C-139 BASIN VEGETABLE PRODUCTION DEMONSTRATION PROJECT

Final Three Year Report
(Fall 2005 to Spring 2008)

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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. This report is dedicated to Dr. Kent Cushman, *Vegetable Specialist and first project leader for this demonstration project. His untimely passing during this project was a loss to all participants in this critical project to south Florida vegetable production.*

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Executive summary

This report presents three year results for the vegetable production demonstration project completed in the C-139 Basin between 2005 and 2008. The goal of this three year field level demonstration project was to improve water quality in the C-139 basin. To accomplish this goal, demonstrate the current soil test index best management practice (BMP) for phosphorus (P) fertilization practices for vegetables, determine accuracy of the current soil P test index under field conditions and provide information on utilizing this index to growers in the C-139 basin. This demonstration project was designed to promote the long-term improvement in water quality through more effective application of P for vegetable production and was supported by the University of Florida, Institute of Food and Agricultural Sciences (UF-IFAS) and the South Florida Water management District (SFWMD) to explore BMPs for improving water quality in the C-139 basin. The soils of the C-139 Basin were found to have higher pH (>7.0) and very high Calcium (Ca) concentrations (>400 ppm) compared with similar soils in other locations in the state. 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 and during each of the field studies in this project were high or very high in extractable soil P as determined by current UF-IFAS soil test P index recommendations using Mehlich 1 extractant. These high to very high P index values would indicate that no additional fertilizer P should be required for optimum crop production. The P concentrations extracted by Mehlich 1 did not decrease appreciably over the three years of this demonstration at all sites. However, during this demonstration project it became clear that growth and yield of green beans increased with increased P application when the P index indicated that no added P should be required. This observation was not true for tomato crops grown during this demonstration project.

Results of the C-139 demonstration project are:

- Green bean growth significantly increased with increased fertilizer P rate in five of the nine crops grown during the demonstration project. Green bean yield data suggest that the full rate of P fertilization produced higher yield of large pod size in seven out of nine crops grown. Increased yield of the large size pods occurred in years two and three while increased biomass accumulation was observed in year three. These results may indicate that while soil test P is still high, soil P may be less available for plant growth and yield in plots where no fertilizer P has been applied. If this observation is correct, then the effect of zero P on reduced growth and yield should increase with time. Using these results it would appear that a rate of 40 to 50 pounds of P per acre at a high soil P index would be justified. Under current recommendations, no yield response to added soil P should be expected at soil test P index of high or better. Therefore, soil test P index in soils with pH greater than 7.0 and Ca concentrations greater than 400 ppm need to be re-evaluated for green beans.
- Tomato growth and yield was less affected by fertilizer P applications compared with green bean. No biomass increase with increasing fertilizer P rate was observed over the three years of this demonstration. The lack of effect of fertilizer P rate on tomato growth was reflected in the low number of significant differences in leaf P. Leaf P increased with increasing fertilizer P at 120 DAP but not 60 DAP in two out of the five tomato crops grown. However, a possible delay in tomato fruit maturity with reduced fertilizer P

application is suggested by an increase in large fruit production at the first harvest for one crop out of five vs. an increase in large fruit production at the third harvest for two crops out of five (Table 11). Due to the low number of significant between time of maturity and fertilizer P applications, these results are not definitive and needs additional data to be conclusive.

- One crop each of eggplant, peppers and corn were grown with little indication of impact on growth and yield by additional fertilizer P application. Conclusions for these crops are not advisable with results from only one crop each.

Precipitation of soil P by $CaCO_3$ at pH values >7.0 renders large amounts of soil P unavailable for crop uptake. The overall conclusion of this project is that current UF-IFAS soil P test index using Mehlich 1 extraction is not effective in determining P fertilizer requirements in soils with pH>7.0 and Ca>400 ppm for green beans. Greater than 75% of the green bean studies over the three year of this demonstration project resulted in greater growth and/or yield with additional P application compared with zero P recommended by the current UF-IFAS recommendations. Only 20% of the tomato studies resulted in significantly greater yield of large sized fruit with greater P rate compared to the zero P rate recommended by current soil P index. A conclusion that the current soil test P indexes for tomato are too low for high pH and high Ca content soil in south Florida is suggested by the growth and yield data but can not be made this low amount of significant data. Additional testing is needed to further validate a new soil test P index for growth tomato and crops in addition to green beans on soils with pH>7.0 and Ca>400 ppm. Furthermore, refinement of soil test P index using other soil extractants (e.g. Olsen and Brey) that are known to provide more representative indications of soil P availability under soil chemical characteristics similar to those in the C-139 basin should be conducted. These alternate soil extracts are currently being used in soils with pH>6.5 because they do not extract as great an amount of precipitated P and are thus more representative of plant available P. Improving growth and yield statistics by adding one more P rate and one or more replication(s) per study, as well as, the testing of additional extractants should provide the needed evidence on which to base the modification of the current UF-IFAS soil test P recommendations.

The only means of making this “fixed” P (i.e. precipitated soil P) available for crop plant growth and improved yield is to lower soil pH which results in dissociation of calcium P compounds (e.g. $CaCO_{3)}$ and release of P. The source of $CaCO_3$ was either an accumulation of Ca over geologic time or as a result of over liming of the soil during the past four to five decades. Regardless of the origin, Ca CO_3 is removed from field soil at a rate of approximately 150 pound per acre per year by plant uptake and will take 10 years or more to be reduced to levels that will not significantly precipitate P (T.A. Obreza, unpublished data). The fact that Mehlich 1 extractable P did not decrease greatly over the course of the 3 year demonstration projects is indicative of a large reserve of extractable soil P in these soils. However, availability of soil P to the crop plant is lacking in the soils of the C-139 basin as indicated by the significant increase in green bean growth and yield with added fertilizer P. Field scale testing of BMPs to increase soil P availability such as moderation of soil pH with application of soil amendments should be conducted; amendments and/or application methods that would not impact down-stream water quality should be investigated. The plots at each grower field that had no added P over the three years of this demonstration should be maintained with no added P to determine the rate that the fixed pool of soil P is reduced when no fertilizer P is added. Likewise, the lowering of pH at these plots that have not received fertilizer P for three years will provide data on improved availability from these P precipitates that are now unavailable to the crop plants.

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. With the exception of WY 2008, 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. Rainfall in the basin in WY2008 was below normal (41.9 inches, FAWN SWFREC weather station) and may have lead to the basin being in compliance. If this one year trend of compliance with historic P loadings in the basin continues during years with normal to above normal rainfall remains to be determined.

C-139 Basin agriculture has historically consisted of pasture, sugarcane and citrus. However, vegetable production has been increasing and dominating agricultural production in the basin (Cushman, 2006). 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. For selected plant nutrient the University of Florida – Institute of Food and Agricultural Sciences (UF-IFAS) has developed a range of nutrient specific soil concentrations into classifications called indexes of very low, low, medium, high and very high using data collected under field conditions. The range of nutrient concentrations in the soil are based on growth and yield response to a wide range of nutrient fertilizer application in a large number of field studies. The exact number of nutrient amounts applied and number of field studies used vary by nutrient and crop but must be preformed over at least a three year period and result in statistically valid data to determine a crop response curve. The response curve has soil nutrient concentration or addition on the X axis and crop growth or yield on the Y axis (Fig. 1). Typically, crop growth or yield increases with increased nutrient application to a point where the curve flattens and no significant increase in growth or yield is discernable. This point is considered the recommended fertilizer rate for a given starting soil concentration or index. The field conditions are as close to weather, soil characteristics, water management and horticultural practices that most growers would use as possible. In most cases, the experiments are conducted in grower fields or at UF-IFAS experiment stations. A soil test index of high or very high indicates that no response is likely to added fertilizer nutrient. The other three indexes (very low, low and medium) have nutrient recommendations specific for each index and crop. For example, the very low, low, medium, high, and very high index ranges for phosphorus are <10, 10-15, 16-30, 31-60 and >60 ppm, respectively with fertilizer recommendations of 150, 120, 100, 0 and 0 pounds P_2O_5 per acre, respectively (Table 1).

Figure 1. Generic yield response curve arrows indicating relationship between nutrient application rate (X axis) for maximum yield (Y axis).

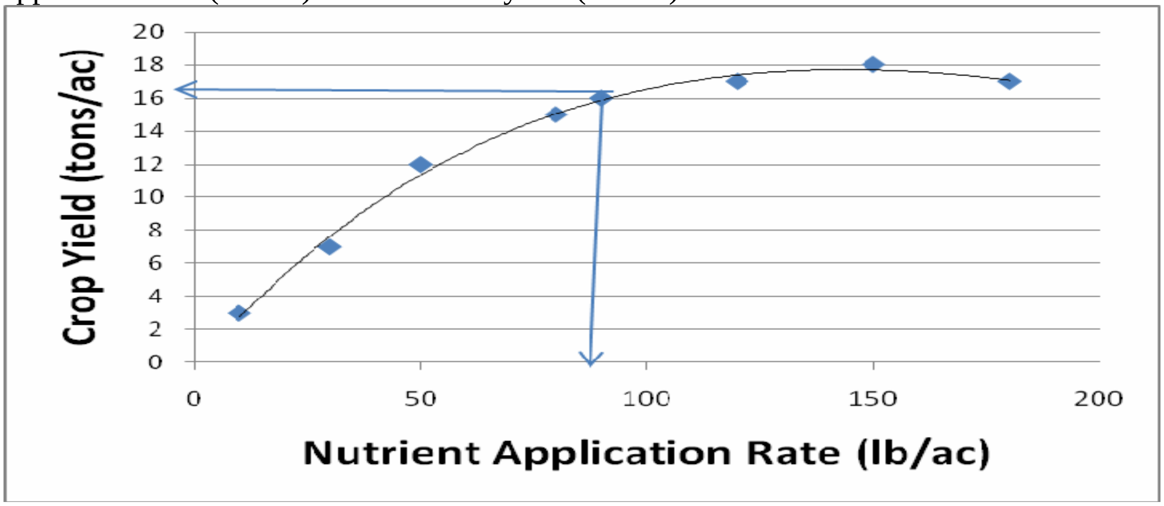

Table 1..Soil sample analysis index using Mehlich 1 extractant.

Nutrient	*Very Low*	*Low*	*Medium*	*High*	*Very High*
	Parts per million soil				
Phosphorus (P)	<10	10-15	16-30	31-60	>60
Potassium (K)	<20	20-35	36-60	61-125	>125
Magnesium (Mg)	<10	10-20	21-40	41-60	>60
Calcium (Ca)	<100	100-200	201-300	301-400	>400
	Fertilizer P Recommendation (lb ac^{-1})				
All vegetable crops	150	120	100	0	0

Olson, S.M. and E. Simonne. 2007. Vegetable Production Handbook for Florida 2006-2007. UF/IFAS.

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 provided 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 UF-IFAS recommendations,
- Evaluate plant P uptake during the season, and measure crop yield and quality at harvesting. Monitor indicators that may cause deviations from UF-IFAS recommendations,
- 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 SFWMD.

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 as: 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 the phosphate ion 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. Because the vast majority of soils in Florida are classified as acid sands, 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 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. Soils in Florida with pH values above 7.0 are limited to south Florida and are limited in area compared with soils used for agriculture in other parts of the state. However; citrus, sugarcane and vegetable acreage in south Florida have increased greatly over the past 40 years. The choice of extractant for these high pH soils and recommendations based on soil tests need to be re-evaluated.

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 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 October of 2005 and the project time table was adjusted to begin with the spring season of 2006. Therefore, year one of the project consisted of corps in the spring of 2006, Fall 2006 and Spring 2007 was considered year two and the third year studies were conducted in Fall 2007 and Spring 2008. 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.

Table 2. Crops Grown in Research Plots at Five Cooperator Sites: Spring 2006 To Spring 2008.

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

Crops grown for this demonstration project were green beans (10), tomato (7), eggplant (1), pepper (1) and corn (1). 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, is 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/.

Farm 1. The experimental design was a randomized complete block (RCB) with three replications of all three P rates (Fig. 2). Each plot was six rows wide and 500 to 700 feet long, or approximately 0.4 to 0.6 acres depending on field location. Four crops of tomatoes were grown at the farm.

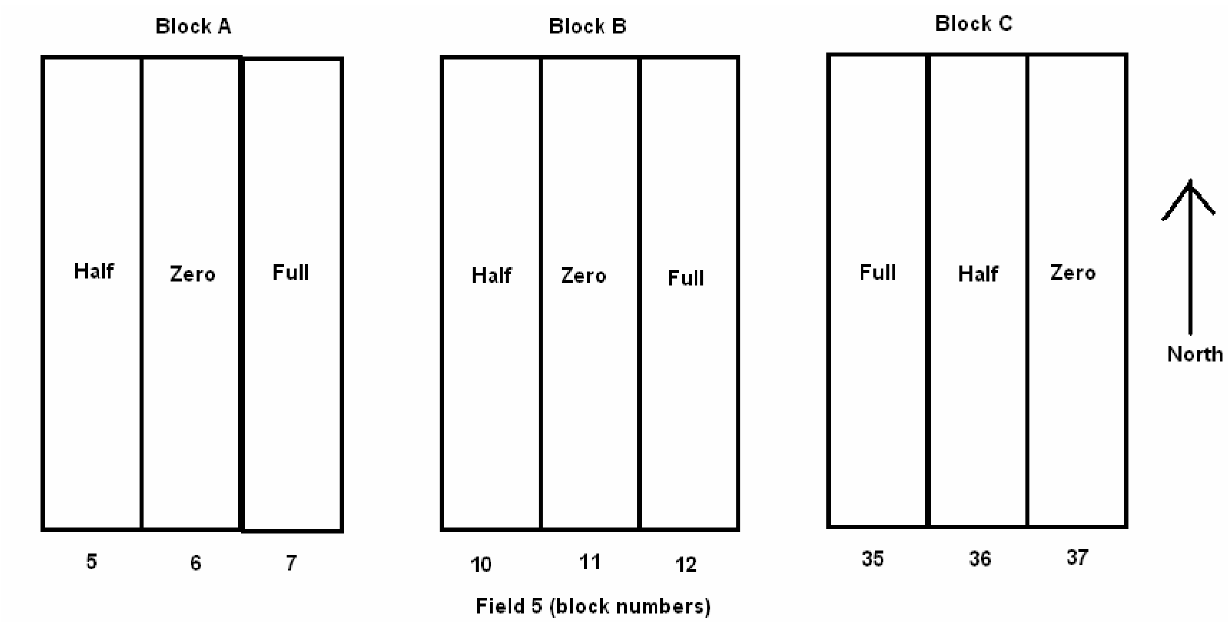

Figure 2. Randomized complete block design for demonstration project site at Farm 1 (n-1 = 8).

Farm 2. A wide variety of specialty vegetables for the fresh market are produced on Farm 2. The experimental design was randomized complete block with three replications of each P rate (Fig. 3). Each plot was 14 rows wide and about 900 feet long and covered about 0.88 acres. Crops grown (4) for the demonstration project at Farm 2 were eggplant, peppers, green beans and corn.

