Preliminary Data on Phosporus Soil Test Index Validation in Southwest Florida

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The soils of the C-139 Basin were found to have higher pH and very high Ca concentrations compared with similar soils in other Florida locations. These conditions result in precipitation of fertilizer P, rendering it unavailable for crop uptake. Soil test results indicated that the soil samples at the beginning of each season of a three-year field demonstration project were high or very high in extractable soil P using Mehlich 1 extractant and would indicate that no additional fertilizer P should be required for optimum crop production. Green bean (*Phaseolus vulgaris* L.) biomass significantly increased with increased fertilizer P rate in five of the nine crops grown during the demonstration project. Likewise, green bean yield data of large pod size increased with increased fertilizer P application in seven out of nine crops grown. Tomato (*Solanum lycopersicum* L.) biomass and yield was less affected by fertilizer P applications compared with green bean. No tomato biomass increase with increasing fertilizer P rate was observed over the 3 years. However, delay in tomato fruit maturity with reduced fertilizer P application was suggested by an increase in large fruit production at the first harvest and an increase in large fruit production at the third harvest.

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 P loading (SFWMD, 2006). 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. With the exception of 2008, the basin has been unable to meet historic P levels since the program's inception (William Donovan, personal communications). Rainfall in the basin in 2008 was below normal (41.9 inches, Florida Automated Weather Network, Immokalee station) and may have lead to the basin being in compliance. C-139 Basin agriculture has historically consisted of pasture, sugarcane and citrus. However, vegetable production has been increasing and dominates agricultural production in the basin (Cushman, 2005. On-farm projects intended to demonstrate optimum P fertilizer rates for vegetable producers that have been identified as an opportunity for implementation of cost effective BMPs.

Plants acquire P in the form of dihydrogen phosphate ion $H_2PO_4^-$ by root uptake from the soil (Bieleski, 1973). Soils may contain low to very high concentration of P in an insoluble and immobile form (Agyin-Birikorang et al., 2004, 2008; Rhue and Everett, 1987). 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. Soil testing provides 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. The majority of agricultural soils in Florida are classified as acid sands (Graetz and Nair, 1995; Zhang et al., 2002). Mehlich-1 has been determined to be the extractant that provides solution with the most representative amounts of plant nutrient from these acid sandy soils and is thus the procedure widely used for the sandy soils (Gartley and Sims, 1994). However, this procedure may not be the most accurate at a pH of 7.3 or greater (Mehlich, 1953).

The use of soil testing results as an index of P availability for Florida vegetable production has existed for more than 20 years (Hochmuth and Hanlon, 1995; Hochmuth et al., 1999). A soil test allows grower to accurately predict soil P availability and adjust P fertilizer rates accordingly. For selected plant nutrients, the University of Florida–Institute of Food and Agricultural Sciences (UF–IFAS) has developed ranges of soil nutrient concentrations corresponding to indices of very low, low, medium, high, and very high (Table 1). The ranges of nutrient concentrations has been determined for each of the five indices based on growth and yield response to a wide range of nutrient fertilizer applica-

Table 1. Soil sample analysis index using Mehlich 1 extractant.[z]

Nutrient	Very low	Low	Medium	High	Very high
			Parts per million soil		
P	<10	10–15	16–30	31–60	>60
K	<20	20–35	36–60	61–125	>125
Mg	<10	10–20	21–40	41–60	>60
Ca	<100	100–200	201–300	301–400	>400
			Fertilizer P recommendation (lb/acre)		
All vegetable crops	150	120	100	0	0

[z]Olson, S.M. and E. Simonne. 2007. Vegetable production handbook for Florida 2006–07. University of Florida, IFAS.

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tion in a large number of field studies. Typically, in soils with an index of very low to medium soil P concentrations, crop growth or yield increases with increased nutrient application to a point where the crop growth response curve flattens and no significant increase in growth or yield should be discernable with increased P application.

