transplant.

This was the only farm where netting was used over each 10-plant plot. The netting was installed that completely covered the plot and with a large enough mesh so as not to interfere with sprayer and pesticide operations. Netting was used in an attempt to prevent unplanned harvest of eggplant within each plot by farm workers. Harvesters worked these fields frequently and it was not possible to schedule plot harvests before commercial harvests as with the other farms. However, netting was not too effective in that it sometimes was dislodged by tractor operations and, possibly, the harvest crews themselves.

Results

P fertilization did not affect marketable yield of eggplant (Table 4). P fertilization caused a small reduction in unmarketable yield with the zero rate producing fewer unmarketable fruit (no/acre) for mid-season, late-season, and total harvests compared to the full rate. Despite the effect of P rate on number of unmarketable fruit, P rate did not affect weight of unmarketable fruit (lb/acre).

P fertilization did not affect plant biomass accumulation when determined 60, 120, or 180 days after transplant (Table 5).

Extractable soil P ranged from a low of 227 to a high of 275 ppm during the experiment. P fertilization did not affect extractable soil P (Table 5). Though not statistically significant, extractable soil P of the zero rate was always numerically lower than the two other rates. P fertilization did not affect extractable amounts of other plant nutrients. K values ranged from a low of 67 ppm to a high of 175 ppm. K was lowest before transplant, highest 60 days after transplant, and low again at 180 days after transplant. Mg was not affected by treatment, though there were significant differences among treatments before the trial was installed. Values ranged from a low of 90 ppm to a high of 176 ppm with values increasing steadily throughout the duration of the study. Ca was not affected by treatment. Values ranged from a low of 2310 ppm to a high of 2680 ppm. Values for pH_w ranged from a low of 6.6 to a high of 7.5, with differences among treatments significant only at 120 days after transplant. Differences among treatments at this time were small. Values for pH_g ranged from 7.8 to 8.0. CEC was not affected by treatment. Values ranged from a low of 13.2 to a high of 15.9. Despite variability in values of soil K, Mg, Ca, pH_w, pH_g and CEC before transplant, during crop production, and after harvest, these values appeared unaffected by P fertilization and variability among these values was not great enough to affect plant growth or productivity.

P fertilization did not greatly affect leaf tissue elemental concentration (Table 6). Percent N, P, or K concentration of leaf tissue was not affected by treatment 60 or 120 days after transplant. Of the micronutrients, only Fe was significantly different at 60 days, but not at 120 days, and the trend was not consistent with rate of P application. As discussed in the Methodology section at the beginning of this document, the differences in Fe concentration at 60 days were significant but so small as to be of no practical influence on plant growth or productivity. Analyses of tissue collected 180 days after transplant was not yet available at the time of writing this report.

Conclusions

Extractable soil P tended to be higher with higher P rates, but soil and tissue P concentration were, overall, rather unresponsive to the rate of P applications used in this study. This may be a result of high levels of P in the soil. Increasing rates of P fertilization did not affect yield components of eggplant except in the unmarketable category. The full rate exhibited greater numbers of defective fruit than the zero rate. Fruit were considered unmarketable most often for being small and with a somewhat undesirable color. Fruit were also considered unmarketable sometimes for being misshapen or having scars. Misshapen fruit often had undesirable growths or projections. It is not known how higher rates of P fertilization may have increased incidences of these defects. The evidence is rather weak that P fertilization affected the unmarketable yield category because despite increased numbers of unmarketable fruit at the full rate, marketable yields were not affected by P fertilization at any time—for early-, mid-, late- or total-season harvest totals. In addition, while the number of unmarketable fruit was significantly affected by P fertilization the weight of unmarketable fruit was not. Finally, the effect was not always consistent, with the half rate sometimes significantly greater than the zero rate and sometimes the full rate significantly greater. Again, how this can be due to P fertilization is not known.

This report represents research supported by a grant from the South Florida Water Management District. Information contained in this report has not been subjected to scientific peer review, nor has it yet been incorporated into IFAS recommendations.