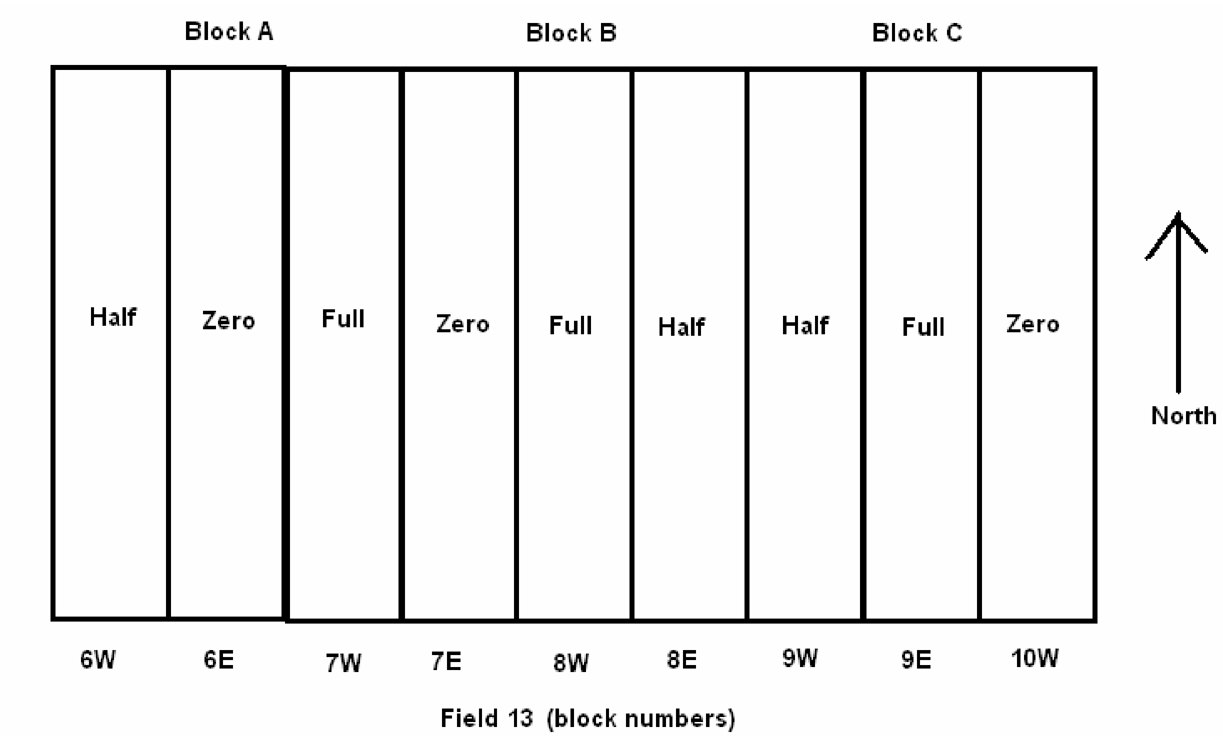

Figure 3. Randomized complete block design for demonstration project site at Farm 2 (n-1 = 8).

Farms 3a and 3b. Farms 3a and 3b produced green beans during the fall growing season of each year. Farm 3a typically (exception was Spring 2008) followed beans with tomatoes in the spring. Whereas, Farm 3b planted green beans in both the fall and spring seasons of all 3 years. The experimental design differed between the 2 farms, and the design at Farm 3a differed between years 1 and 2. Initially (year 1) each plot at Farm 3a (block A, B and C in Fig. 4a) were 12 rows and about 400 feet long covering about 0.68 acres each. In year two the plots at Farm 3a were split in half (Fig. 4a) resulting in six 6 row plots. Plots at Farm 3b (Fig. 4b) had 12 rows about 600 feet 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. However, 3 P rates were used when tomatoes were grown.

In spring of year 1 at Farm 3a, tomatoes were grown in three plots (block A, B and C, Fig. 4a) at the full, half and zero rates. At the same farm (3a), the same three plots were used for the fall green bean crop in year 2 as were used for the spring tomato crop, however, as stated above, only two P rates were used. Therefore, no fertilizer P was applied to the zero P rate plot, and the full P rate was applied to the plots that had received the half and full P rates previously. These fertilizer applications resulted in one replication of the zero P rate and two replications of the full P rate. The experimental design for the fall and spring green bean crop grown on Farm 3b was the same each season. The same two fertilizer P rates (zero and full) were applied to the same plots and replicated twice resulting in two plots with no fertilizer P applied and two plots with the full P rate. In Fall 2006, the green bean crops at Farms 3a and 3b were combined to take advantage of similar planting dates and P rates resulting in an unbalanced design with three replications of the zero P rate and four replications of the full P rate. Data from the two studies were pooled and analyzed statistically using a mixed model rather than the general linear model because this procedure allows for the analysis of different numbers of replications without reduced degrees of freedom. The plots at Farm 3a were split for the Spring 2007 tomato crop with each treatment replicated 2 times. This experimental design continued for the next three crops. The result was that the green bean crops in fall and spring of year 3 had three replications of two P rates and were analyzed as CRB design. The green bean crops grown at Farm 3b were also analyzed as a CRB with two replicates.

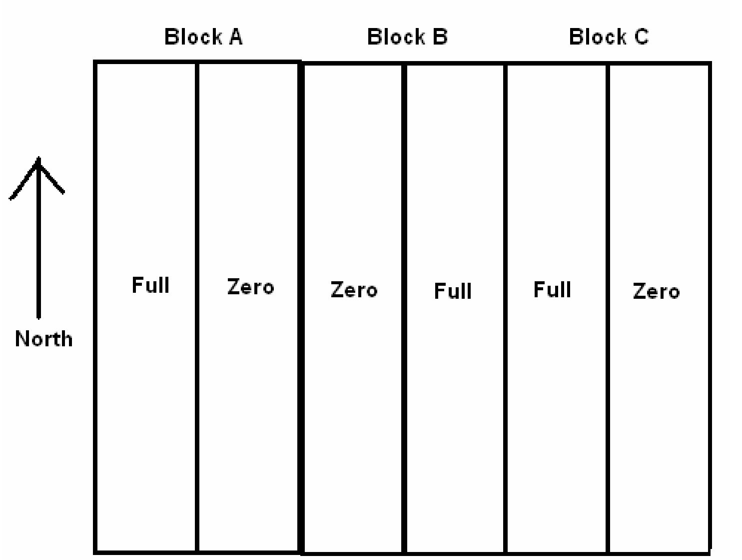

Figure 4a. Experimental design of Farm 3a. The design was changed from three plots (blocks A, B and C) in year 1 (n-1 = 2) to six plots in year 2 (n-1 = 5).

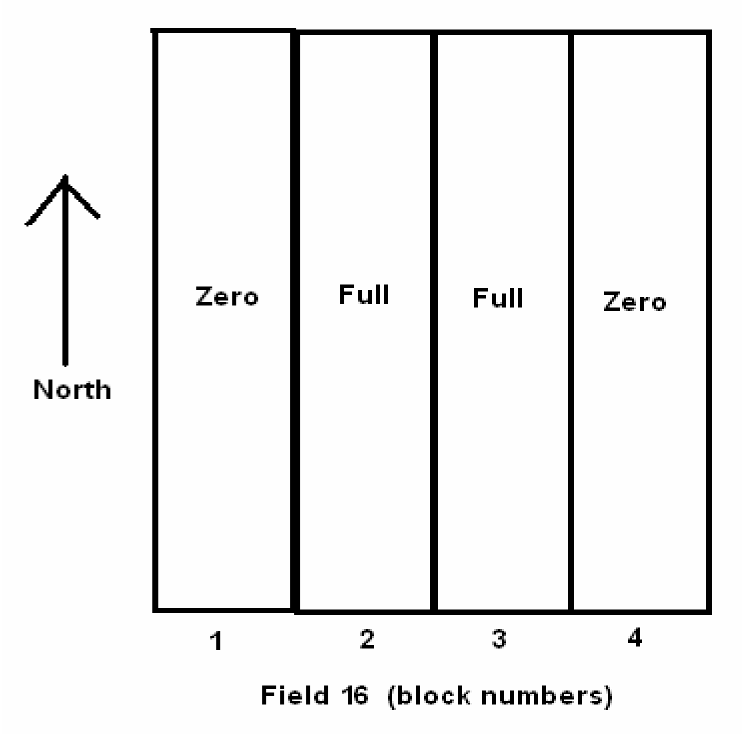

Figure 4b. Randomized complete block design for demonstration project site at Farm 3b (n-1 = 3).

Farm 4. Farm 4 produced tomatoes for the fresh market 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 (Fig. 5). Each plot was six rows wide and about 300 to 400 feet long covering 0.21 to 0.28 acres depending on location.

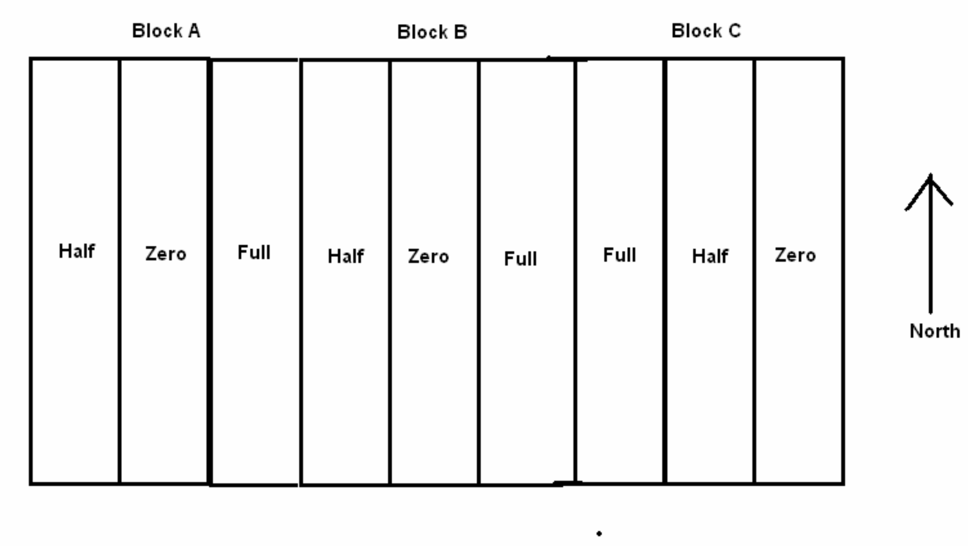

Figure 5. Randomized complete block design for demonstration project site at Farm 4 (n-1 = 8).

Fertilizer P 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, if the soil from “Farm A” tested “very high” in extractable P, then the recommendation was to apply no P. Second, it was determined what the typical farm practice or “grower rate” was. For example if the typical practice was to apply 100 lb/acre P_2O_5 at “Farm A” then 100 lb/acre was the grower or full fertilizer P rate. Finally, it was decided how many treatments to install. For “Farm A” 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 or half rate, and (3) 100 lb/acre P_2O_5, “grower rate” or full rate. 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. If the “grower rate were small (for example 50 lb/acre P_2O_5) only one rate in addition to the IFAS recommended rate was used at the site. The relative fertilizer phosphorus (P) rates used in each study were the same as the preceding crops with plots receiving zero, half and full P rate receiving the same amounts relative to the full P treatment in all season during the demonstration project.

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 bean and corn crops 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 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.

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

	Spring 2006	Fall 2006	Spring 2007	Fall 2007	Spring 2008
	Fertilizer P rate[Z] (lbs/ac)				
Farm 1					
Zero rate	0	0		0	0
Half rate	50	84		80	80
Full rate	100	168		160	160
Farm 2					
Zero rate	0	0	0	0	0
Half rate	50	25	50	30	50
Full rate	100	50	100	60	100
Farm 3a[Y]					
Zero rate	0	0	0	0	0
Half rate	50	-	50	-	-
Full rate	100	40	100	50	50
Farm 3b					
Zero rate	0	0	0	0	0
Full rate	39	40	40	50	50
Farm 4					
Zero rate			0		
Half rate			56		
Full rate			112		

[Z] Fertilizer rate 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/ac to 160 lbs/ac 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 pounds/ac) 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.

Extractable soil nutrients

The selection of soil extractant influences the amount of nutrient extracted from the soil and is estimated to estimate nutrient availability for many Florida soils. In this project, soil tests using Mehlich 1 extractant are used to measure extractable plant nutrients because UF/IFAS recommendations are based on use of this extractant (Table 4). 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. 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 because only the application rates of P was varied and application rates for other plant nutrients remained the same in each treatment.

Table 4.Soil sample analysis index using Mehlich 1 extractant.

Nutrient	*Very Low*	*Low*	*Medium*	*High*	*Very High*
	Parts per million soil				
Phosphorus (P)	<10	10-15	16-30	31-60	>60
Potassium (K)	<20	20-35	36-60	61-125	>125
Magnesium (Mg)	<10	10-20	21-40	41-60	>60
Calcium (Ca)	<100	100-200	201-300	301-400	>400

The preferred soil pH for vegetables production is about 6.0 to 6.5, but many soils in the C-139 basin range 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 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.

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

Biomass

A measure of plant performance is biomass accumulation. This is simply dry weight of plant material. For this project, the above ground biomass was measured. 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 30-day intervals during the growth of the crop.

Biomass accumulation is a direct measure of plant growth. For fruiting crops only a small portion of the plant is harvested and sold. For these crops, yield is a direct measure of plant productivity. It is assumed that larger plants produce higher yields, but this is only generally accurate. 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.

Leaf tissue nutrient concentration

Plant nutrients accumulate in plant tissues at different rates and different concentrations depending on the nutrient, the plant tissue, growing conditions and stage of growth. Nutrients accumulate in plant tissue as a function of their availability to the plant. If not available in sufficient amounts and thus limiting, plant tissue will not contain nutrients in adequate concentrations for optimum growth and the nutrient or nutrients are then considered to be deficient. Nutrient deficiencies often lead to reduced growth and productivity or morphological abnormalities. Sufficiency ranges for nutrients have been determined for vegetables and should be applicable regardless of soil type (Table 5). The plant tissue most often used to determine nutrient sufficiency is the "most recently mature" leaf. This recently mature leaf is about four to six leaves down from the apex of the plant, 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.

Table 5. Sufficiency range of plant nutrients based on crop growth stage

Crop [z]	*Stage of growth*	*Sufficiency range (% P on dry weight basis)*
Tomato	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
Pepper	Early bloom	0.3 to 0.5
Green bean	First bloom	0.3 to 0.4
Eggplant	Early fruit set	0.3 to 0.6
Corn	Early fruit set	0.2 to 0.5

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

Ten to fifteen "most recently mature" leaves were collected from the plants selected for biomass weight determination and then dried in a drying oven until all water content was removed. These leaves were used to indicate the nutrient status of the crop plants at the time the samples were taken. Dry leaf samples were ground and analyzed chemically for plant nutrient elements.

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. For example, 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 leaf tissue nutrient concentrations.

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 that 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 were found to be significantly different among treatments even though there seems no reason for them to be different. This can be explained by inherent variability among crops selected for sampling. It is almost certain that small difference in leaf nutrient concentration would not lead to changes in plant growth or productivity. Thus, significant differences in leaf micronutrients (nutrients needed in relatively small amounts compared with macronutrients such as N, P and K) among treatments 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 differences in micronutrient concentrations occur and how these differences in concentrations may be related to or affected by P uptake and accumulation.

Yields

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 as lettuce yield would be measured. There are several categories of yield for fruit crops like tomato. Total yield is a measure of everything the plant can produce, regardless of marketability. Marketable yield is that portion of total yield that is considered saleable. In the case of a tomato crop, marketable tomatoes are fruit with little or no defects. Unmarketable yield is that portion of total yield that is not saleable and is composed of vegetables that are not harvested, discarded because of insect or disease damage, or culled because of size or blemish.

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 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 losses 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.

Tomato. Total yield for tomato is every tomato fruit the plants can produce. 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 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. 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.