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. The goals of the 3-year demonstration project were to: 1) demonstrate soil test-based P fertilization application rate recommendations for commercial vegetables crops grown in the C-139 Basin; 2) transfer soil test results and methodology to develop optimized P fertilization rates to vegetable farm managers; and 3) disseminate results of demonstration trials in the C-139 Basin to the region's growers.

Materials and Methods

Locations. There were four demonstration plantings installed in commercial vegetable production fields during each of the spring and fall growing seasons over the period Spring 2005 to Spring 2008 for a total of five growing seasons (Table 2). The original project proposal called for an initial fall season in 2005 for a total of six seasons. However, Hurricane Wilma devastated the south Florida vegetable industry in Oct. 2005 and the project time table was adjusted to begin with the spring season of 2006. Five growers in the C-139 basin volunteered to participate in the demonstration project with the same field blocks being used at each of the four sites throughout the project. Although data were collected on all crops indicated in Table 2, only data from the 10 green bean and seven tomato crops are presented in this paper.

Crops grown for this demonstration project were green beans (*Phaseolus vulgaris* L.) and tomato (*Solanum lycopersicum* L.). Production practices for these crops were site specific, that is, every grower has their own method and procedure for establishing their crop and obtaining high yields of high quality produce.

Farm 1. The experimental design was a randomized complete block (RCB) with three replications of all three P rates. Each plot was six rows wide and 500 to 700 ft long, or approximately 0.4 to 0.6 acres depending on field location.

Farm 2. A wide variety of specialty vegetables for the fresh market were produced with a randomized complete block experimental design with three replications of each P rate. Each plot was 14 rows wide and about 900 ft long and covered about 0.88 acres.

Table 2. Crops grown in research plots at five cooperator sites: Spring 2006 to Spring 2008.

	2006		2007		2008
Farms	Spring	Fall	Spring	Fall	Spring
1	Tomato	Tomato		Tomato	Tomato
2		Green beans		Green beans	
3a	Tomato	Green beans	Tomato	Green beans	Green beans
3b	Green beans	Green beans	Green beans	Green beans	Green beans
4			Tomato		

Farms 3a and 3b. Green beans were produced during the fall growing season of each year at this location. Farm 3a typically (exception was Spring 2008) followed beans with tomatoes in the spring. Whereas, green beans were planted at Farm 3b in both the fall and spring seasons of all 3 years. The experimental design differed on the two farms, and the design at Farm 3a differed between years 1 and 2. Initially (year 1) each plot at Farm 3a were 12 rows and about 400 ft long covering about 0.68 acres each. In year two the plots at Farm 3a were split in half to increase the number of replications of each treatment resulting in six 6-row plots. Plots at Farm 3b had 12 rows about 600 ft long each covering about one acre were replicated twice for a total of 4 plots. There were only two fertilizer P treatments used for the green beans crops at both Farms 3a and 3b because the farm rate of P fertilization on beans was lower than other participating growers.

Farm 4. Tomatoes for the fresh market were grown at this location and grew only one crop per year at this site. This site was used only in the second year of the demonstration project because no crops were grown in the Spring 2008 season. The experimental design was randomized complete block with three replications of each of the three fertilizer P rates. Each plot was six rows wide and about 300 to 400 ft long covering 0.21 to 0.28 acres each depending on location.

Fertilizer P rates. Rates of P fertilization were determined for each farm in the following manner. A soil analysis was completed to determine Mehlich 1 extractable P and the recommended fertilizer rate. For example, if the soil from "Farm A" tested "very high" in extractable P, then the recommendation was to apply no P. The typical farm practice or "grower rate" was determined. For example if the typical practice was to apply 43.0 lb P per acre at "Farm A" then 43.0 lb/acre was the grower or full fertilizer P rate. It was not known whether a difference of 43.0 lb P per acre between the zero and full farm rate would result in small or large effects on plant growth and crop productivity. Therefore, the intermediate rate, 21.5 lb P per acre, was included in the study. Thus, for farms with three P fertilization rates, a zero lb P per acre, an intermediate or half rate, and "grower rate" or full rate were applied. At one farm only two rates could be used with zero and the full rates being selected.