Table 4. Eggplant yields. Yield of 33-lb boxes per acre determined by harvest of two 10-plant subsample areas within each plot. Harvests were made about once per week from 10 Mar. to 1 June 2006. Differences among treatments are statistically significant at levels of "*0.050*" or less and are marked with lettering "a", "ab" or "b". Values that have letters in common are not significantly different.

P fertilizer rate	Marketable			Unmarketable	
	(no/ac)	(33-lb boxes/ac)	(lb/fruit)	(no/ac)	(33-lb boxes/ac)
		----------------- *Early yield* -----------------			
Zero	2060	97	1.55	726	33
Half	2780	138	1.67	968	37
Full	2180	108	1.61	847	41
Significance	*0.462*	*0.421*	*0.367*	*0.444*	*0.812*
		----------------- *Mid yield* -----------------			
Zero	26,900	1,180	1.45	730 b	34
Half	28,300	1,250	1.46	1,750 a	65
Full	28,400	1,260	1.46	1,210 ab	48
Significance	*0.736*	*0.568*	*0.871*	*0.046*	*0.165*
		----------------- *Late yield* -----------------			
Zero	19,800	744	1.25	3,330 b	104
Half	20,200	762	1.22	3,750 b	118
Full	18,500	716	1.28	4,600 a	140
Significance	*0.843*	*0.882*	*0.457*	*0.009*	*0.107*
		----------------- *Total marketable yield* -----------------			
Zero	48,800	2,020	1.37	4,780 b	171
Half	51,200	2,150	1.37	6,470 a	221
Full	49,100	2,090	1.40	6,660 a	229
Significance	*0.620*	*0.479*	*0.216*	*0.009*	*0.071*

Table 5. Eggplant biomass and extractable soil nutrients. Plant biomass accumulation was determined by harvest of two to four individual plants at separate locations throughout each plot. Plant tissue was then dried to remove water content. Soil samples were taken with a ¾ inch diameter probe inserted in the center of the plant bed, halfway between bed shoulders, and to a depth of 6 to 10 inches. Ten to twelve individual cores were taken throughout each plot and then combined. Differences among treatments are statistically significant at levels of "*0.050*" or less and are marked with lettering "a" or "b". Values with different letters are significantly different. (See biomass discussion in Methodology section at beginning of document.)

P fertilizer rate	Plant biomass (g)	Soil P (ppm)	Soil K (ppm)	Soil Mg (ppm)	Soil Ca (ppm)	Soil pHw	Soil pHg	Soil CEC
				Before transplant				
Zero	--	250	112	113 a	2560	7.0	8.0	14.4
Half	--	272	97	102 b	2630	7.0	8.0	14.6
Full	--	255	80	90 c	2360	7.0	8.0	13.2
Significance	--	*0.592*	*0.198*	*<.001*	*0.234*	*0.790*	--	*0.180*
				60 days after transplant				
Zero	32.6	227	132	124	2310	6.8	7.9	14.1
Half	34.3	275	168	117	2360	6.9	7.9	14.4
Full	30.3	254	175	140	2410	6.6	7.8	15.2
Significance	*0.477*	*0.213*	*0.374*	*0.627*	*0.826*	*0.105*	*0.111*	*0.582*
				120 days after transplant				
Zero	333	233	119	137	2380	7.3 a	7.9	14.1
Half	324	243	120	144	2430	7.3 a	7.9	14.3
Full	330	260	89	135	2400	7.1 b	7.9	14.4
Significance	*0.829*	*0.509*	*0.763*	*0.967*	*0.972*	*0.042*	*0.284*	*0.981*
				180 days after transplant				
Zero	441	244	93	176	2650	7.5	7.9	15.9
Half	553	267	88	160	2680	7.5	7.9	15.9
Full	527	255	67	151	2570	7.5	7.9	15.1
Significance	*0.282*	*0.212*	*0.682*	*0.164*	*0.583*	*0.871*	*0.694*	*0.536*

Table 6. Eggplant leaf tissue elemental concentration. Ten to fifteen leaves were removed at separate locations throughout each plot and then combined into one composite sample per plot. Youngest fully expanded leaves were selected and were generally the fifth unfurled leaf from the tip of a dominate shoot. Values are based on dry weight. Differences are statistically significant at levels of "*0.050*" or less and are marked with lettering "a", "ab" or "b". Values that have letters in common are not significantly different.