Eggplant. 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 cropping period is 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.

Pepper. Two varieties of peppers, Jalapeno and Cubanelle, were grown during this study. Jalapeno peppers are dark green in color and range from 3-5 inches long. Both types of peppers are commonly grown in the C-139 basin. The cultural practices for these pepper varieties are similar to the more popular bell pepper. Peppers are indeterminate bloomers, that is, they continue to bloom and are not limited to one bloom per crop as are most tomato varieties. Therefore, commercial crops can be harvested ten times or more, with each harvest typically being smaller than the last. In this study we harvested 5 times. Yield at each harvest and total harvest is recorded in average weight per fruit, weight of fruit per 10 plants harvested and estimated number of 25-pound boxes of fruit per acre based on fruit weight per 10 plants.

Corn. Sweet corn is a relatively minor crop in the C-139 basin, but was included in this study because it is included in some crop rotations. The corn is grown for the fresh market, therefore we collected data on fresh weight and number of ears per 10 feet or row. Cull ears were also counted and weighed.

Statistical Analysis

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 most of 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. The RCB experimental design was chosen to reduce variation from site conditions related to soil characteristics and water movement by applying one treatment per block across the demonstration area. By having all treatments in each of several blocks, variations in soil characteristics across the demonstration area, the likelihood of significant impact of block on treatment results will not be greater for one treatment compared with another treatment, therefore reducing the likelihood of a significant treatment/block interaction term. In the event of a significant treatment/block interaction the multiple comparisons should not be used. Statistical analysis using RCB could not be done on data from Farm 3b because only two blocks are used reducing the degrees of freedom. 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 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.

For all data, both Duncan's multiple range and Tukey's multiple comparison was used for separation of means. These two tests were used because Duncan's and Tukey's comparisons are seen as providing a range of interpretations with Tukey's being the more conservative. 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 not statistically different from values labeled "ab" but are significantly different than values labeled "b". Values without lettering are not significantly different at the 0.05 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, significant differences are traditionally accepted at the 95% level or greater confidence level which equates to significant levels of 0.05 or less. Some in the business community often accept confidence levels less than 95% being considered "significantly different".

Degrees of freedom (n-1) and Shapiro-Wilk test for normality results for all data analyses are provided in each table of data in the appendices of this report. The Shapiro-Wilk test for normality was applied to determine if the residuals or differences between the linear model estimate and the collected data were normally distributed. The Prob < W value or p-values are provided in this report. IF the p-value is less than 0.05, then the null hypothesis that the data are normally distributed is rejected. If the p-value is greater than 0.05, then the null hypothesis has not been rejected and the multiple comparisons are the correct method of means separation.

Results and Discussion

The discussion of results for the three years of data collection and sample analysis is organized in to two sections. The first section will be the review of data on a year by year basis to reflect results collected under the same relative weather conditions. There variations in weather (e.g. tropical storms, drought) can influence 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 weather conditions in individual years did not influence the data at one farm differently than at any other farm. The second discussion section will look at the soil nutrient concentration, biomass accumulation, leaf N concentrations and crop yield data collected by individual commodities. The major two commodities are green beans and tomatoes, and represent the majority of the data collected during the demonstration project and are two of the major commodities in the C-139 Basin. Other commodities studied in this demonstration project are eggplant, hot pepper and corn. Mean, soil, biomass, leaf and yield data are provided for each season at each farm over the three year study in Appendix A of this report.

Year by Year Data Review

Year one (2005/2006) All farms tested “very high” in extractable P and few differences were detected among the P treatments before applying fertilizer. Six out of eight samplings indicated higher soil P with the grower P application rate at 30 and 60 days after planting (DAP) for green beans or 60 and 120 DAP for tomatoes and egg plant (Table 6), however only one sampling date indicated significant differences among treatments. That sampling showed higher extractable P for the full rate compared to the zero rate.

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 5). Leaf tissue P concentrations were within or above sufficiency levels regardless of farm, crop, or time of sampling. Out of a total of eight sampling dates, six samples indicated higher leaf P with the full fertilizer P treatment. However, only one detected significant differences in leaf tissue P concentration among treatments. The both of the sample dates for green bean and three of the four samples dates from tomato had higher leaf P in the full P rate compared with the zero P rate.

Total yield of tomato tended to be greater for the zero and half rates compared to the full rate, but none of these results were statistically significant (Table 7). Increasing P fertilization at one farm appeared to increase yield of extra large fruit at first harvest. However, this difference did not cause a significant increase in total yield in comparison to the no P rate. Yield of green beans was consistently greater for the grower rate compared with the zero P rate (Table 6). However, only yield of the 3-4 inch bean size was significantly greater than the zero rate.

Table 6. Year One Project Summary for Extractable Soil P Content, Plant Biomass Dry Weight and Total Leaf P Concentrations at Selected Intervals During the Growing Season.

			Soil P			Biomass			Leaf P		
Parcels	Crop	Date[z]	Significant[y]	Highest Treatment[x]	Difference[w]	Significant[y]	Highest Treatment[x]	Difference[w]	Significant[y]	Highest Treatment[x]	Difference[w]
Farm 1	Tomatoes	0	No	H	10.9						
		60	Yes	**G**	38.7	No	H	3.1	No	**G**	12.5
		120	No	G=Z[v]	19.1	No	**G**	8.7	Yes	**G**	15.9
Farm 2	Egg Plant	0	No	H	8.8						
		60	No	H	21.4	No	H	13.2	No	H=G[u]	12.1
		120	No	**G**	11.6	No	**Z**	2.8	No	**Z**	10.3
Farm 3a	Tomatoes	0	No	H	20.8						
		60	No	Z	3.4	No	**G**	22.3	No	**G**	5.9
		120	No	**G**	7.5	No	**G**	12.8	No	H	13.8
Farm 3b	Green	0									
	Beans	30	No	**G**	3.5	No	**G**	29.3	No	**G**	23.3
		60	No	**G**	2.4	No	**G**	20.6	No	**G**	6.9

[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≤ 0.05 level (95% confidence level)
[x]G=grower 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 grower 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 7. 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 2	Egg Plant	total	No	H	42.6						
Farm 3a	Tomatoes	Medium	No	Z	51.0	No	Z	24.6			
		Large	No	Z	10.6	No	H	60.2			
		x-large	No	G	10.7	No	H	67.5			
Farm 3b	Green	4-6	No	G	3.0						
	Beans	3-4	Yes	G	12.8						
		<3	No	G	9.7						

[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≤ 0.05 level (95% confidence level)
[x]G=grower 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

Year two (2006/2007) Summary data in Table8 indicate that the grower (green text) and half rates of fertilizer P accounted for half or more of the greatest values of soil P content in green bean and tomato crops (four out of eight for green bean and 8 out of 9 for tomato), biomass dry weight (three out of six for green bean and three out of six for tomato) and leaf P concentrations (five out of six for green bean and three out of five for tomato) compared with the zero P rate. However, few of these increased values at the grower P rate were significantly different than the other rates. Conversely, the zero P rate accounted for only one-fourth of the greatest values for soil and leaf P concentrations (four out of 20 and four out of 14, respectively). However, similar to the grower rate, the zero P rate also accounted for nearly half the greatest biomass values (seven out of 15) compared with the half and grower P application rates. As with the samples where the greatest values were associated with the grower P rate, most of the results were not significantly different compared with the half and grower P rates. These data would indicate that additional P at 40 to 168 pounds of P per acre (the range of P applications in these studies) tended to increase extractable soil and total leaf P concentration but produced nearly equal biomass dry weights. Soils were in the high to very high soil P test range prior to planting, therefore one possible conclusion would be that the addition of P to these soils was not needed to supply adequate nutrition to the different crops.

Although not statistically significant in most cases, data in Table 9 indicate that in two of the three tomato studies production of larger sized fruit was greater in plots with grower P rate compared with fruit from plots with zero added P (Farms 1 and 3a). Likewise, the grower and half P rates increased early (first harvest) and total (first, second and third harvests) at Farms 1 and 3a. Tomato production at Farm 4 was limited to two harvests with mixed results with the zero P rate (blue text) producing larger fruit than half and grower rates. Peppers were grown at only one location with mixed results. Cubanelle peppers had similar results as tomatoes produced at Farms 1 and 3a. Cubanelle production was not significantly different among the treatments, but increased in the first and second harvest with increased P fertilizer application rates. The third harvest was dominated by higher yields of the zero rate plots. Jalapeno pepper production was not significantly different for the three P rates but had numerically greater yield in the zero P rate plots in the second and third harvests. Green bean production at Farms 2 and 3 showed the most consistent data with significantly greater production of the largest two size categories for the half or grower P rate compared with the zero rate.

Table 8. Year Two Project Summary for Extractable Soil P Content, Plant Biomass Dry Weight and Total Leaf P Concentrations at Selected Intervals During the Growing Season.

			Soil P			Biomass			Leaf P		
Parcels	Crop	Date^z	Significant^y	Highest Treatment^x	Difference^w	Significant^y	Highest Treatment^x	Difference^w	Significant^y	Highest Treatment^x	Differemce^z
Farm 1	Tomatoes	0	No	H	14.9						
		60	No	H	54.4	No	G	15.6	No	H	31.0
		120	No	H	20.9	No	Z	24.5	Yes	G	20.5
Farm 2	Green	0	No	Z	119.2						
	Beans	30	No	G	17.0	No	Z	42.7	No	Z	7.7
		60	No	Z	12.4	No	Z	17.9	No	G	26.1
Farm 2	Hot	90	No	G	26.8	No	G	28.8	No	G	23.1
	peppers	120	No	G	87.0	No	Z	15.4	No	Z	3.6
		150	No	G	56.5	No	G	26.9	No	H	7.3
Farm 3a	Green	0	No	G	18.4						
and b	Beans	30	No	Z	16.2	No	G	30.0	Yes	Z	9.6
		60	No	G	34.5	No	Z	19.3	No	G	12.4
Farm 3a	Tomatoes	0	No	G	31.6						
		60	No	H	23.8	Yes	H	29.8	No	Z	39.6
		110	Yes	H	67.5	No	H	30.2	Yes	G	26.3
Farm 3b	Green										
	Beans	30	No	G	47.8	No	G	37.2	No	G	12.4
		45	No	Z	30.2	No	G	58.2	No	G	12.4
Farm 4	Tomatoes	0	No	G =H=Z^v	0						
		60	No	G	93.2	No	Z	4.6	No	Z	8.6
		120	No	G	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}G=grower 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 Two Project Summary for Yield at One to Three Harvest Events per Crop for Selected Fruit Size Categories.

Parcels	Crop	Size[z]	First Harvest Significant[y]	First Harvest Highest Treatment[x]	First Harvest Difference[w]	Second Harvest Significant[y]	Second Harvest Highest Treatment[x]	Second Harvest Difference[w]	Third Harvest Significant[y]	Third Harvest Highest Treatment[x]	Third Harvest Difference[w]
Farm 1	Tomatoes	medium	No	**Z**	163.9	No	Z	164.7	No	G	10.0
		large	No	**G**	31.4	No	H	16.5	No	G	15.9
		xlarge	No	H	1.5	No	G	9.9	No	G	22.1
Farm 2	Green	4-6	No	H=**G**[v]	4.2						
	Beans	3-4	Yes	H	38.9						
		<3	No	**G=Z**[u]	20.0						
Farm 2	Hot	Jalapeno	No	H	17.4	No	Z	8.5	No	Z	51.5
	Peppers	Cubanelle	No	**G**	17.4	No	G	14.3	No	Z	20.0
Farm 3a	Green	4-6	Yes	**G**	21.9						
and b	Beans	3-4	No	G =H=Z[t]	0						
		<3	Yes	**G**	14.3						
Farm 3a	Tomatoes	medium	Yes	H	102.4	No	G	62.5	No	H	22.7
		large	Yes	H	127.0	No	H	55.1	Yes	Z	64.7
		xlarge	No	G	11.0	No	Z	5.3	No	G	31.5
Farm 3b	Green	4-6	Yes	G	25.6						
	Beans	3-4	No	G	26.3						
		<3	No	G =H=Z[t]	0						
Farm 4	Tomatoes	medium	No	Z	39.1	No	G	15.3			
		large	No	H	12.1	No	Z	10.4			
		xlarge	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, other crops presented as total yield
[y]Statistically Different at the p≤ 0.05 level (95% confidence level)
[x]G=grower 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 grower applied P rates produced numerically similar results that were higher than the zero applied P rate
[u] Both grower 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

Year three (2007/2008) As in the past two years, all farms in both fall and spring seasons had soil test P indexes of high or very high. Only one crop of tomatoes was grown in year three of this study. Soil P was greater at 60 and 120 DAP with the grower P rate compared with the zero P rate treatment (Table 10). Soil P content increased in plots where P was applied compared with the zero rate plots indicating that the treatments were properly applied but were not significantly different from the zero P rate. Accumulation of tomato plant dry biomass weight was higher in plots with lower P rates (zero and half P) but not significantly different compared with biomass from plots with higher P rates (grower P rate) (Table 10). Leaf P concentrations were not significantly different by P treatments, however, grower and half P rates had higher P leaf concentration compared with the zero rate at 60 and 120 days, respectively (Table 10). Leaf P concentrations in the 60 day samples was greater than the sufficiency level recommended for tomato in all treatment plots indicating high availability in plots including the plots to which no P had been added. Leaf P concentrations decreased between 60 and 120 DAT, however, P concentrations were still within the sufficiency range for all treatments indicating no benefit on growth or yield should be observed due to P availability in the soil.

Yield of tomatoes in this one study was not significantly affected at any harvest date by P fertilizer rate (Table 11). Marketable yields of extra large (5x6) or large (6x6) fruit were not significantly different for half or full P rates compared with the zero P rate for either first or second harvest. However, higher P rates tended to increase the number of boxes per acre of extra large size fruit for the first and second harvests compared with the zero P rate. The zero P rate tended to increased marketable yield of larger sized fruit. The fresh weight of cull fruit were, however, significantly greater for the zero P rate compared with the full rate at first harvest but were not significantly different at second harvest (Table A8.3). These yield data suggest that increased P in soil with high soil P index influences the size of tomato fruit produced and bottom line economic returns for the grower, however this can not be said conclusively due to lack of significance.

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 10). In the one crop, the plots receiving the grower 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 one 60 DAP sample at one out of five crops, no significant differences were observed for any soil P concentrations at any others location nor on any other sample dates. Biomass at 30 and 60 DAP were highest in the grower or half P rates compared with the zero P rate and were significantly greater in four out of five crops for each sampling period (Table 10). All but one of the significantly greater biomass observations were in plots receiving the grower P rate. Leaf P concentration tended to increase with increased P application rate with the majority of the concentration being in the grower P rate plots (Table 10). Significantly greater P concentrations were found in grower or half P rates on 30 DAP in 4 out of 5 crops compared with the zero P rate. However, only one out of five crops were statistically different on 60 DAP. Leaf P concentrations were within the sufficiency range at 30 DAP but decreased with some concentration being slightly below the range on 60 DAP. These data indicate great affect of P rate on green bean plant growth and leaf tissue P status.

Yield of the large (4-6 inch) bean size was significantly greater for the grower P rates compared with the zero P rate in five out of five crops (Table 11). 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 grower and half P rates. The grower 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 grower rates. These results would infer that increased P rate increases yield of large and moderate pod size of green beans.

Fertilizer P rate did not significantly influence soil P, biomass or leaf P concentration for the one corn crop produced in year three (Table 10). Yield for corn was not significantly different for P treatment but was greater for the zero P rate (Table 11). These data may suggest that increased P has no influence on biomass, plant nutrient status or yield of corn.