Fertilizer P rates (Table 3) were applied to the various crops used in this project in two different ways. All fertilizers were applied prior to planting. Green beans were fertilized with dry granular fertilizer mixed into the bed prior to direct seeding with the exception of Farm 2. At Farm 2, liquid fertilizer was injected under the soil surface at the same time that the seeds were planted into the bed. Fertilizer P amounts in each single application fertilizer were adjusted to provide the appropriate amount of P to each plot. Tomato, peppers and eggplant crops received two types of pre-plant fertilizer. 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. 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 any fertilizer P. All other fertilizer nutrients were consistent for all plots and determined by the growers.

Extractable soil nutrient, biomass, and yield measurement. Soil tests using Mehlich 1 extractant were used to measure extractable plant nutrients however, only P was evaluated in this paper. Although recommended soil pH for vegetables production is about 6.0 to 6.5, the pH of many soils in the C-139 basin was greater than 7.0. Soil samples were collected at two depths (0–6

Table 3. Fertilizer P rate by participating farm in the C-139 soil test P fertilizer rate demonstration project by at eachowing season from Spring 2006 to Spring 2008.

Farms	2006		2007		2008
	Spring	Fall	Spring	Fall	Spring
	Fertilizer P rate[z] *(lb/acre)*				
Farm 1					
Zero rate	0	0		0	0
Half rate	41.5	36.1		34.4	34.4
Full rate	43.0	72.3		68.8	68.8
Farm 2					
Zero rate		0		0	
Half rate		20.7		13.0	
Full rate		41.5		25.9	
Farm 3a[y]					
Zero rate	0	0	0	0	0
Half rate	41.5	---	21.5	---	---
Full rate	43.0	17.0	43.0	21.5	21.5
Farm 3b					
Zero rate	0	0	0	0	0
Full rate	17.0	17.0	17.0	21.5	21.5
Farm 4					
Zero rate			0		
Half rate			24.1		
Full rate			48.2		

[z]Fertilizer rate pounds P per acre, rates varied from season to season with crop grown and production practices of the grower/cooperator. The grower at Farm 1 chose to increase his P application rate from 100 lb/acre to 160 lb/acre not because of soil test results but because the grower perceived that the lower rate resulted in a decrease in yield and fruit quality compared with previous crops. P rates for green bean at Farms 3a and 3b were allowed to increase in Fall 2007 and Spring 2008 because these rates were within recommendation rate (60 lb/acre) using the current medium soil test index.

[y]Tomato crops at farm 3a had three P rates: green bean crops had only two P rates.

inches and 6–12 inches) from the center of the row, in line with plants, at 10 locations per plot prior to planting and at 30-d increments during crop growth using a ¾ inch soil auger. The 10 to 15 sub-samples per plot were then combined into one sample.

Biomass, or dry weight accumulation was used as a measure of plant performance. The aboveground plant biomass was measured by cutting plant stems at the soil surface and weighing the dry plant material. When conditions are less than optimum, that is, when stressed in any way, biomass accumulation normally suffers. Biomass was determined at the same 30-d intervals used for soil sample collection.

Green bean. The growers 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 were harvested when the beans that develop first on the plant were the correct size. This ensuredthat most of the rest of the beans on the plant werealso ready to harvest. Marketable beans were mostly 4 to 6 inches long and straight or almost straight.

Tomato. The tomato crops in these studies were of the "large round" red type and grown for the "gas-green" market. Gas-green means the tomatoes were picked at the mature green stage and then sorted by size and quality in packing sheds. At the sheds, tomatoes were 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 were shipped by truck to distant markets. The traditional USDA size categories are medium, large, and extra large. These correspond to industry size categories of 6 × 7, 6 × 6, and 5 × 6. The terms "6 × 7", "6 × 6", and "5 × 6" 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 lb of tomatoes regardless of size category.