P fertilizer rate	N (%)	P [z] (%)	K (%)	Mg (%)	Ca (%)	S (%)	B (ppm)	Zn (ppm)	Mn (ppm)	Fe [y] (ppm)	Cu (ppm)
					---------------- 60 days after transplant ----------------						
Zero	5.89	0.58	5.13	0.44	2.17	0.45	41	44	181	75 b	295
Half	6.14	0.65	5.17	0.42	2.19	0.48	50	46	247	81 a	451
Full	6.11	0.65	5.14	0.39	2.01	0.45	51	44	209	78 ab	334
Significance	*0.068*	*0.276*	*0.873*	*0.120*	*0.519*	*0.180*	*0.301*	*0.808*	*0.352*	*0.023*	*0.422*
					---------------- 120 days after transplant ----------------						
Zero	4.36	0.32	4.11	0.61	3.95	0.33	52	34	158	66	43
Half	4.66	0.30	4.02	0.60	4.19	0.36	56	32	208	69	45
Full	4.58	0.29	4.28	0.55	4.05	0.35	69	31	213	70	48
Significance	*0.083*	*0.496*	*0.365*	*0.075*	*0.378*	*0.174*	*0.072*	*0.053*	*0.106*	*0.489*	*0.835*

[z] Values of 0.3% to 0.6% are considered adequate concentrations of P in leaf tissue of eggplant at the time of early fruit set (about 60 days after transplant).

[y] See discussion of leaf tissue concentration in Methodology section at beginning of document on page 10 concerning differences that are at times significant but not practical.

C-139 Basin Vegetable Production Demonstration Project
Annual summary report

Farm 3a -Tomatoes
Winter 2005 to Spring 2006

C-139 Basin Vegetable Production Demonstration Project
Annual summary report

Farm 3a -Tomatoes

"Farm 3a" produced large round tomatoes for the gas-green market. Vegetable beds were installed on Farm 3a on 4 Jan. 2006. Phosphorus (P) fertilization treatments were applied immediately before bedding by using preplant fertilizer mixes that contained 0%, 5%, or 10% P_2O_5. Nitrogen (N) and potassium (K) rates were the same for all P treatments. Treatments were defined by P fertilization:

(1) Zero rate – no soil-applied P, IFAS recommended rate
(2) Half rate – 50 lb/acre P_2O_5
(3) Full rate – 100 lb/acre P_2O_5, Grower rate

As with Farm 1 (tomato) two types of preplant fertilizer were used. The "bottom mix" was applied before bedding and was incorporated in the soil during the pre-bedding and bedding operation. Treatments were applied by adjusting the P content of the bottom mix as described above. The "top mix" was applied in grooves on the right and left shoulders of plant beds as they were formed. The top mix did not contain P. It is not known how much, if any, starter solution may have been applied to the tomato seedlings after transplant. It is also not known how much, if any, foliar-applied fertilizers were used on the crop during the growing season.

Tomato transplants were planted 6 Feb. 2006 to establish a winter-to-spring crop. There was no experimental design because treatments were replicated only once. Each plot was 12 rows wide (a "land" of two sets of six rows with a drive row between) and about 500 ft long. Four 10-plant subsample plots within each replication were harvested for yield determinations. Harvests were made by hand and fruit were sorted and weighed in the field. Harvest of all subsample areas was made one, two, or three days before commercial harvest of the field on 3 and 12 May 2006. Soil was sampled at 0, 60, and 120 days after transplant, leaf tissue was sampled 60 and 120 days after transplant, and plant biomass was sampled 60 and 120 days after transplant.