Table 10. Year Three Project Summary for Extractable Soil P Content, Plant Biomass Dry Weight and Total Leaf P Concentrations at Selected Intervals During the Growing Season.

			Soil P			Biomass			Leaf P		
Parcels	**Crop**	**Date[z]**	**Significant[y]**	**Highest Treatment[x]**	**Difference[w]**	**Significant[y]**	**Highest Treatment[x]**	**Difference[w]**	**Significant[y]**	**Highest Treatment[x]**	**Difference[w]**
Farm 1	Tomatoes	0	No	Z	21.7						
		60	No	G	13.3	No	Z	20.3	No	G	3.9
		120	No	G	12.7	No	H	40.4	No	H	20.0
Farm 2	Green	0	No	Z	6.1						
	Beans	30	No	Z	15.6	Yes	H	10.1	No	H	17.1
		60	No	Z	17.6	No		5.5	No	G	3.8
Farm 2	Corn	0	No	Z	5.8						
		30	No	G	4.2				No	H	11.7
		60	No	Z	10.9	No	Z	17.6	No	Z	16.1
Farm 3a	Green	0	No	G	20.0						
	Beans	30	No	G	13.4	Yes	G	11.7	Yes	G	55.6
		60	No	G	16.4	Yes	G	26.5	No	Z	3.8
Farm 3a	Green	0	Yes	G	29.4						
	beans	30	No	G	65.5	No	G	16.7	Yes	G	21.7
		60	No	G	22.0	Yes	G	67.3	No	G =H=Z[v]	0
Farm 3b	Green	0	No	G	15.1						
	Beans	30	No	G	3.9	Yes	G	29.2	Yes	G	38.5
		60	No	G	37.5	Yes	G	28.5	Yes	G	10.0
Farm 3b	Green	0	No	G	18.1						
	Beans	30	No	G	15.4	Yes	G	65.4	Yes	G	85.7
		60	Yes	G	47.7	Yes	G	87.4	No	G	0.8

[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≤ 0.05 level (95% confidence level)
[x]G=grower 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

Table11. 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]	Differnence[w]	Significant[y]	Highest Treatment[x]	Difference[w]	Significant[y]	Highest Treatment[x]	Difference[w]
Farm 1	Tomatoes	medium	No	G	67.5	No	G	11.0			
		large	No	Z	18.5	No	Z	20.8			
		xlarge	No	H	15.7	No	G	29.7			
Farm 2	Green	4-6	Yes	G	129.0						
	Beans	3-4	Yes	Z	54.4						
		<3	No	H	24.4						
Farm 2	Corn	total	No	Z	4.6						
Farm 3a	Green	4-6	Yes	G	19.3						
	Beans	3-4	No	G	6.4						
		<3	Yes	Z	31.4						
Farm 3a	Green	4-6	Yes	G	77.5						
	Beans	3-4	No	G	55.8						
		<3	No	G	56.2						
Farm 3b	Green	4-6	Yes	G	33.4						
	Beans	3-4	No	G	4.4						
		<3	No	G	9.1						
Farm 3b	Green	4-6	Yes	G	41.7						
	Beans	3-4	No	G	0.8						
		<3	No	G =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≤ 0.05 level (95% confidence level)
[x]G=grower 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

Soil Nutrients

Mehlich 1 extractable soil P fluctuated greatly during the study with little reduction by fertilizer P rate. Only minor differences in extractable soil P were evident between any of the P fertilizer treatments for samples taken at approximately 0, 30, 60 and 120 DAP. Of the 19 studies in this project, only the sample taken prior to planting at Farm 3a in the spring season of 2008 (Table A1.5) had significantly greater soil extractable P in the plots receiving the grower fertilizer rate compared with the zero rate. Four additional studies (Farm 1, Fall 2007, Table A5.3; Farm 2, Fall 2006, Table A1.1; Farm 2, Fall 2007, Table A1.2 and Farm 1 Fall 2007, Table A5.3), had non-significantly different soil samples taken at all farms prior to planting with higher extractable soil P in zero P rate compared with the grower rate. These two examples, taken with the fact that little evidence of lower extractable soil P at all farms leads to the conclusion that reduction in soil P from soils high or very high in soil test index will take many years. In a six year study, Obreza and McAvoy (unpublished) found little lowering of soil P concentration when no fertilizer P was added to high pH, high Ca soils and concluded that P in the form of calcium or other precipitates that are not extractable using Mehlich 1 extractant must become soluble over time in the soil by hydrolysis. Extractable soil P was significantly greater in soil collected from grower P fertilizer rate plots than the zero rate plots when taken at 60 days at Farm 1 in Spring 2006 (Table A5.1) and Farm 3b in Spring 2008 (Table A1.9). At the 110 DAP sampling at Farm 3a in Spring 2007 (Table A5.5) the soil P concentration in the half P rate plots were greater than the zero rate. Elevated extractable soil P at 30 and 110 DAP may be the result of excess P from fertilizer applications. However, due to the lack of large numbers of studies with significantly greater soil P in the plots where grower P rates were applied, it would be difficult to make a definite conclusion. Therefore, it seems more likely that the Mehlich 1 soil test P results from all plots represent a combination of soluble soil P (including fertilizer P) available for plant uptake and residual soil P in the form of precipitates that are not available to plants.

Change in soil K between soil samples followed no specific pattern with some samples increasing in soil K between samples and some decreasing for the same period of time. No significant difference was found in soil K concentrations among P rates prior to planting. The only soil samples at 30, 60 or 120 DAP with significant differences were at Farm 1 Fall 2006 (Table A5.2) and Farm 3a, Spring 2007 (Table A5.5). Samples with significant differences in K concentrations from Farm 1 and Farm 3a were taken at 60 DAP. At Farm 1 the half P rate was greater than both grower and zero rates, at Farm 3a the full P rate was greater than half and zero. The low number of significant differences among P treatments is expected since the same amount of K was applied to all plots at a specific farm and would indicate that varying fertilizer P does not significantly alter crop K uptake.

Soil Mg concentration was significantly greater in the zero P rate treatment plots than the grower P rate twice at the same farm (Farm 2, Tables A1.1 and A9.1). The first time was prior to planting for the Fall 2006 crop and then again at 60 and 110 DAP in the Spring 2007 crop. The trend for higher soil Mg with lower fertilizer P was not consistent as soil Mg at 60 and 110 DAP was found to be greater in the grower P rate plots compared with the zero P rates at Farm 3a in the spring of 2007 (Table A5.5). Similar opposing significant soil concentration results were observed with Fe at Farm 3a. Soil Fe concentrations were significantly greater with the zero P rate compared with the grower rate prior to planting in the fall of 2007 (Table A1.4), however, the grower P rate was higher than the zero rate prior to planting and at 29 DAP in the spring of 2008 (Table A1.5). Like Mg and Fe, significant differences in soil Ca concentrations among fertilizer P rates was conflicting. Calcium was high at all farms but varied significantly with fertilizer P rate at only one sampling date in each of three farms. The Ca concentration was greater for the zero rate prior to planting at Farm 3b in Spring 2008 (Table A1.9), for the grower rate on 60 DAP at Farm 3a Spring 2007 (Table A5.5) and for the half rate on 60 DAP at Farm 4 Spring 2007 (Table A5.6). The soil Mg data at two sampling dates in two consecutive crops at Farm 2 (Spring 2006, Table A9.1 and Fall 2006, Table A1.1) indicated that soil Mg at this farm was significantly greater in the zero P rate compared with the grower rate. These data at Farm 2 may be due to greater Mg uptake with increased P rate or spatial difference in soil Mg across the field. Other significant data for Mg and all significant finding for Fe and Ca were isolated sample dates at different farms and were not consistent with P treatment indicating no correlation with fertilizer P rate.

As with soil nutrients, soil pH is highly variable with relatively few sampling dates having significant differences in soil pH among fertilizer P rates. Soil pH was greater in the zero P rate treatments compared with the grower rate prior to planting at Farm 3b in the fall of 2007 (Table A1.8) and spring of 2008 (Table A1.9). The soil pH was also greater in the zero P rate plots than the grower P rate on 29 DAP at Farm 3a in Spring 2008 (Table A1.5), samples taken within 6 days of 60 DAP at Farms 1 in the spring of 2006 (Table A5.1), 3a in the fall of 2007 (Table A1.4) and 3b in the spring of 2008 (Table A1.9). One 120 DAP sampling date had greater soil pH in the zero P rate plots compared with the grower rate at Farm 2 in the spring of 2006 (Table A9.1). The only sampling date with greater soil pH in the half or grower P rate plots than the zero P rate was at 110 DAP at Farm 3a in spring of 2007 (Table A5.5). The reason for the apparent reduction in soil pH with added fertilizer P is unclear and was not consistently correlated with a significantly reduced or elevated soil P or Ca concentrations.

Biomass Accumulation

Plant stand (number of plants per unit length of row) was significantly greater in the half P fertilization compared with the zero and grower P rates on 60 DAP at Farm 2 in the fall of 2006 (Table A2.1). The decreases in plant population from 30 DAP to 60 DAP sampling dates may have been caused by small, weak plants being shaded and smothered by larger and more aggressive plants in the row. This single event would lead to the conclusion that insufficient evidence exists to determine that P fertilization rate affect seed germination and resulting plant populations.

Phosphorus fertilization rate did affect biomass accumulation of green bean, particularly as the crops approached harvest at 60 DAP (Fig. 6). Green bean biomass was significantly greater for the grower P rate compared with the zero rate on 30 DAP at Farm 2 (Fall 2007, Tables A2.2), 3a (Fall 2007, Table A2.4) and 3b (Fall 2007, Table A2.8 and Spring 2008, Table A2.9). Similarly, biomass was significantly greater for the grower P rate compared with the zero rate on 60 DAP at Farm 3a (Fall 2007, Tables A2.4 and Spring 2008, Table A2.4) and 3b (Fall 2007, Table A2.4 and Spring 2008, Table 2.9). The increase in plant size with increased P rate was emphasized when a small portion of a zero rate plot was accidentally fertilized with the same fertilizer as the plots containing the full rate. The plants were noticeably larger in the rows mistakenly fertilized at the higher P rate. These data indicate a strong inference that added P benefits green bean growth. Increased P rate did not greatly affect tomato biomass and any sampling date (Fig 7). No significant increase or decrease in plant biomass with fertilizer P rate was found. These data would support the conclusion that green bean growth is positively impacted by increased fertilizer P rate at soil P test indexes of high or very high in high pH and high Ca soil.

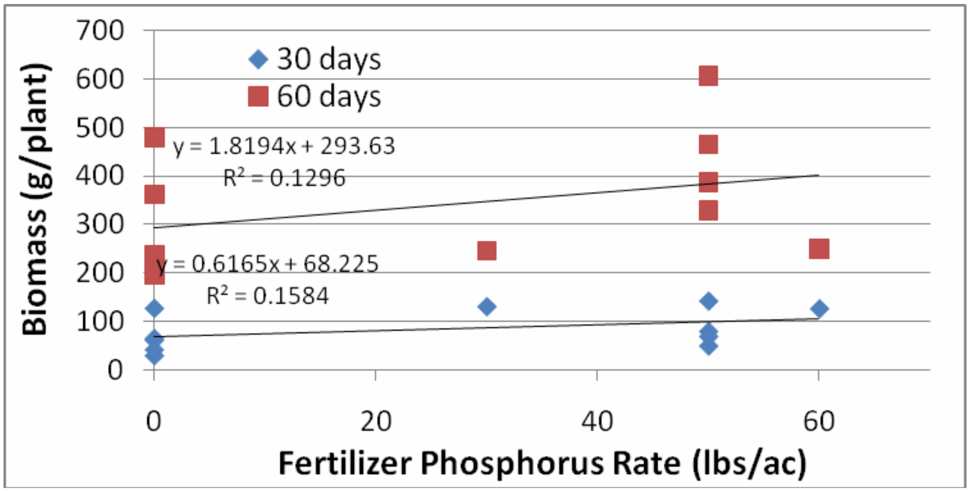

Figure 6. Increase in green bean plant biomass with increased fertilizer phosphorus rate at two sample dates 30 and 60 days after planting (DAP).

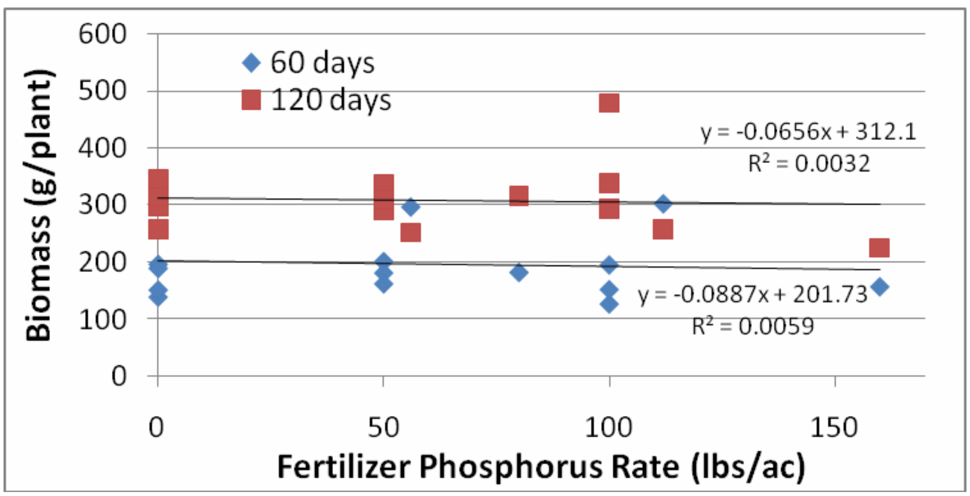

Figure 7. Change in tomato plant biomass with increased fertilizer phosphorus rate at two sample dates 60 and 120 days after planting (DAP).

Leaf Nutrient Concentration

Phosphorus fertilization affected leaf tissue elemental concentration early in the growing season for green beans but not as the crop neared harvest. At 30 DAP, leaf P concentration was greater in samples from the grower P rate plots at Farms 3a (Fall 2007, Table A3.4) and 3b (Fall 2007, Table A3.8 and Spring 2008, Table A3.9). This tendency of greater leaf P with increased fertilizer P was also evident at Farm 3b in the Spring 2008 at 54 DAP (Table A3.9). A similar leaf P concentration pattern was found in tomato, however it was evident later in the growing season. Leaf P concentration was significantly higher in the grower P rate samples compared with the zero rate samples at Farm 1 on 30 and 150 DAP in Spring 2006 (Table A7.1), and 120 DAP in Fall 2006 (Table A7.2). Significantly greater leaf P in the grower P rate plots was also found at Farm 3a on 90 and 110 DAP in Spring 2007 (Table A7.5).

The effect of fertilizer P rate on leaf N was not consistent. Leaf N was significantly greater in the zero P fertilizer rate plot compared with the full rate in leaf samples taken on about 60 DAP at Farm 3a in the spring of 2008 (Table A3.5) and Farm 3b in the spring of 2007 (Table A3.7). Conversely, leaf N was significantly greater in the grower or half rate plots compared with the zero rate plots on 30 DAP at Farm 1 in the Spring 2006 (Table A7.1) and Farm 3b in the Spring 2007 (Table A3.5). Leaf N was also significantly greater in the grower and half rate plots compared with the zero rate plots on 90 and 110 DAP at Farm 3a in the spring of 2007 (Table A7.5.). No other dates or crops were significantly different for leaf N concentration. The majority (all but 2) of these results was from green bean crops and may be explained by the concentration of N in the relatively low leaf biomass produced in the plants given zero fertilizer P.