Statistical analysis. Agricultural experiments are often designed in such a way that data can be statistically analyzed. In most of the demonstration plantings reported here, the experimental design used was a randomized complete block, also known as a "RCB design." Statistical analysis using RCB could not be done on data the first year from Farm 3a and all years from Farm 3b because only two blocks were used reducing the degrees of freedom. As explained above, the number of blocks were increased for Farm 3a to accommodate a RCB design in years 2 and 3. In this case analysis was done using a completely randomized design resulting in no measure of treatment /block interaction. All other Farms had three replications and were analyzed as RCB. When reporting results from experiments in this project, differences among treatments were considered statistically significant at levels of probability of "*0.050*" or less.

Results and Discussion

Soil P concentrations at the beginning of this demonstration project was 167 ppm corresponding to an index of very high. Average soil pH and Ca concentration were 7.6 and 1544 ppm, respectively. Precipitation of soil P by $CaCO_3$ at pH values >7.0 renders large amounts of soil P unavailable for crop uptake (Rhue and Everett, 1987). The discussion of results for the 3 years of data collection and sample analysis was organized on a year-by-year basis to reflect results collected under the same relative weather conditions. Variations in weather (e.g., tropical storms, drought) influences crop responses to nutrient as well as other agricultural inputs. Year-to-year weather conditions are highly variable in Florida but relatively uniform over the small area of the state where the demonstration project was conducted. Thus, it can be assumed that seasonal weather conditions in individual years did not influence the data at one farm differently than at any other farm and can thus we can compare the data on this basis. Two commodities, green beans and tomatoes, represent the majority of the data collected during the demonstration project and are two of the major commodities in the C-139 Basin.

Year one (2005–06). All farms tested "very high" in extractable P and no significant differences were detected among the P treatments before applying fertilizer. One out of eight samplings indicated higher soil P with the full P application rate at 30 and 60 d after planting (DAP) for green beans or 60 and 120 DAP for tomatoes compared with the half and zero P rates (Table 4). In five out of eight sampling dates, there was a trend of greater plant growth (biomass accumulation) with the full P rate, but these differences were not statistically significant (Table 4). Increasing P fertilization for the one green bean crop significantly increased yield of medium sized pods (Table 5). One of the five tomato harvest resulted in significantly greater yield of large sized fruit but no other fruit size or total yield.

Year two (2006–07). Soil sample data indicate that P concentrations in all plots were within the high or very high soil P index prior to fertilizer application with no significant difference

Table 4. Year one project summary for extractable soil P content, and plant biomass dry weight at selected intervals during the growing season.

			Soil P			Biomass		
Parcels	Crop	Date[z]	Significant[y]	Highest treatment[x]	Difference[w]	Significant[y]	Highest treatment[x]	Difference[w]
Farm 1	Tomatoes	0	No	H	10.9			
		60	Yes	F	38.7	No	H	3.1
		120	No	F=Z[v]	19.1	No	F	8.7
Farm 3a	Tomatoes	0	No	H	20.8			
		60	No	Z	3.4	No	F	22.3
		120	No	F	7.5	No	F	12.8
Farm 3b	Green beans	0						
		30	No	F	3.5	No	F	29.3
		60	No	F	2.4	No	F	20.6

[z]Date of sampling in days after transplanting for tomatoes and peppers and days after seeding for green beans.
[y]Statistically different at the $P \leq 0.05$ level (95% confidence level).
[x]F = full fertilizer P rate; H = half of grower fertilizer P rate; and Z = zero fertilizer P applied.
[w]Percent difference mean values for treatments in comparison to the application rate producing the lowest value.
[(Highest treatment mean – lowest treatment mean)/lowest treatment mean] × 100.
[v]Both full and zero applied P rates produced numerically similar results that were higher than the half grower applied P rate.
[u]Both half and grower applied P rates produced numerically similar results that were higher than the zero applied P rate.

Table 5. Year one project summary for yield at one to three harvest events per crop for selected fruit size categories.