Results

P fertilization appeared to have only minor effects on marketable yield, average fruit weight, and unmarketable yield of tomato (Table 7). As mentioned in the introduction, unmarketable tomatoes were considered undesirable due to blemish, poor color or shape, or damage. The full rate appeared to increase yield of 5x6s (extra large) at first harvest by 10% compared to the zero rate. The full rate also appeared to increase fruit size of 5x6s at first harvest by 5% compared to the zero rate. Yields of the first harvest were much greater than the yields of second harvest regardless of P fertilization. In comparison to Farm 1, yields of the first harvest were much greater and of the second harvest much lower than that recorded at Farm 1. Total yields were similar. Fruit size averaged across all harvests and for other size categories appeared unaffected by P rate. Total yield, with all sizes and harvests combined, appeared unaffected by P rate, though fruit weight was higher at the full rate compared to the zero P rate. It is not possible to determine whether these apparent differences were statistically significant.

P fertilization appeared to effect plant biomass accumulation 60 and 120 days after transplant (Table 8). At each date, plant biomass was lowest with zero P rate and highest with full rate.

Extractable soil P ranged from a low of 140 to a high of 180 ppm during the experiment (Table 8). P fertilization did not affect extractable soil P. Extractable soil K ranged from a low of 9 ppm to a high of 66 ppm. K was low before transplant, high 60 days after transplant, and low again at 120 days after transplant. Mg ranged from a low of 89 ppm to a high of 179 ppm. Mg was lowest before transplant. Ca ranged from a low of 890 ppm to a high of 1290 ppm. Values for pH_w increased from a low of 7.2 before transplant to a high of 8.2 at 120 days after transplant. Values for pH_g were 7.9 or 8.0. CEC ranged from a low of 5.6 before transplant to a high of 8.4 at 120 days after transplant. Despite variability in values of soil K, Mg, Ca, pH_w, pH_g and CEC before transplant, during crop production, and after harvest, these values appeared unaffected by P fertilization and the variability was not great enough to affect plant growth or productivity.

P fertilization did not greatly affect leaf tissue elemental concentration (Table 9). Percent N, P, or K concentration of leaf tissue appeared little affected by treatment 60 or 120 days after transplant. Of the micronutrients, only B was lower for the full rate compared to the zero or half rates 60 and 120 days after transplant.

Conclusions

Extractable soil P was unresponsive to P rate, but there were small increases in leaf tissue P concentration and plant biomass with increasing P rate. There were no large or obvious affects of P rates on yield components of tomato, extractable soil nutrients, or tissue elemental concentrations, but increasing P fertilization appeared to increase yield of 5x6s at first harvest. However, this difference did not cause a significant increase in total yield in comparison to the no P rate.

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Table 7. Tomato yields. Yields of 25-lb boxes per acre determined by harvest of four 10-plant subsample areas within each treatment. Harvests were made 3 and 12 May 2006. Treatments were replicated once and as a result statistical comparisons were not possible. Size categories are 5x6 (extra large), 6x6 (large), 6x7 (medium). Yields are reported in units of 25-lb boxes/acre. Cull fruit were defective and considered unmarketable.

P fertilizer rate	5x6 Marketable Yield (boxes/ac)	5x6 Avg Wt (oz/fruit)	5x6 Unmarketable yield (boxes/ac)	6x6 Marketable Yield (boxes/ac)	6x6 Avg Wt (oz/fruit)	6x6 Unmarketable yield (boxes/ac)	6x7 Marketable Yield (boxes/ac)	6x7 Avg Wt (oz/fruit)	6x7 Unmarketable yield (boxes/ac)	Total marketable Marketable Yield (boxes/ac)	Total marketable Avg Wt (oz/fruit)	Total marketable Unmarketable yield (boxes/ac)
First harvest												
Zero	1890	8.3	60	277	5.8	16	74	4.7	3	2241	7.7	79
Half	1954	8.5	102	197	5.6	16	49	4.5	6	2200	8.0	124
Full	2092	8.7	54	207	5.6	12	60	4.6	2	2358	8.1	68
Second harvest												
Zero	336	7.1	18	176	5.2	5	162	4.4	8	674	5.7	30
Half	464	7.0	22	282	5.3	5	157	4.4	4	903	5.8	32
Full	277	7.1	32	180	5.2	4	130	4.2	12	587	5.6	48
Total marketable												
Zero	2226	8.1	78	453	5.5	21	236	4.5	11	2915	7.1	110
Half	2418	8.2	124	479	5.4	22	207	4.4	10	3103	7.2	155
Full	2368	8.5	86	386	5.4	16	191	4.3	14	2945	7.5	115