Of the other nutrients tested, leaf K, S, Mg and Ca were significantly different by fertilizer P rate in a relatively few samples. Leaf K was significantly greater in the zero P rate plots compared with the grower rate plots on 60 DAP at Farm 3b in the Fall of 2007 (Table A3.8) while both the grower and zero P rates were greater than the half rate on 60 DAP at Farm 3a in the Spring of 2008 (Table A7.5). Leaf Mg was greater in the zero P rate plots compared with the grower rate at Farm 3a in the Fall of 2006 (30 DAP, Table A3.3) and Spring 2007 (110 DAP, Table A7.5) while the grower P rate had significantly greater leaf Mg than the zero rate on 30 DAP at Farm 1 in the spring of 2006 (Table A7.1). Leaf S and Ca concentrations had opposite tendency. Leaf S decreased with increased fertilizer P rate on 30 DAP at Farm 3a (Fall 2006, Table A3.3) and on 30 and 110 DAP at Farm 1 (Spring 2006, Table A7.1). Leaf Ca decreased with increased fertilizer P rate on 60 and 110 DAP at Farm 3a (Spring 2007, Table 7.5) and on 60 DAT at Farm 3b (Fall 2007). No strong trends are apparent for leaf nutrient concentration other than P with fertilizer P rate, sampling time or crop.

Crop Yield

Phosphorus fertilization had a great affect on yield of the largest (4-6 inch) size green beans but not the smaller pod sizes (Fig.8). For the 4 to 6 inch size category, the full rate of P fertilizer produced significantly more yield than the zero rate in seven out of nine crops (Tables 7, 9, and 11) including five out of five in the third year of the demonstration project (Tables A4.2, A4.3, A4.4, A4.5, A4.7, A4.8 and A4.9). In these five crops the 4 to 6 inch size category contributed an average of 89.1% of the total marketable yield among all farms and is the highest revenue generating category due to the combination of higher yield and price. This yield category represented the greatest portion of total marketable yield. Medium (3 to 4 inch) green bean pod category accounted for an average of only 8.1% of total marketable yield among the five crops grown at all farms in 2007/2008 (Tables A4.2, A4.3, A4.4, A4.5, A4.7, A4.8 and A4.9) and pods less than 3 inches in length, that bring the lowest price, averaged 2.8%.

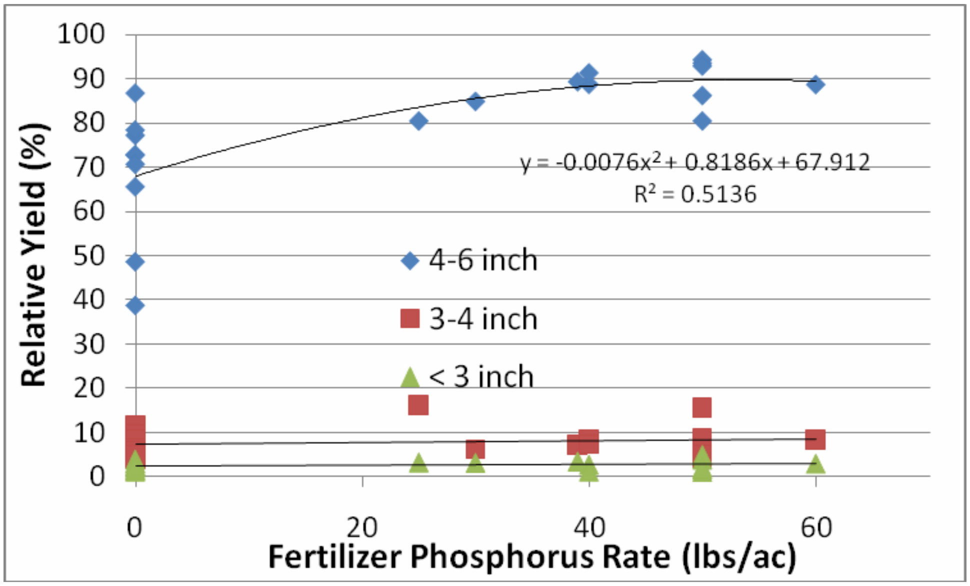

Figure 8. Green been yeild for three size categories by fertilzier P application rate.

Few yields of the smaller two pod categories (3-4 inch and <3 inch) differed significantly by fertilizer P rate, and results for the 3-4 inch category were highly variable. No 3 to 4 inch pod yields were significantly greater for the full rate compared with the zero rate, only one crop was significantly greater for the zero rate. Medium pod size yield for one crop at Farm 2 in the fall of 2006 (Table A4.1) was significantly greater for the half and full rates compared with the zero P fertilizer rates and a crop at Farm 2 in the fall of 2007 (Table A4.2) had non-significantly greater yield of medium length beans in the zero P rate plots compared with the grower rate. The two conflicting results would indicate little consistent influence of P rate on the medium green bean size category. Only one crop (Farm 3a Fall 2007, Table A4.4) had significantly greater yield of pod length less than 3 inches for the grower P rate compared with the zero rate. Green bean pods tended to be larger at Farm 2 (Tables A4.1 and A4.2) compared with those harvested at Farms 3a (Tables A4.3-A4.5) and 3b (Tables A4.6-A4.9). Green beans grown at Farm 2 were fertilized with liquid fertilizer and higher P rates (50-60 lbs P/ac, Table 3) compared with Farms 3a and 3b that were fertilized with dry soluble fertilizer at lower P rates (40-50 lbs P/ac). However, direct comparison of these two P application methods may not be reasonable.

Few crops of tomato resulted in significantly different yield of the three fruit size categories for up to three harvests per season (Tables 7, 9, and 11). Therefore, tomato yield for the three fruit sizes varied little with fertilizer P rate (Fig. 9). Large size fruit yield at first harvest was greater for the half P rate compared with the zero P rate at Farm 3a in the Spring of 2007 (Table 8.5). However, the large size yield was greater for the zero P rate than the grower rate at the third harvest at Farm 1 in the spring of 2006 (Table A8.1) and 3a in the spring of 2007 (Table A8.5). These results would indicate no effect of fertilizer P rate on extra large tomato fruit yields in soils with high or very high soil P test index but may delay production of large fruit to the third harvest if no fertilizer P is applied. This conclusion is based on only two out of six crops and needs more testing. Using these results it would appear that a rate of 40 to 50 pounds of P per acre at a high soil P index would be justified for production of large fruit at the first harvest. Under current recommendations, no yield response to added soil P should be expected at soil test P index of high or better. Therefore, soil test P index in soils with high pH and Ca concentrations need to be re-evaluated.

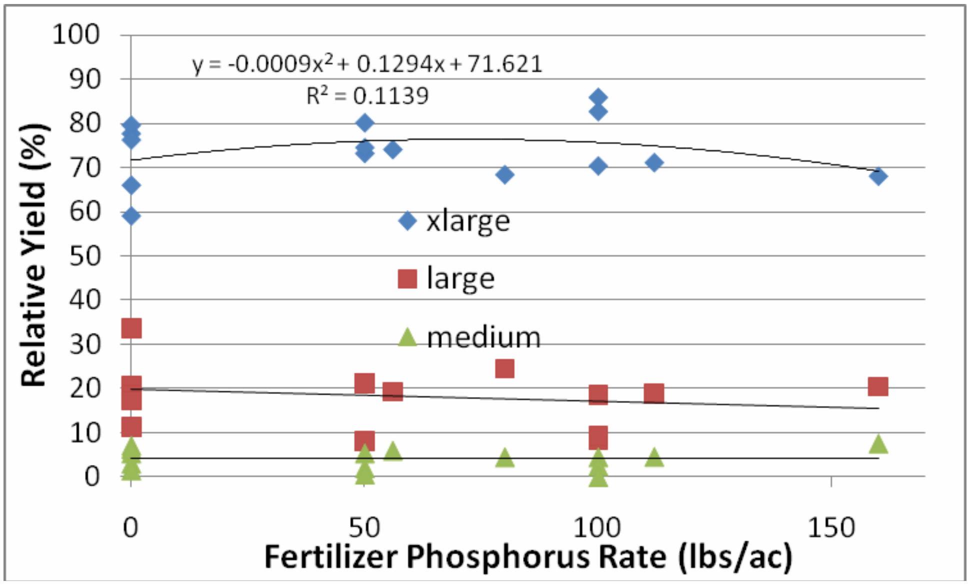

Figure 9. Tomato yield for three size categories by fertilzier P application rate.

Three miscellaneous crops (eggplant, hot peppers and corn, Appendix 9) were grown in the three years of the demonstration project**.** Phosphorus fertilization did not affect extractable amounts of other plant nutrients (Tables A9.1, A9.4 and A9.8), plant biomass (Tables A9.1, A9.5 and A9.9) and leaf tissue elemental concentration (Tables A9.2, A9.6 and A9.10). Leaf P concentration was near or in the sufficiency range throughout the study. Phosphorus fertilization rate did not significantly affect marketable yield of eggplant, peppers or corn grown in this study (Tables A9.3, A9.7 and A9.11). However a small reduction in marketable yield of all three crops were noted with the zero fertilizer P rate compared with the full rate.

Project Conclusions

The two crops grown the most number of time during the three years of this grower demonstration project were green beans and tomato. These crops plus sweet and hot peppers dominate vegetable production in the C-139 Basin. Tomatoes were used as representative crop of the solanaceous varieties that include peppers. Three other crops were grown during the project because these crops are commonly grown in rotation with green beans and tomatoes. However, because only one crop of each were grown these results did not lead to significant conclusions. Soil P test index in the zero P rate plots at all farms were high or very high throughout the three years of studies and in only one soil test prior to planting was P significantly greater in the grower P rate plots compared with the zero P rate. Also, all three soil tests at greater than 0 DAP were significantly greater in the grower or half P rate plots compared with the zero P rate plots. Therefore, it can be concluded that the zero fertilizer P rate had little effect on soil P concentrations indicating it may take many years to reduce residual P concentrations below the high soil P index concentration.

Increased growth of green bean plants with increased fertilizer P rate was observed in five of the nine crops grown during the demonstration project. Green bean yield data suggest that the full rate of P fertilization produced higher yield of large pod size in seven out of nine crops grown. Increased yield of the large size pods occurred in years two and three while increased biomass accumulation was observed in year three. These results may indicate that while soil test P is still high, soil P may be less available for plant uptake resulting in reduced growth and yield in plots where no fertilizer P has been applied. If this observation is correct, then the effect of zero P on growth and yield should increase with time. Leaf P concentration supports this conclusion with increased leaf P with increased fertilizer P on 30 DAP in four of five crops grown in year three. Leaf P concentrations improve as the plants grow resulting in increased leaf P with increased fertilizer P in only one out of five crop in the third year. This would be consistent with leaf nutrient status of leaves in a crop with reduced biomass compared to leaves of a larger plant provided with increased fertilizer P. Using these results it would appear that a rate of 40 to 50 pounds of P per acre at a high soil P index would be justified. Under current recommendations, no yield response to added soil P should be expected at soil test P index of high or better. However, increased growth and yield was determined for green beans and suggested for tomato. Therefore, soil test P index in soils with pH greater than 7.0 and Ca concentrations greater than 400 ppm needs to be re-evaluated for tomato and other vegetable crops.

The tomato crops grown in this study showed little positive effect of P fertilization. No biomass increase with increasing fertilizer P rate was observed over the three years of this demonstration. The lack of effect of fertilizer P rate on tomato growth was reflected in the low number of significant differences in leaf P. Leaf P increased with increasing fertilizer P at 120 DAP but not 60 DAP in two out of the five tomato crops grown. However, the observed increase in large fruit production at first harvest for one tomato crop out of five along with increase in large fruit production at third harvest with reduced fertilizer P for two tomato crops out of five suggests a delay in time for fruit maturity with reduced fertilizer P even at high soil P index. Due to the low number of significant between time of maturity and fertilizer P applications, these results are not definitive and needs additional data to be conclusive.

Biomass, tissue P concentration and yield of the three miscellaneous crops in this study were, overall, unresponsive to the rate of P applications; however, because only one crop of each of the three miscellaneous crops (i.e. egg plant, peppers and corn) was grown, no firm conclusions could be drawn.

Future Work

Data collected during this three year demonstration project has provided the growers of the C-139 basin and the South Florida Water Management District with valuable information on the use of soil P test based fertilizer recommendations for vegetable crops. The results of this project have been presented to participating growers on a one-to-one basis and the grower community at two public meetings each year. These meetings have maintained the interest of the growers cooperating in the project. Several interesting conclusions can be made from the data presented in this report. The main conclusion of the current project that the soil test indexes using Mehlich 1 soil extractant is not effective in determining fertilizer P recommendations in soils of south Florida with high pH and Ca concentrations suggest that several lines of investigation are needed.

1) The use of other soil extractants as a soil P test index in these soils prone to “fixing” P should be evaluated. Olsen and Brey extractants are currently being used in other soils with similar soil pH and Ca concentrations. A multiple year study with several crops and several P rates should be conducted to evaluate these alternative extractants. Soil samples prior to and during crop production would be extracted using these extractants along with Mehlich 1. Results of analysis from the resulting soil extracts would be evaluated along with crop growth and yield data to determine an appropriate P index for each extractant. To more effectively evaluate the results of these studies the number of P rates needs to be increased to four or more with the same number used at each location. Additionally, more than the three replications used in the current study should improve the statistics and increase the likelihood of obtaining significant difference among treatment means if an effect of fertilizer P rate exists.
2) To understand the form of P being extracted by the different soil test extractants and to better evaluate the effectiveness of the soil test extractants to represent total soil P concentrations, the soils being extracted need to be tested using a sequential extraction technique. This technique uses a series of soil extractant with increasing acidity to remove soil P that are in labile forms, several different precipitated forms and organic forms. Knowing the relative amounts of P in each of these forms will lead to better understanding of the form of P being extracted by each soil test extractant and thus the extractant that provides the best information on labile or plant available P.
3) Reduction of soil pH will allow for improved availability of residual and applied P. Application of a soil acidifying agent in the fertilizer zone should improve the availability of the applied P as well as any residual P. These should be evaluated using at least two target pH values along with the soil extractants above to understand the source of available P. Caution in applying the agent to only to the planted bed where crop roots will access the soil P will limit impact on the environment beyond the targeted soil. Application of plastic mulch to the planted beds will reduce and mostly eliminate any surface runoff of the acidifying agents. Soil samples and water quality testing will be needed to determine any leaching of the acidifying agent beyond the root zone.