			First harvest			Second harvest			Third harvest		
Parcels	Crop	Size[z]	Significant[y]	Highest treatment[x]	Difference[w]	Significant[y]	Highest treatment[x]	Difference[w]	Significant[y]	Highest treatment[x]	Difference[y]
Farm 1	Tomatoes	Medium	No	H=Z[v]	20.4	No	Z	18.5	No	Z	21.5
		Large	No	H	14.8	No	Z	3.0	Yes	Z	17.4
		X-large	No	H	10.9	No	H	15.6	No	Z	16.1
Farm 3a	Tomatoes	Medium	No	Z	51.0	No	Z	24.6			
		Large	No	Z	10.6	No	H	60.2			
		X-large	No	F	10.7	No	H	67.5			
Farm 3b	Green	4–6	No	F	3.0						
	Beans	3–4	Yes	F	12.8						
		<3	No	F	9.7						

[z] Fruit size in marketable categories: tomatoes sorted by fruit diameter, green beans sorted by length of bean pods, and other crops presented as total yield.
[y]Statistically different at the $P \leq 0.05$ level (95% confidence level).
[x]F =full fertilizer P rate; H= half of grower fertilizer P rate; and Z = zero fertilizer P applied.
[w]Percent difference mean values for treatments in comparison to the application rate producing the lowest value.
[(Highest treatment mean – lowest treatment mean)/lowest treatment mean] × 100.
[v]Both half and zero applied P rates produced numerically similar results that were higher than the grower applied P rate..

among treatments (Table 6). One out of six subsequent soil samples taken from tomato were significantly greater for P (110 DAT, Farm 3a). None of the two soil samples taken from green bean plots after fertilizer application indicated significant different soil P concentration among treatments. Only one biomass samplings out of six were significantly greater for the half P rate treatment compared with both the full and zero rates indicating inconsistent results of added fertilizer P on tomato growth.

Green bean yield were significantly greater in two of the three crops for the largest size categories for the full P rate compared with the half and zero rate (Table 7). The third green bean crop was not significantly different among treatments for the large size category but the medium size was significantly greater for the half rate compared with the full and zero rates. In one of the three tomato studies, yield of large and medium sized fruit at the first harvest was greater for the half P rate compared with fruit from plots with zero added P. The same crop produced significantly greater large fruit for the zero P rate at the third harvest indicating a possible delay in maturity with reduced fertilizer P rate.

Year three (2007–08). All farms in both fall and spring seasons had soil test P indices of high or very high prior to planting. Soil P was significantly greater for the full P rate plots in one out of five crops for green beans prior to harvest (Table 8). Five crops of green beans were grown in year three of the demonstration project and provided very good information on the effect of P on growth and productivity of this crop. In four out of five crops, no significant differences in soil P concentrations were found for soil samples collected before planting (Table 8). In the one crop with significantly different soil P concentrations, the plots receiving the full rate had significantly greater soil P concentration prior to planting. This crop was the second crop of the year at that location and may indicate that extractable P applied to the previous crop had not yet precipitated to a form that is not extractable using Mehlich 1. With the exception of one 60 DAP sample, no significant differences were observed for any soil P concentrations at any others location nor on any other sample dates. Biomass

Table 6. Year two project summary for extractable soil P content, and plant biomass dry weight at selected intervals during the growing season.

			Soil P			Biomass		
				Highest			Highest	
Parcels	Crop	Date[z]	Significant[y]	treatment[x]	Difference[w]	Significant[y]	treatment[x]	Difference[w]
Farm 1	Tomatoes	0	No	H	14.9			
		60	No	H	54.4	No	F	15.6
		120	No	H	20.9	No	Z	24.5
Farm 2	Green beans	0	No	Z	119.2			
		30	No	F	17.0	No	Z	42.7
		60	No	Z	12.4	No	Z	17.9
Farm 3a and b	Green beans	0	No	F	18.4			
		30	No	Z	16.2	No	F	30.0
		60	No	F	34.5	No	Z	19.3
Farm 3a	Tomatoes	0	No	F	31.6			
		60	No	H	23.8	Yes	H	29.8
		110	Yes	H	67.5	No	H	30.2
Farm 3b	Green beans							
		30	No	F	47.8	No	F	37.2
		45	No	Z	30.2	No	F	58.2
Farm 4	Tomatoes	0	No	F = H = Z[v]	0			
		60	No	F	93.2	No	Z	4.6
		120	No	F	91.2	No	Z	2.3