Table 8. Tomato biomass and extractable soil nutrients. Plant biomass accumulation was determined by harvesting four individual plants at separate locations throughout each plot. Plant tissue was then dried to remove water content. Soil samples taken with a ¾ inch diameter probe inserted in the center of the plant bed, halfway between bed shoulders, and to a depth of 6 to 10 inches. Ten to fifteen individual cores were taken throughout each plot and then combined. Treatments were replicated once and as a result statistical comparisons were not possible.

P fertilizer rate	Plant biomass (g)	Soil P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	pHw	pHg	CEC
				Before transplant				
Zero	--	140	18	89	890	7.3	8.0	5.6
Half	--	180	22	140	1170	7.2	8.0	7.5
Full	--	149	18	123	1080	7.3	8.0	6.8
				60 days after transplant				
Zero	269	180	51	151	1140	7.5	8.0	7.5
Half	307	174	64	168	1210	7.6	8.0	8.0
Full	329	175	66	166	1160	7.6	7.9	8.1
				120 days after transplant				
Zero	405	161	12	136	1140	8.2	8.0	7.3
Half	448	172	9	163	1210	8.2	8.0	7.8
Full	457	173	9	179	1290	8.1	8.0	8.4

Table 9. Tomato leaf tissue elemental concentration. Ten to fifteen leaves were removed at separate locations throughout each plot and then combined into one composite sample per plot. Youngest fully expanded leaves were selected and were generally located about the fifth unfurled leaf from the tip of the dominate shoot. Values are based on dry weight. Treatments were replicated once and as a result statistical comparisons were not possible.

P fertilizer rate	N (%)	P (%)	K (%)	Mg (%)	Ca (%)	S (%)	B (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
					----------------- *60 days after transplant* -----------------						
Zero	4.25	0.51	4.72	0.73	2.85	1.18	82	88	119	79	629
Half	4.52	0.52	4.81	0.72	2.82	1.22	86	97	122	74	677
Full	4.59	0.54	5.25	0.79	2.86	1.29	49	112	125	81	756
					----------------- *120 days after transplant* -----------------						
Zero	3.14	0.29	2.29	1.13	4.06	0.95	130	65	162	83	493
Half	3.25	0.33	2.37	1.16	3.91	1.05	140	65	178	77	462
Full	3.34	0.31	2.39	1.20	4.07	1.05	89	77	169	80	514

C-139 Basin Vegetable Production Demonstration Project
Annual summary report

Farm 3b – Green Beans
Winter 2005 to Spring 2006

C-139 Basin Vegetable Production Demonstration Project
Annual summary report

Farm 3b – Green Beans

Farm 3b produced green beans for the produce market. Vegetable beds were installed on Farm 3b on 3 Feb. 2006. Farm 3b used two phosphorus (P) fertilizer treatments installed at planting by using preplant fertilizer mixes that contained 0% or 6% P_2O_5. Nitrogen (N) and potassium (K) rates were the same for all P treatments.

Treatments were defined by P fertilization:

(1) Zero rate – no soil-applied phosphorus fertilization, IFAS recommended rate & Grower rate
(2) Full rate – 39 lb/acre P_2O_5

No preplant fertilizer was used on this farm. Plant beds were formed, the crop direct seeded, and granular fertilizer applied in grooves alongside each seeded row. Treatments were applied by adjusting the P content of the granule mix as described above. On "Farm 3b", the soil tested "very high" in extractable P. However, the typical farm practice at this site was to apply 39 lb/acre P_2O_5. It is a common practice at this farm to determine rate of P fertilization based on soil test results. At the demonstration site it was decided by the grower to apply 39 lb/acre P_2O_5 based on recent soil test results. It was decided by the project leader to install only two treatments because an intermediate rate, at 19.5 lb/acre P_2O_5, was too small a difference compared to the zero and full rates. It was assumed that significant differences would not be detected with such small differences among rates.