Appendix 1 – Green Bean Soil Sample Data

Table A1.1. Farm 2 - Fall 2006 Soil Nutrient Content. 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. Samples were collected at time of planting (25 August 2006), and at 30 (9 November 2006) and 60 (15 December 2006) days after planting. (n-1 = 8)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	pH
			-------------------- Before seeding --------------------		
Zero	57	26	107	1920	7.6
Half	26	22	90	1780	7.5
Full	37	20	80	1633	7.6
		Significance[Y]			
Treatment	0.133	0.658	0.065	0.082	0.640
Block	0.849	0.397	0.841	0.854	0.978
Treatment x Block	0.873	0.893	0.785	0.978	0.789
			---------------- 30 days after seeding ----------------		
Zero	100	55	80	1687	7.5
Half	94	76	101	1697	7.7
Full	110	69	105	2013	7.6
		Significance[Y]			
Treatment	0.463	0.802	0.567	0.415	0.768
Block	0.834	0.264	0.782	0.723	0.783
Treatment x Block	0.897	0.902	0.783	0.978	0.842
			---------------- 60 days after seeding ----------------		
Zero	109	71	113 a a	920	7.6
Half	106	44	94 b b	1147	7.7
Full	97	34	89 b b	1137	7.8
		Significance[Y]			
Treatment	0.658	0.083	0.021	0.721	0.532
Block	0.890	0.834	0.872	0.978	0.897
Treatment x Block	0.782	0.872	0.894	0.723	0.827
Shapiro-Wilk[X]	0.989	0.378	0.534	0.802	0.837

[Z] zero (0 lb P/acre), Half (25 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A1.2. Farm 2 - Fall 2007 Soil Nutrient Content. 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. Samples were collected at time of planting (3 September 2007), and at 29 (1 October 2007) and 54 (26 October 2007) days after planting. (n-1 = 8)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Ca (ppm)	Fe (ppm)	pH
		---------------- *Before planting* ----------------			
Zero	347	69	3010	10	7.9
Half	330	62	2778	10	7.8
Full	327	39	2717	9	7.8
		Significance [Y]			
Treatment	*0.721*	*0.524*	*0.692*	*0.602*	*0.179*
Block	*0.023*	*0.062*	*0.033*	*0.494*	*0.220*
Treatment x Block	*0.312*	*0.599*	*0.687*	*0.350*	*0.602*
		---------------- *29 days after planting* ----------------			
Zero	355	83	2901	3	7.8
Half	307	40	2473	12	7.7
Full	350	62	2815	13	7.7
		Significance [Y]			
Treatment	*0.099*	*0.569*	*0.101*	*0.138*	*0.692*
Block	*0.018*	*0.317*	*0.019*	*0.866*	*0.756*
Treatment x Block	*0.128*	*0.653*	*0.160*	*0.727*	*0.814*
		---------------- *54 days after planting* ----------------			
Zero	348	61	3001	10	7.9
Half	296	25	2495	11	7.8
Full	309	43	2808	11	7.9
		Significance [Y]			
Treatment	*0.245*	*0.347*	*0.257*	*0.252*	*0.313*
Block	*0.094*	*0.067*	*0.020*	*0.022*	*0.007*
Treatment x Block	*0.711*	*0.627*	*0.572*	*0.329*	*0.131*
Shapiro-Wilk[X]	*0.253*	*0.229*	*0.466*	*0.148*	*0.097*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A1.3. Farm 3a and 3b - Fall 2006 Soil Nutrient Content. 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. Samples were collected at time of planting (Farm 3a on 28 September and Farm 3b on 23 October 2006), and at 30 (Farm 3a on 31 October 2006 and Farm 3b on 22 November 2006) and 60 (Farm 3a on24 November 2006 and Farm 3b on 22 December 2006) days after planting. (n-1= 5)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	pH
	----------------	*Before seeding*	----------------		
Zero	87	24.67	393	905.9	7.133
Full	103	31.25	506	653.9	6.475
			Significance[Y]		
Treatment	*0.410*	*0.625*	*0.727*	*0.717*	*0.554*
Block	*0.874*	*0.823*	*0.834*	*0.683*	*0.824*
Treatment x Block	*0.789*	*0.789*	*0.754*	*0.782*	*0.894*
	----------	*30 days after seeding*	----------------		
Zero	61	46.2	286.2	897.4	7.42
Full	52.5	39.83	353.8	692.4	6.783
			Significance[Y]		
Treatment	*0.968*	*0.776*	*0.648*	*0.712*	*0.377*
Block	*0.984*	*0.872*	*0.871*	*0.833*	*0.284*
Treatment x Block	*0.981*	*0.371*	*0.478*	*0.873*	*0.473*
	----------	*60 days after seeding*	----------------		
Zero	38.8	57.2	241	1199.5	7.32
Full	52.17	56.67	355.8	859.2	6.883
			Significance[Y]		
Treatment	*0.204*	*0.390*	*0.717*	*0.653*	*0.715*
Block	*0.233*	*0.238*	*0.871*	*0.289*	*0.827*
Treatment x Block	*0.237*	*0.234*	*0.873*	*0.843*	*0.872*
Shapiro-Wilk[X]	*0.541*	*0.398*	*0.873*	*0.789*	*0.873*

[Z] zero (0 lb P/acre) and Full (40 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A1.4. Farm 3a - Fall 2007 Soil Nutrient Content. 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. Samples were collected at time of planting (8 October 2007), and at 29 (9 November 2007) and 66 (1 December 2007) days after planting. (n-1 = 5)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Ca (ppm)	Fe (ppm)	pH
	---------------------- *Before planting* -------------------------				
Zero	164	16	470	39 a a	8.1
Half	175	16	539	26	7.9
Full	186	16	579	35 b a	7.8
Significance[Y]					
Treatment	*0.175*	*0.953*	*0.074*	*0.038*	*0.255*
Block	*0.995*	*0.053*	*0.420*	*0.063*	*0.760*
Treatment x Block	*0.391*	*0.316*	*0.129*	*0.344*	*0.658*
	------------------- *29 days after planting* -------------------				
Zero	185	53	608	34	7.9
Half	201	49	621	35	7.8
Full	222	45	656	38	7.7
Significance[Y]					
Treatment	*0.387*	*0.659*	*0.476*	*0.303*	*0.204*
Block	*0.207*	*0.478*	*0.038*	*0.652*	*0.239*
Treatment x Block	*0.117*	*0.505*	*0.187*	*0.900*	*0.452*
	------------------- *66 days after planting* -------------------				
Zero	162	304	524	32	7.9 a a
Half	178	287	543	33	7.8 b b
Full	188	273	561	35	7.8 b b
Significance[Y]					
Treatment	*0.407*	*0.059*	*0.485*	*0.195*	*0.022*
Block	*0.887*	*0.828*	*0.848*	*0.223*	*0.039*
Treatment x Block	*0.878*	*0.147*	*0.149*	*0.498*	*0.106*
Shapiro-Wilk[X]	*0.318*	*0.162*	*0.827*	*0.291*	*0.158*

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A1.5. Farm 3a - Spring 2008 Soil Nutrient Content. 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. Samples were collected at time of planting (6 January 2008), and at 29 (8 February 2008) and 56 (6 March 2008) days after planting. (n-1 = 5)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Ca (ppm)	Fe (ppm)	pH
	------------------------- *At planting* ----------------------------				
Zero	146 b b	51	483	38 a a	8.0
Half	156 b b	48	524	35	7.9
Full	189 a a	42	554	39 b b	7.9
	Significance [Y]				
Treatment	*0.021*	*0.251*	*0.054*	*0.040*	*0.118*
Block	*0.334*	*0.031*	*0.015*	*0.631*	*0.049*
Treatment x Block	*0.303*	*0.207*	*0.738*	*0.128*	*0.099*
	----------------- *29 days after planting* ---------------------				
Zero	148	48	421	37 b b	8.3 a a
Half	198	54	578	48	7.6 b b
Full	245	61	569	55 a a	7.3 b b
	Significance [Y]				
Treatment	*0.103*	*0.302*	*0.131*	*0.005*	*0.007*
Block	*0.844*	*0.115*	*0.492*	*0.221*	*0.814*
Treatment x Block	*0.136*	*0.348*	*0.227*	*0.741*	*0.482*
	----------------- *56 days after planting* ---------------------				
Zero	159	19	524	32	8.0
Half	187	17	539	33	8.2
Full	194	17	561	34	8.2
	Significance [Y]				
Treatment	*0.127*	*0..227*	*0.040*	*0.288*	*0.316*
Block	*0.887*	*0.828*	*0.849*	*0.223*	*0.039*
Treatment x Block	*0.521*	*0.401*	*0.144*	*0.498*	*0.309*
Shapiro-Wilk[X]	*0.316*	*0.196*	*0.493*	*0.661*	*0.341*

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A1.6. Farm 3b - Spring 2006 Soil Nutrient Content. 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. Samples were collected at time of planting (3 February 2006), and at 30 (5 March 2006) and 60 (4 April 2006) days after planting. (n-1 = 3)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	pH
	------------- *Before planting* --------------				
Average	67	42	80	1270	7.6
	---------- *30 days after planting* -----------				
Zero	83	81	109	2220	7.4
Full	86	81	97	1970	7.4
	Significance[Y]				
Treatment	0.401	0.896	0.238	0.232	0.782
Block	0.876	0.875	0.782	0.872	0.727
Treatment x Block					
	---------- *60 days after planting* -----------				
Zero	84	36	113	2200	7.9
Full	86	48	106	2050	7.8
	Significance[Y]				
Treatment	0.233	0.273	0.389	0.873	0.345
Block	0.872	0.891	0.892	0.345	0.435
Treatment x Block					
Shapiro-Wilk[X]	0.908	0.672	0.214	0.364	0.345

[Z] zero (0 lb P/acre) and Full (40 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A1.7. Farm 3b - Spring 2007 Soil Nutrient Content. 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. Samples were collected at time of planting (8 February 2007), and at 30 (12 March 2007) and 45 (30 March 2007) days after planting. (n-1 = 3)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	pH
	---------- *30 days after planting* ----------				
Zero	33.5	105.0	83.5	1610	7.10
Full	49.50	83.50	85.50	1390	7.35
	Significance[Y]				
Treatment	*0.274*	*0.843*	*0.285*	0.492	*0.394*
Block	*0.789*	*0.584*	*0.289*	0.344	*0.235*
Treatment x Block					
	---------- *45 days after planting* -----------				
Zero	58.00	60.00	94.00	1215	7.25
Full	40.50	91.50	85.50	1715	7.30
	Significance[Y]				
Treatment	*0.385*	*0.295*	*0.785*	*0.289*	*0.357*
Block	*0.948*	*0.343*	*0.734*	*0.363*	*0.346*
Treatment x Block					
Shapiro-Wilk[X]	0.256	0.152	0.253	0.263	0.362

[Z] zero (0 lb P/acre) and Full (40 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A1.8. Farm 3b - Fall 2007 Soil Nutrient Content. 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. Samples were collected at time of planting (11 October 2007), and at 27 (9 November 2007) and 62 (17 December 2007) days after planting. (n-1 = 3)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Ca (ppm)	Fe (ppm)	pH
	----------------------- *Before planting* -------------------------				
Zero	86	20	923	6.0	8.1 a a
Full	99	15	830	6.5	7.9 b b
	Significance [Y]				
Treatment	*0.152*	*0.203*	*0.246*	*0.246*	*0.047*
Block	*0.930*	*0.549*	*0.021*	*0.512*	*0.098*
Treatment x block					
	------------------- *27 days after planting* --------------------				
Zero	102	24	1017	4.60	7.9
Full	106	16	902	5.15	7.9
	Significance [Y]				
Treatment	*0.714*	*0.057*	*0.389*	*0.347*	*0.636*
Block	*0.956*	*0.312*	*0.063*	*0.167*	*0.485*
Treatment x Block					
	------------------- *60 days after planting* -------------------				
Zero	72	21	763	7.4	8.0
Full	99	17	763	7.6	7.8
	Significance [Y]				
Treatment	*0.057*	*0.214*	*0.998*	*.0874*	*0.088*
Block	*0.0737*	*0.338*	*0.019*	*0.561*	*0.312*
Treatment x Block					
Shapiro-Wilk[X]	*0.145*	*0.389*	*0.143*	*0.148*	*0.127*

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A1.9. Farm 3b – Spring 2008 Soil Nutrient Content. 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. Samples were collected at time of planting (20 January 2008), and at 31 (21 February 2008) and 58 (20 March 2008) days after planting. (n-1 = 3)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Ca (ppm)	Fe (ppm)	pH
	---------------------- *Before planting* ---------------------------				
Zero	83	32	877 a a	7.3	8.2 a a
Full	98	38	750 b b	7.7	8.0 b b
		Significance [Y]			
Treatment	*0.265*	*0.248*	*0.025*	*0.437*	*0.006*
Block	*0.928*	*0.137*	*0.002*	*0.062*	*0.082*
Treatment x Block					
	------------------ *31 days after planting* ------------------------				
Zero	78	19	879	7.4	8.3
Full	90	19	716	6.6	8.1
		Significance [Y]			
Treatment	*0.189*	*0.980*	*0.072*	*0.493*	*0.308*
Block	*0.078*	*0.901*	*0.005*	*0.177*	*0.070*
Treatment x Block					
	------------------- *58 days after planting* ----------------------				
Zero	65 b b	28	746	5.2	8.3 a a
Full	96 a a	17	652	3.1	7.7 b b
		Significance [Y]			
Treatment	*0.024*	*0.179*	*0.533*	*0.342*	*0.003*
Block	*0.373*	*0.456*	*0.149*	*0.803*	*0.012*
Treatment x Block					
Shapiro-Wilk[X]	*0.131*	*0.094*	*0.113*	*0.136*	*0.147*

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Appendix 2 Green Bean Biomass Data

Table A2.1. Farm 2 – Fall 2006 Green Bean Plant Stand and Biomass. Two to four individual plants throughout each plot were harvested. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected at 30 (9 November 2006) and 60 (15 December 2006) DAP. (n-1 = 8)

P Fertilizer Rate[Z]	Plant Stand (plants/acre)	Plant Biomass (g/plant)
	----------30 days after planting----------	
Zero	57,435	147
Half	57,435	107
Full	53,885	103
	Significance[Y]	
Treatment	*0.514*	*0.142*
Block	*0.723*	*0.433*
Treatment x Block	*0.782*	*0.343*
	----------60 days after planting----------	
Zero	51,304 b b	250
Half	55,983 a a	223
Full	51,949 b b	212
	Significance[Y]	
Treatment	*0.036*	*0.576*
Block	*0.232*	*0.245*
Treatment x Block	*0.131*	*0.643*
Shapiro-Wilk[X]	*0.253*	*0.235*

[Z] zero (0 lb P/acre), Half (25 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A2.2. Farm 2 – Fall 2007 Green Bean Plant Stand and Biomass. Two to four individual plants throughout each plot were harvested. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected at 29 (1 October 2007) and 54 (26 October) DAP. (n-1 = 8)

P Fertilizer Rate[Z]	Plant Stand (no/10ft)	Plant Biomass (g/plant)
	-- 29 days after planting --	
Zero	38.50	65.52 b b
Half	43.17	131.71 a a
Full	38.50	127.33 a a
	Significance[Y]	
Treatment	*0.697*	*0.009*
Block	*0.906*	*0.476*
Treatment x Block	*0.810*	*0.988*
	-- 54 days after planting --	
Zero	41.50	236
Half	45.83	245
Full	47.50	249
	Significance[Y]	
Treatment	*0.514*	*0.797*
Block	*0.790*	*0.483*
Treatment x Block	*0.888*	*0.594*
Shapiro-Wilk[X]	*0.777*	*0.747*

[Z] zero (0 lb P/acre), Half (30 lb P/acre) and Full (60 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A2.3. Farm 3a and 3b – Fall 2006 Green Bean Plant Stand and Biomass. Two to four individual plants throughout each plot were harvested. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected at 30 (Farm 3a on 31 October 2006 and Farm 3b on 22 November 2006) and 60 (Farm 3a on 24 November 2006 and Farm 3b on 22 December 2006) DAP. (n-1 = 5)