[z]Date of sampling in days after transplanting for tomatoes and peppers and days after seeding for green beans.
[y]Statistically different at the $P \leq 0.05$ level (95% confidence level)
[x]F = full fertilizer P rate; H = half of grower fertilizer P rate; and Z = zero fertilizer P applied.
[w]Percent difference mean values for treatments in comparison to the application rate producing the lowest value.
[(Highest treatment mean – lowest treatment mean)/lowest treatment mean] × 100.
[v]All three applied P rates produced numerically similar results.

Table 7. Year two project summary for yield at one to three harvest events per crop for selected fruit size categories.

			First harvest			Second harvest			Third harvest		
				Highest			Highest			Highest	
Parcels	Crop	Size[z]	Significant[y]	treatment[x]	Difference[w]	Significant[y]	treatment[x]	Difference[w]	Significant[y]	treatment[x]	Difference[y]
Farm 1	Tomatoes	Medium	No	Z	163.9	No	Z	164.7	No	F	10.0
		Large	No	F	31.4	No	H	16.5	No	F	15.9
		X-large	No	H	1.5	No	F	9.9	No	F	22.1
Farm 2	Green beans	4–6	No	H = F[v]	4.2						
		3–4	Yes	H	38.9						
		<3	No	F = Z[u]	20.0						
Farm 3a and b	Green beans	4–6	Yes	F	21.9						
		3–4	No	F = H = Z[t]	0						
		<3	Yes	F	14.3						
Farm 3a	Tomatoes	Medium	Yes	H	102.4	No	F	62.5	No	H	22.7
		Large	Yes	H	127.0	No	H	55.1	Yes	Z	64.7
		X-large	No	F	11.0	No	Z	5.3	No	F	31.5
Farm 3b	Green beans	4–6	Yes	F	25.6						
		3–4	No	F	26.3						
		<3	No	F = H = Z[t]	0						
Farm 4	Tomatoes	Medium	No	Z	39.1	No	F	15.3			
		Large	No	H	12.1	No	Z	10.4			
		X-large	No	Z	7.3	No	H	30.1			

[z]Fruit size in marketable categories: tomatoes sorted by fruit diameter, green beans sorted by length of bean pods, and other crops presented as total yield.
[y]Statistically different at the $P \leq 0.05$ level (95% confidence level).
[x]F = full fertilizer P rate; H = half of grower fertilizer P rate; and Z = zero fertilizer P applied.
[w]Percent difference mean values for treatments in comparison to the application rate producing the lowest value.
[(Highest treatment mean – lowest treatment mean)/lowest treatment mean] × 100.
[v]Both half and full applied P rates produced numerically similar results that were higher than the zero applied P rate.
[u]Both full and zero applied P rates produced numerically similar results that were higher than the half applied P rate.
[t]All three applied P rates produced numerically similar results.

Table 8. Year three project summary for extractable soil P content, and plant biomass dry weight at selected intervals during the growing season.