Green beans were direct seeded on 3 Feb. 2006 to establish a winter-to-spring crop. The experimental design was a randomized complete block with two replications. Each experimental unit (plot) was about an acre. Beans were planted on raised beds with two rows per bed. Four 5-ft subsample plots within each replication were harvested for biomass determinations 30 days after planting and again for yield and biomass determinations 60 days after planting. Harvest was made by hand on 7 Apr. 2006. Plants were cut at ground level and bagged. In the laboratory, beans were removed from plants by hand, sorted and weighed, and plant material dried to determine biomass. Harvest was made one day before commercial harvest of the field. Soil was sampled at 0, 30, and 60 days after planting, and bean leaf tissue was sampled at 30 and 60 days after planting.

Results

Except for the 3-4 inch size category, P fertilization did not affect marketable yields of green beans (Table 10). For the 3-4 inch size category, the full rate of P fertilizer produced more marketable yield than the zero rate. The 3-4 inch size category contributed only 6% to 7% of the total marketable yield. Even though statistically significant this yield category represented only a small portion of total marketable yield. P fertilization did not affect unmarketable yield.

Marketable beans must be straight and unblemished, and beans were considered unmarketable because they were curved or blemished.

P fertilization did not affect plant stand (Table 11). Plant stand was about 72,000 plants/acre at 30 days after planting and about 63,000 plants/acre at 60 days after planting. Decreases in plant population may have been caused by small, weak plants being shaded and smothered by larger and more aggressive plants in the row. P fertilization did not significantly affect biomass accumulation when determined 30 or 60 days after planting, though biomass was numerically increased 29.3% and 20.7% at 30 and 60 days after planting, respectively (Table 11).

Extractable soil P ranged from a low of 67 ppm at the beginning of the study to values of 83 to 86 ppm during the study (Table 12). Only minor differences in extractable soil P were evident between the two treatments at 30 and 60 days after planting. Soil K ranged from a low of 42 ppm before planting to a high of 81 ppm 30 days after planting and back down to 36 to 48 ppm at harvest. Soil Mg ranged from a low of 80 ppm to a high of 113 ppm and appeared to increase slightly throughout the duration of the study. Soil Ca ranged from a low of 1270 ppm to a high of 2220 ppm. Values for pH_w ranged from a low of 7.4 to a high of 7.9. Values for pH_g did not change from 7.9. CEC ranged from a low of 7.8 before planting to values of 11.5 to 13.0 during the study. Despite variability in values of soil K, Mg, Ca, pH_w, pH_g and CEC before seeding, during crop production, and after harvest, these values appeared unaffected by P fertilization and the variability was not great enough to affect plant growth or productivity.

P fertilization did not greatly affect leaf tissue elemental concentration (Table 13). Percent N, P, or K concentration of leaf tissue was not affected by treatment 30 or 60 days after planting. Of the micronutrients, only Mn was significantly affected at 30 days but not at 60 days. Though not statistically significant, almost all values of macro (N, P, K, Mg, Ca, S) and micronutrients (B, Zn, Mn, Fe, and Cu) were higher for the full rate of P compared to the zero rate.

Conclusions

Trends in the data suggest that the full rate of P fertilization produced higher yields and better plant performance than the zero rate; however, most of these differences were not large enough to be statistically significant. Of most interest was the soil and tissue values that showed no differences, or very small differences, in P concentration between the full and zero rates. This indicates that the full rate of P fertilization probably contributed only a minor fraction of plant available P over and above what was already available in the soil. In previous research with green bean, experimental plots receiving no P fertilization showed no negative effects until the sixth year of the study when extractable P were reduced to values of 30 ppm, a level intermediate between “medium” and “high” (Gene McAvoy, oral presentation, Immokalee, FL, 20 Sep 2006). The extractable soil P for Farm 3b ranged from 67 to 86 ppm, values that were above the 30 ppm value found to affect yields in the previous study.