P fertilizer Rate[Z]	Plant Stand (no/acre)	Plant Biomass (g/plant)
	-- 30 days after planting --	
Zero	79,860	140
Full	79,406	182
	Significance[Y]	
Treatment	*0.452*	*0.285*
Block	*0.792*	*0.348*
Treatment x Block	*0.893*	*0.542*
	-- 60 days after planting --	
Zero	78,045	346
Full	76,139	290
	Significance[Y]	
Treatment	*0.715*	*0.356*
Block	*0.734*	*0.458*
Treatment x Block	*0.874*	*0.573*
Shapiro-Wilk[X]	*0.257*	*0.245*

[Z] zero (0 lb P/acre) and Full (40 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A2.4. Farm 3a – Fall 2007 Green Bean Plant Stand and Biomass. Two to four individual plants throughout each plot were harvested. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected at 29 (9 November 2007) and 66 (11 December) DAP.(n-1 = 5)

P Fertilizer Rate[Z]	Plant Stand (no/10ft)	Plant Biomass (g/plant)
	-- 29 days after planting --	
Zero	53.25	128 b b
Half	51.92	141.a a
Full	51.12	143 a a
Significance[Y]		
Treatment	*0.173*	*0.028*
Block	*0.208*	*0.578*
Treatment x Block	0.683	0.983
	-- 66 days after planting --	
Zero	50.00	479 b b
Half	53.38	601 a a
Full	54.25	606 a a
Significance[Y]		
Treatment	*0.405*	*0.004*
Block	*0.863*	*0.732*
Treatment x Block	0.324	0.886
Shapiro-Wilk[X]	0.543	0.225

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A2.5. Farm 3a – Spring 2008 Green Bean Plant Stand and Biomass. Two to four individual plants throughout each plot were harvested. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected at 30 (7 February 2008) and 60 (6 March 2008) DAP. (n-1 = 5)

P Fertilizer Rate[Z]	Plant Stand (no/10ft)	Plant Biomass (g/plant)
	-- 30 days after planting --	
Zero	54.75	30
Half	53.92	32
Full	52.50	35
	Significance[Y]	
Treatment	*0.251*	*0.128*
Block	*0.190*	*0.272*
Treatment x Block	0.606	0.297
	-- 60 days after planting --	
Zero	54.25	196 b b
Half	53.29	312 a a
Full	51.88	328 a a
	Significance[Y]	
Treatment	*0.392*	*<0.0001*
Block	*0.480*	*0.626*
Treatment x Block	0.754	0.595
Shapiro-Wilk[X]	0.330	0.133

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A2.6. Farm 3b – Spring 2006 Green Bean Plant Stand and Biomass. Two to four individual plants throughout each plot were harvested. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected at 30 (5 March 2006) and 60 (6 April 2006) DAP. (n-1 = 3)

P fertilizer Rate[Z]	Plant Stand (no/acre)	Plant Biomass (g/plant)
	-- 30 days after planting --	
Zero	72,200	58
Full	71,700	75
	Significance[Y]	
Treatment	*0.500*	*0.164*
Block	*0.823*	*0.854*
Treatment x Block		
	-- 60 days after planting --	
Zero	63,000	474
Full	62,400	572
	Significance[Y]	
Treatment	*0.742*	*0.222*
Block	*0.874*	*0.345*
Treatment x Block		
Shapiro-Wilk[X]	*0.348*	*0.643*

[Z] zero (0 lb P/acre) and Full (39 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A2.7. Farm 3b – Spring 2007 Green Bean Plant Stand and Biomass. Two to four individual plants throughout each plot were harvested. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected at 30 (12 March 2007) and 45 (30 March 2007) DAP. (n-1 = 3)

P fertilizer Rate[Z]	Plant Stand (no/acre)	Plant Biomass (g/plant)
	-- 30 days after planting --	
Zero	72,056	68.5
Full	74,597	94.0
	Significance[Y]	
Treatment	0.331	0.155
Block	0.723	0.284
Treatment x Block		
	-- 45 days after planting --	
Zero	68,607	280.3
Full	71,693	443.4
	Significance[Y]	
Treatment	0.182	0.121
Block	0.245	0.237
Treatment x Block		
Shapiro-Wilk[X]	0.231	0.124

[Z] zero (0 lb P/acre) and Full (40 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A2.8. Farm 3b – Fall 2007 Green Bean Plant Stand and Biomass. Two to four individual plants throughout each plot were harvested. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected at 27 (9 November 2007) and 62 (17 December 2007) DAP. (n-1 = 3)

P Fertilizer Rate^{Z}	Plant Stand (no/10ft)	Plant Biomass (g/plant)
	-- 27 days after planting --	
Zero	52.25	61.95 b b
Full	51.36	80.07 a a
	Significance^{Y}	
Treatment	0.683	0.008
Block	0.600	0.317
Treatment x Block		
	-- 62 days after planting --	
Zero	50.63	361.5 b b
Full	50.00	464.5 a a
	Significance^{Y}	
Treatment	0.852	0.002
Block	0.360	0.795
Treatment x Block		
Shapiro-Wilk^{X}	0.500	0.179

^{Z} zero (0 lb P/acre) and Full (50 lb P/acre)
^{Y} Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
^{X} The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A2.9. Farm 3b – Spring 2008 Green Bean Plant Stand and Biomass. Two to four individual plants throughout each plot were harvested. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected at 30 (20 February 2008) and 68 (30 March 2008) DAP. (n-1 = 3)

P Fertilizer Rate[Z]	Plant Stand (no/acre)	Plant Biomass (g/plant)
	-- 31 days after planting --	
Zero	53.12	42.06 b b
Full	55.00	69.56 a a
	Significance[Y]	
Treatment	0.394	<0.0001
Block	0.529	0.002
Treatment x Block		
	-- 68 days after planting --	
Zero	51.12	206.2 b b
Full	53.38	386.4 a a
	Significance[Y]	
Treatment	0.355	<0.0001
Block	0.054	0.006
Treatment x Block		
Shapiro-Wilk[X]	0.146	0.137

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Appendix 3 Green Bean Leaf Sample Data

Table 3.1. Farm 2 – Fall 2006 Green Bean Leaf Tissue Elemental Content. Nutrient content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 30 (9 November 2006) and 60 (15 December 2006) days after planting. Final leaf tissue concentrations are based on dry weight. (n-1 = 8)

P fertilizer Rate[Z]	N (%)	S (%)	P (%)	K (%)	Mg (%)	Ca (%)
		---------------- *30 days after seeding* ----------------				
Zero	2.83	0.190	0.390	3.420	0.390	1.450
Half	2.43	0.223	0.420	3.230	0.297	1.193
Full	2.63	0.237	0.410	3.377	0.287	1.153
			Significance[Y]			
Treatment	*0.808*	*0.128*	*0.584*	*0.847*	*0.196*	*0.286*
Block	*0.892*	*0.346*	*0.246*	*0.357*	*0.236*	*0.435*
Treatment x Block	0.834	0.254	0.336	0.556	0.154	0.455
		---------------- *60 days after seeding* ----------------				
Zero	3.367	0.147	0.280	2.287	0.273	1.827
Half	3.333	0.150	0.230	2.123	0.270	1.913
Full	3.833	0.163	0.290	2.593	0.247	1.467
			Significance[Y]			
Treatment	*0.237*	*0.713*	*0.978*	*0.308*	*0.412*	*0.235*
Block	*0.535*	*0.565*	*0.375*	*0.541*	*0.454*	*0.234*
Treatment x Block	*0.326*	*0.556*	*0.675*	*0.474*	*0.474*	*0.234*
Shapiro-Wilk[X]	*0.236*	*0.454*	*0.345*	*0.356*	*0.236*	*0.342*

[Z] zero (0 lb P/acre), Half (25 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A3.2. Farm 2 – Fall 2007 Green Bean Leaf Tissue Elemental Content. Nutrient content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 29 (1 October 2007) and 54 (26 October 2007) days after planting. Final leaf tissue concentrations are based on dry weight. (n-1 = 8)

P Fertilizer Rate[Z]	N (%)	P (%)	K (%)
	----- *29 days after transplant* -------		
Zero	4.41	0.35	2.13
Half	4.54	0.41	1.86
Full	4.83	0.38	2.14
	Significance[Y]		
Treatment	*0.560*	*0.330*	*0.850*
Block	*0.025*	*0.206*	*0.620*
Treatment x Block	*0.698*	*0.619*	*0.681*
	----- *54 days after transplant* -------		
Zero	3.91	0.27	1.99
Half	3.95	0.27	1.82
Full	3.85	0.28	1.46
	Significance[Y]		
Treatment	*0.870*	*0.850*	*0.556*
Block	*0.025*	*0.337*	*0.736*
Treatment x Block	*0.978*	*0.723*	*0.760*
Shapiro-Wilk[X]	*0.431*	*0.059*	*0.271*

[Z] zero (0 lb P/acre), Half (30 lb P/acre) and Full (60 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A3.3. Farm 3a and 3b – Fall 2006 Green Bean Leaf Tissue Elemental Content. Nutrient content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 30 (Farm 3a on 31 October 2006 and Farm 3b on 22 November 2006) and 60 (Farm 3a 22 November 2006 and Farm 3b on 22 December 2006) days after planting. Final leaf tissue concentrations are based on dry weight. (n-1 = 5)

P Fertilizer Rate[Z]	N (%)	S (%)	P (%)	K (%)	Mg (%)	Ca (%)
			---------------- 30 days after seeding ----------------			
Zero	4.775	0.147 b b	0.320 a a	3.512	0.427 a a	2.087
Full	4.850	0.162 a a	0.292 b b	3.485	0.355 b b	2.162
			Significance[Y]			
Treatment	*0.519*	*<0.0001*	*0.022*	*0.916*	*<0.0001*	*0.620*
Block	*0.347*	*0.437*	*0.573*	*0.354*	*0.235*	*0.566*
Treatment x Block	0.274	0.345	0.544	0.544	0.154	0.545
			---------------- 60 days after seeding ----------------			
Zero	4.350	0.167	0.258	3.200	0.495	2.299
Full	3.987	0.146	0.290	3.218	0.492	2.288
			Significance[Y]			
Treatment	*0.437*	*0.401*	*0.081*	*0.938*	*0.936*	*0.949*
Block	*0.342*	*0.344*	*0.326*	*0.362*	*0.342*	*0.563*
Treatment x Block	*0.363*	*0.434*	*0.343*	*0.753*	*0.334*	*0.753*
Shapiro-Wilks[X]	*0.365*	*0.215*	*0.346*	*0.436*	*0.423*	*0.432*

[Z] zero (0 lb P/acre) and Full (40 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A3.4. Farm 3a – Fall 2007 Green Bean Leaf Tissue Elemental Content. Nutrient content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 29 (9 November 2007) and 66 (11 December 2007) days after planting. Final leaf tissue concentrations are based on dry weight. (n-1 = 3)

P Fertilizer Rate[Z]	N (%)	P (%)	K (%)
	---------- *29 days after planting* -----------		
Zero	5.34	0.27 b b	2.45
Half	5.21	0.35 a a	253
Full	5.20	0.42 a a	2.55
	Significance[Y]		
Treatment	*0.210*	*0.004*	*0.263*
Block	*0.224*	*0.984*	*0.088*
Treatment x Block	*0.373*	*0.423*	*0.231*
	--------- *66 days after planting* -----------		
Zero	3.97	0.26	1.18
Half	3.85	0.27	1.09
Full	3.71	0.27	1.07
	Significance[Y]		
Treatment	*0.732*	*0.256*	*0.404*
Block	*0.650*	*0.357*	*0.738*
Treatment x Block	*0.331*	*0.546*	*0.452*
Shapiro-Wilk[X]	*0.880*	*0.066*	*0.746*

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A3.5. Farm 3a – Spring 2008 Green Bean Leaf Tissue Elemental Content. Nutrient content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 29 (8 February 2008) and 56 (6 March 2008) days after planting. Final leaf tissue concentrations are based on dry weight. (n-1 = 5)

P Fertilizer Rate[Z]	N (%)	P (%)	K (%)
	------------ *29 days after planting*		------------
Zero	5.14	0.23 b b	2.34
Half	5.23	0.27a a	2.41
Full	5.38	0.28 a a	2.43
	Significance[Y]		
Treatment	*0.057*	*0.025*	*0.673*
Block	*0.600*	*0.555*	*0.170*
Treatment x Block	*0.259*	*0.035*	*0.632*
	------------ *56 days after planting*		------------
Zero	4.20 a a	0.26	2.10
Half	3.86 b b	0.26	1.98
Full	3.64 b b	0.26	1.84
	Significance[Y]		
Treatment	*0.014*	*0.659*	*0.210*
Block	*0.373*	*0.021*	*0.478*
Treatment x Block	*0.345*	*0.644*	*0.343*
Shapiro-Wilk[X]	*0.607*	*0.311*	*0.326*

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A3.6. Farm 3b – Spring 2006 Green Bean Leaf Tissue Elemental Content. Nutrient content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 30 (5 March 2006) and 60 (6 April 2006) days after planting. Final leaf tissue concentrations are based on dry weight.(n-1 = 3)

P Fertilizer Rate[Z]	N (%)	S (%)	P (%)	K (%)	Mg (%)	Ca (%)
	---------------- *30 days after planting* ----------------					
Zero	4.11	0.27	0.30	3.45	0.35	2.31
Full	4.65	0.31	0.37	4.07	0.46	2.58
	Significance[Y]					
Treatment	*0.187*	*0.156*	*0.126*	*0.126*	*0.058*	*0.374*
Block	*0.345*	*0.455*	*0.547*	*0.356*	*0.534*	*0.433*
Treatment x Block						
	---------------- *60 days after planting* ----------------					
Zero	2.90	0.17	0.27	1.77	0.37	1.75
Full	3.02	0.20	0.29	1.94	0.38	1.71
	Significance[Y]					
Treatment	*0.742*	*0.374*	*0.626*	*0.567*	*0.334*	*0.570*
Block	*0.343*	*0.342*	*0.534*	*0.543*	*0.546*	*0.434*
Treatment x Block						
Shapiro-Wilk[X]	*0.342*	*0.443*	*0.421*	*0.423*	*0.234*	*0.343*

[Z] zero (0 lb P/acre) and Full (39 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A3.7. Farm 3b – Spring 2007 Green Bean Leaf Tissue Elemental Content. Nutrient content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 30 (12 March 2007) and 45 (30 March 2007) days after planting. Final leaf tissue concentrations are based on dry weight. (n-1 = 3)

P Fertilizer Rate[Z]	N (%)	S (%)	P (%)	K (%)	Mg (%)	Ca (%)
	---------------- *30 days after seeding* ----------------					
Zero	4.43	0.158	0.338	4.395	0.348	2.323
Full	4.45	0.185	0.380	4.178	0.293	2.173
	Significance[Y]					
Treatment	*0.875*	*0.072*	*0.304*	*0.305*	*0.134*	*0.558*
Block	*0.803*	*0.873*	*0.894*	*0.592*	*0.694*	*0.734*
Treatment x Block						
	---------------- *60 days after seeding* ----------------					
Zero	4.525 a a	0.178	0.298	4.300	0.378	2.400 a a
Full	4.275 b b	0.195	0.335	4.328	0.375	1.855 b b
	Significance[y]					
Treatment	*0.034*	*0.537*	*0.185*	*0.817*	*0.695*	*0.005*
Block	*0.874*	*0.823*	*0.743*	*0.478*	*0.873*	*0.378*
Treatment x Block						
Shapiro-Wilk[X]	*0.236*	*0.354*	*0.474*	*0.344*	*0.423*	*0.233*