			Soil P			Biomass		
Parcels	Crop	Date[z]	Significant[y]	Highest treatment[x]	Difference[w]	Significant[y]	Highest treatment[x]	Difference[w]
Farm 1	Tomatoes	0	No	Z	21.7			
		60	No	F	13.3	No	Z	20.3
		120	No	F	12.7	No	H	40.4
Farm 2	Green	0	No	Z	6.1			
	beans	30	No	Z	15.6	Yes	H	10.1
		60	No	Z	17.6	No		5.5
Farm 3a	Green	0	No	F	20.0			
	beans	30	No	F	13.4	Yes	F	11.7
		60	No	F	16.4	Yes	F	26.5
Farm 3a	Green	0	Yes	F	29.4			
	beans	30	No	F	65.5	No	F	16.7
		60	No	F	22.0	Yes	F	67.3
Farm 3b	Green	0	No	F	15.1			
	beans	30	No	F	3.9	Yes	F	29.2
		60	No	F	37.5	Yes	F	28.5
Farm 3b	Green	0	No	F	18.1			
	beans	30	No	F	15.4	Yes	F	65.4
		60	Yes	F	47.7	Yes	F	87.4

[z]Date of sampling in days after transplanting for tomatoes and peppers and days after seeding for green beans.
[y]Statistically different at the $P \leq 0.05$ level (95% confidence level)
[x]F= full fertilizer P rate; H= half of grower fertilizer P rate; and Z = zero fertilizer P applied.
[w]Percent difference mean values for treatments in comparison to the application rate producing the lowest value. [(Highest treatment mean – lowest treatment mean)/lowest treatment mean] × 100.
[v]All three applied P rates produced numerically similar results.

Table 9. Year three project summary for yield at one to three harvest events per crop for selected fruit size categories.

			First harvest			Second harvest			Third harvest		
Parcels	Crop	Size[z]	Significant[y]	Highest treatment[x]	Difference[w]	Significant[y]	Highest treatment[x]	Difference[w]	Significant[y]	Highest treatment[x]	Difference[y]
Farm 1	Tomatoes	Medium	No	F	67.5	No	F	11.0			
		Large	No	Z	18.5	No	Z	20.8			
		X-large	No	H	15.7	No	F	29.7			
Farm 2	Green	4–6	Yes	F	129.0						
	beans	3–4	Yes	Z	54.4						
		<3	No	H	24.4						
Farm 3a	Green	4–6	Yes	F	19.3						
	beans	3–4	No	F	6.4						
		<3	Yes	Z	31.4						
Farm 3a	Green	4–6	Yes	F	77.5						
	beans	3–4	No	F	55.8						
		<3	No	F	56.2						
Farm 3b	Green	4–6	Yes	F	33.4						
	beans	3–4	No	F	4.4						
		<3	No	F	9.1						
Farm 3b	Green	4–6	Yes	F	41.7						
	beans	3–4	No	F	0.8						
		<3	No	F=H=Z[v]	0						

[z]Fruit size in marketable categories tomatoes sorted by fruit diameter, green beans sorted by length of bean pods, other crops presented as total yield.
[y]Statistically different at the $P \leq 0.05$ level (95% confidence level).
[x]F = full fertilizer P rate; H= half of grower fertilizer P rate; and Z = zero fertilizer P applied.
[w]Percent difference mean values for treatments in comparison to the application rate producing the lowest value. [(Highest treatment mean – lowest treatment mean)/lowest treatment mean] × 100.
[v]All three applied P rates produced numerically similar results.

at 30 and 60 DAP were significantly highest in the half or full P rates compared with the zero P rate in eight out of 10 samples taken (Table 8). All but one of the significantly greater biomass observations were in plots receiving the full P rate. Yield of the large (4-6 inch) bean size was significantly greater for the full P rates compared with the zero P rate in five out of five crops (Table 9). Significant difference in yield of the moderate bean size (3-4 inch) was found in only one out of five crops with the zero rate being greater than the full and half P rates. The full P rate had higher yields of moderate size beans in the remaining four out of five crops. The yield of small (<3 inch) size beans was inconclusive with one out of five yields being significantly greater for the zero P rate compared with the half and full rates. These results would infer that increased P rate increases yield of large pod size of green beans.

Soil P was significantly different among fertilizer P application rates at 60 or 120 DAT for the one tomato crop. Biomass and marketable yields of any fruit size were not significantly different for half or full P rates compared with the zero P rate.

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