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Table 10. Green bean yields. Yield of 30-lb boxes per acre determined by harvest of four 5-ft subsample areas within each plot. There were two rows per bed. Harvest was made once on 7 Apr. 2006. Differences are statistically significant at levels of "*0.050*" or less and are marked with lettering "a" or "b". Values with different letters are significantly different.

P fertilizer rate	Beans 4-6"	Beans 3-4"	Beans <3"	Total marketable	Unmark-etable
		---------------- (30-lb boxes/ac) ----------------			
		---------------- *60 days after planting* ----------------			
Zero	303	25 b	11	336	16
Full	312	22 a	12	349	15
Significance	*0.135*	*0.039*	*0.633*	*0.163*	*0.276*

Table 11. Green bean plant stand and biomass. Plant biomass accumulation determined 30 and 60 days after planting. Plant biomass reported in units of grams of dry weight per 30 ft^2. Differences between treatments are statistically significant at levels of "*0.050*" or less.

P fertilizer rate	Plant stand (no/acre)	Plant biomass (g)
	-- *30 days after planting* --	
Zero	72,200	58
Full	71,700	75
Significance	*0.500*	*0.164*
	-- *60 days after planting* --	
Zero	63,000	474
Full	62,400	572
Significance	*0.742*	*0.222*

Table 12. Extractable soil nutrients. Soil samples taken with a ¾ inch diameter soil probe inserted in the center of the row, in line with plants, and to a depth of 6 to 10 inches. Ten to fifteen individual cores were taken throughout each plot and then combined.

P fertilizer rate	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	pHw	pHg	CEC
			Before planting				
Average	67	42	80	1270	7.6	7.9	7.8
			30 days after planting				
Zero	83	81	109	2220	7.4	7.9	13.0
Full	86	81	97	1970	7.4	7.9	11.5
			60 days after planting				
Zero	84	36	113	2200	7.9	7.9	12.7
Full	86	48	106	2050	7.8	7.9	11.9

Table 13. Green bean leaf tissue elemental concentration. Ten to fifteen leaves were removed at separate locations throughout each plot and then combined into one composite sample per plot. Youngest fully expanded leaves were sampled for analysis. Values are based on dry weight. Differences are statistically significant at levels of "*0.050*" or less and are marked with lettering "a" or "b". Values with different letters are significantly different.

P fertilizer rate	N (%)	P (%)	K (%)	Mg (%)	Ca (%)	S (%)	B (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)
						30 days after planting					
Zero	4.11	0.30	3.45	0.35	2.31	0.27	30	24	**62 a**	73	6.0
Full	4.65	0.37	4.07	0.46	2.58	0.31	62	26	**176 b**	75	6.5
Significance	*0.187*	*0.126*	*0.126*	*0.058*	*0.374*	*0.156*	*0.060*	*0.500*	*0.050*	*0.295*	*0.500*
						60 days after planting					
Zero	2.90	0.27	1.77	0.37	1.75	0.17	29	21	83	73	5.0
Full	3.02	0.29	1.94	0.38	1.71	0.20	48	22	82	81	6.5
Significance	*0.742*	*0.626*	*0.567*	--	*0.570*	*0.374*	*0.113*	*0.795*	*0.958*	*0.500*	*0.500*

Overall conclusions

In conclusion, extractable soil P was “very high” (60 ppm or greater) for each farm and each planting. With relatively high levels of P in the soil, it was difficult to detect differences due to P fertilization regardless of the type of measurement recorded: yield, biomass accumulation, leaf tissue P concentration, or extractable soil P. Differences may be more easily detected in future plantings as long as areas receiving the zero rate continue to receive no P fertilizer. The assumption is that P will be slowly depleted in these areas and differences between the zero rate and the high rate will become more obvious. When differences in plant productivity become more obvious, it may be necessary to begin adding P fertilizer at a rate that sustains productivity at an acceptable level.