[Z] zero (0 lb P/acre) and Full (40 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A3.8. Farm 3b – Fall 2007 Green Bean Leaf Tissue Elemental Content. Nutrient content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 27 (9 November 2007) and 54 (17 December 2007) days after planting. Final leaf tissue concentrations are based on dry weight. (n-1 = 3)

P Fertilizer Rate[Z]	N (%)	P (%)	K (%)
	------------ *27 days after planting* ------------		
Zero	5.21	0.26 b b	2.61
Full	5.34	0.36 a a	2.61
	Significance[Y]		
Treatment	*0.503*	*0.048*	*0.952*
Block	*0.452*	*0.674*	*0.027*
Treatment x Block			
	-------------- *54 days after planting* -----------		
Zero	4.48	0.27 b b	1.41 a a
Full	4.25	0.30 a a	1.21 b b
	Significance[Y]		
Treatment	*0.193*	*0.007*	*0.030*
Block	*0.884*	*0.004*	*0.171*
Treatment x Block			
Shapiro-Wilk[X]	*0.509*	*0.040*	*0.680*

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A3.9. Farm 3b – Spring 2008 Green Bean Leaf Tissue Elemental Content. Nutrient content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 31 (21 February 2008) and 54 (20 March 2008) days after planting. Final leaf tissue concentrations are based on dry weight. (n-1 = 3)

P Fertilizer Rate[Z]	N (%)	P (%)	K (%)
	----- *31 days after planting* -------		
Zero	4.30 b b	0.21 b b	2.28
Full	4.86 a a	0.39 a a	2.23
	Significance[Y]		
Treatment	*0.001*	*<0.0001*	*0.621*
Block	*0.024*	*0.084*	*0.170*
Treatment x Block			
	----- *54 days after planting* -------		
Zero	3.86	0.23	1.48 a a
Full	3.68	0.26	1.02 b b
	Significance[Y]		
Treatment	*0.270*	*0.058*	*0.025*
Block	*0.983*	*0.752*	*0.039*
Treatment x Block			
Shapiro-Wilk[X]	*0.473*	*0.048*	*0.559*

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at $P \le 0.05$ (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \le 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Appendix 4 Green Bean Yield Data

Table A4.1. Farm 2 – Fall 2006 Green Bean Yield. Three 10-foot lengths of single row sub-samples for green beans within each plot were harvested and separated by fruit size. Harvest was made once on 15 December 2006. (n-1 = 8)

P Fertilizer Rate[Z]	Beans 4-6" *(boxes/ac)*	Beans 3-4" *(boxes/ac)*	Beans <3" *(boxes/ac)*	Total marketable *(boxes/ac)*	Culls *(boxes/ac)*
Zero	119	18 b b	6	143	10
Half	124	25 a a	5	153	10
Full	124	24 a a	6	153	8
			Significance[Y]		
Treatment	*0.803*	*0.012*	*0.641*	*0.331*	*0.537*
Block	*0.807*	*0.345*	*0.364*	*0.643*	*0.357*
Treatment x Block	*0.873*	*0.244*	*0.547*	*0.546*	*0.354*
Shapiro-Wilk[X]	0.234	0.124	0.346	0.332	0.324

[Z] zero (0 lb P/acre), Half (25 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A4.2. Farm 2 – Fall 2007 Green Bean Yield. Three 10-foot lengths of single row sub-samples for green beans within each plot were harvested and separated by fruit size. Harvest was made once on 29 October 2006. (n-1 = 8)

P Fertilizer Rate[Z]	Beans 4-6" (boxes/ac)	Beans 3-4" (boxes/ac)	Beans <3" (boxes/ac)	Total Marketable (boxes/ac)	Culls (boxes/ac)
Zero	202 b b	5 a a	1	206 b b	2 b b
Half	443 a a	3 b b	2	442 a a	6 a a
Full	463 a a	4 a a	2	464 a a	5 a a
		Significance[Y]			
Treatment	*<0.0001*	*0.002*	*0.534*	*<0.0001*	*0.003*
Block	*0.915*	*0.022*	*0.567*	*0.852*	*0.703*
Treatment x Block	*0.980*	*0.047*	*0.566*	*0.919*	*0.608*
Shapiro-Wilk[X]	0.096	0.131	0.121	0.330	0.112

[Z] zero (0 lb P/acre), Half (30 lb P/acre) and Full (60 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A4.3. Farm 3a and 3b – Fall 2006 Green Bean Yield. Three 10-foot lengths of single row sub-samples for green beans within each plot were harvested and separated by fruit size. Harvest was made once on 24 November 2006 (Farm 3a) and 22 December 2006 (Farm 3b). (n-1 = 5)

P Fertilizer Rate[Z]	Beans 4-6” (boxes/ac)	Beans 3-4” (boxes/ac)	Beans <3” (boxes/ac)	Total marketable (boxes/ac)	Culls (boxes/ac)
		---------------- *65 days after planting*		----------------	
Zero	215 b b	25	7 b b	247 b b	19
Full	262 a a	25	8 a a	294 a a	17
			Significance[Y]		
Treatment	*0.019*	*0.672*	*0.019*	*0.038*	*0.466*
Block	*0.438*	*0.897*	*0.546*	*0.536*	*0.745*
Treatment x Block	*0.923*	*0.745*	*0.564*	*0.364*	*0.364*
Shapiro-Wilk[X]	*0.783*	*0.545*	*0.556*	*0.346*	*0.545*

[Z] zero (0 lb P/acre) and Full (40 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan’s (first letter) and Tukey’s (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A4.4. Farm 3a – Fall 2007 Green Bean Yield. Three 5-foot lengths of single row sub-samples for green beans within each plot were harvested and separated by fruit size. Harvest was made once on 11 December 2006. (n-1 = 5)

P Fertilizer Rate[Z]	*Beans 4-6"* (boxes/ac)	*Beans 3-4"* (boxes/ac)	*Beans <3"* (boxes/ac)	*Total Marketable* (boxes/ac)	*Culls* (boxes/ac)
		---------------- *56 days after planting* ----------------			
Zero	157 b b	10	3 a a	178	34 a a
Half	176a a	11	2 b b	187	25b b
Full	188 a a	11	2 b b	201	26 b b
		Significance[Y]			
Treatment	0.001	0.562	0.004	0.106	0.019
Block	0.917	0.125	0.425	0.334	0.805
Treatment x Block	*0.552*	*0.097*	*0.178*	*0.248*	*0.031*
Shapiro-Wilk[X]	0.137	0.234	0.437	0.1807	0.102

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A4.5. Farm 3a – Spring 2008 Green Bean Yield. Three 10-foot lengths of single row sub-samples for green beans within each plot were harvested and separated by fruit size. Harvest was made once on 11 March 2008. (n-1 = 5)

P Fertilizer Rate[Z]	Beans 4-6” (boxes/ac)	Beans 3-4” (boxes/ac)	Beans <3” (boxes/ac)	Total Marketable (boxes/ac)	Culls (boxes/ac)
	---------------- *65 days after planting* ----------------				
Zero	327b b	28	15	280 b b	81 b b
Half	412 a a	34	21	456 b b	153 a a
Full	421 a a	43	24	488 a a	163 a a
		Significance[Y]			
Treatment	*0.012*	*0.159*	*0.315*	*0.007*	*0.017*
Block	*0.813*	*0.222*	*0.126*	*0.592*	*0.063*
Treatment x Block	*0.71*	*0.436*	*0.926*	*0.097*	*0.413*
Shapiro-Wilk[X]	0.268	0.469	0.106	0.382	0.130

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan’s (first letter) and Tukey’s (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A4.6. Farm 3b – Spring 2006 Green Bean Yield. Three 10-foot lengths of single row sub-samples for green beans within each plot were harvested and separated by fruit size. Harvest was made once on 7 April 2006. (n-1 = 3)

P Fertilizer Rate[Z]	Beans 4-6" (boxes/ac)	Beans 3-4" (boxes/ac)	Beans <3" (boxes/ac)	Total Marketable (boxes/ac)	Culls (boxes/ac)
		---------------- *60 days after planting* ----------------			
Zero	303	22 b b	11	340	16
Full	312	25 a a	12	349	19
			Significance[Y]		
Treatment	*0.135*	*0.039*	*0.633*	*0.163*	*0.276*
Block	*0.834*	*0.364*	*0.436*	*0.489*	*0.342*
Treatment x Block					
Shapiro-Wilk[X]	*0.536*	*0.234*	*0.453*	*0.443*	*0.253*

[Z] zero (0 lb P/acre) and Full (39 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A4.7. Farm 3b – Spring 2007 Green Bean Yield. Three 10-foot lengths of single row sub-samples for green beans within each plot were harvested and separated by fruit size. Harvest was made once on 9 April 2007. (n-1 = 3)

P Fertilizer Rate[Z]	Beans 4-6” (boxes/ac)	Beans 3-4” (boxes/ac)	Beans <3” (boxes/ac)	Total marketable (boxes/ac)	Culls (boxes/ac)
		---------------- *65 days after planting* ----------------			
Zero	238 b b	19	4	261 b b	17
Full	299 a a	24	4	327 a a	24
			Significance[Y]		
Treatment	*0.035*	*0.056*	*0.947*	*0.002*	*0.097*
Block	*0.363*	*0.463*	*0.634*	*0.632*	*0.653*
Treatment x Block					
Shapiro-Wilk[X]	*0.346*	*0.356*	*0.213*	*0.331*	*0.732*

[Z] zero (0 lb P/acre) and Full (40 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan’s (first letter) and Tukey’s (second letter) multiple range tests using SAS Proc. GLM.
[Z] zero (0 lb P/acre), Half (80 lb P/acre) and Full (160 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan’s (first letter) and Tukey’s (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A4.8. Farm 3b – Fall 2007 Green Bean Yield. Three 10-foot lengths of single row sub-samples for green beans within each plot were harvested and separated by fruit size. Harvest was made once on 17 December 2007. (n-1 = 3)

P Fertilizer Rate[Z]	Beans 4-6" (boxes/ac)	Beans 3-4" (boxes/ac)	Beans <3" (boxes/ac)	Total Marketable (boxes/ac)	Culls (boxes/ac)
	---------------- *62 days after planting* ----------------				
Zero	131 b b	7	3	141 b b	23 b b
Full	175 a a	8	3	185 a a	32 a a
	Significance[Y]				
Treatment	*0.002*	*0.689*	*0.611*	*0.002*	*0.015*
Block	*0.076*	*0.567*	*0.700*	*0.268*	*0.019*
Treatment x Block					
Shapiro-Wilk[X]	0.316	0.188	0.139	0.356	0.758

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A4.9. Farm 3b – Spring 2008 Green Bean Yield. Three 10-foot lengths of single row sub-samples for green beans within each plot were harvested and separated by fruit size. Harvest was made once on 30 March 2008. (n-1 = 3)

P Fertilizer Rate[Z]	Beans 4-6" (boxes/ac)	Beans 3-4" (boxes/ac)	Beans <3" (boxes/ac)	Total Marketable (boxes/ac)	Culls (boxes/ac)
		---------------- *58 days after planting* ----------------			
Zero	105 b b	6	3	115 b b	23 b b
Full	148 a a	6	3	102 a a	34 a a
		Significance[Y]			
Treatment	*0.002*	*0.884*	*0.967*	*<0.0001*	*0.004*
Block	*0.848*	*0.081*	*0.099*	*0.0301*	*0.001*
Treatment x Block					
Shapiro-Wilk[X]	0.226	0.153	0.095	0.201	0.848

[Z] zero (0 lb P/acre) and Full (50 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=4). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Appendix 5 Tomato Soil Sample Data

Table A5.1. Farm 1 – Spring 2006 Tomato biomass and extractable soil nutrients. Plant biomass accumulation was determined by harvest of four individual plants at separate locations throughout each plot sampled 75 days after transplant. 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. (n-1 = 8)

P Fertilizer Rate[Z]	Plant Biomass[z] (g/plant)	Soil P (ppm)	Soil K (ppm)	Soil Mg (ppm)	Soil Ca (ppm)	Soil pH
				Before transplant		
Zero	--	137	4.8	47	803	7.2
Half	--	152	7.0	52	816	7.1
Full	--	137	5.5	43	761	7.1
				Significance[Y]		
Treatment	--	*0.558*	*0.263*	*0.708*	*0.827*	*0.538*
Block	--	*0.789*	*0.346*	*0.344*	*0.344*	*0.334*
Treatment x Block	--	*0.674*	*0.454*	*0.436*	*0.349*	*0.363*
				60 days after transplant		
Zero	217	142 b b	110	104	871	6.3 a a
Half	209	171 ab ab	55	90	811	6.0 b b
Full	206	197 a a	114	121	805	5.9 b b
				Significance[Y]		
Treatment	*0.676*	*0.031*	*0.130*	*0.430*	*0.679*	*0.012*
Block	*0.253*	*0.343*	*0.343*	*0.343*	*0.534*	*0.435*
Treatment x Block	*0.433*	*0.453*	*0.453*	*0.423*	*0.343*	*0.453*
				150 days after transplant		
Zero	--	168	26	92	843	8.0
Half	--	141	26	89	844	8.1
Full	--	168	28	116	819	7.9
				Significance[Y]		
Treatment	--	*0.175*	*0.940*	*0.558*	*0.952*	*0.801*
Block	--	*0.343*	*0.232*	*0.343*	*0.542*	*0.422*
Treatment x Block	--	*0.235*	*0.342*	*0.422*	*0.432*	*0.673*
Shapio-Wilk[X]	--	*0.231*	*0.234*	*0.432*	*0.123*	*0.215*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by

letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A5.2. Farm 1 – Fall 2006 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. Samples were collected prior to planting (2 November 2006), and at 60 (2 January, 2007) and 120 (2 march 2007) days after transplanting. (n-1 = 8)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	pH
	----------------	*Before transplanting*	----------------		
Zero	94	55	86	1270	6.9
Half	108	77	84	1225	6.8
Full	100	73	92	1299	6.8
			Significance [Y]		
Treatment	*0.071*	*0.356*	*0.504*	*0.722*	*0.318*
Block	*0.782*	*0.344*	*0.323*	*0.543*	*0.453*
Treatment x Block	*0.234*	*0.345*	*0.433*	*0.453*	*0.533*
	----------------	*60 days after transplanting*	----------------		
Zero	79	38 a a	84	707	7.7
Half	122	46 a a	95	687	7.5
Full	102	19 b b	79	760	7.4
			Significance [Y]		
Treatment	*0.135*	*0.046*	*0.302*	*0.633*	*0.077*
Block	*0.345*	*0.543*	*0.453*	*0.453*	*0.543*
Treatment x Block	*0.332*	*0.433*	*0.343*	*0.535*	*0.435*
	----------------	*120 days after transplanting*	----------------		
Zero	129	15	112	1003	8.2
Half	156	17	126	980	8.1
Full	150	17	99	1053	7.9
			Significance [Y]		
Treatment	*0.055*	*0.715*	*0.297*	*0.625*	*0.147*
Block	*0.234*	*0.346*	*0.346*	*0.453*	*0.456*
Treatment x Block	*0.343*	*0.546*	*0.234*	*0.544*	*0.433*
Shapiro-Wilk[X]	*0.233*	*0.434*	*0.344*	*0.453*	*0.122*

[Z] zero (0 lb P/acre), Half (84 lb P/acre) and Full (168 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A5.3. Farm 1 – Fall 2007 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. Samples were collected prior to planting (29 October 2007), and at 60 (28 December, 2007) and 103 (8 February, 2007) days after transplanting. (n-1 = 8)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Ca (ppm)	Fe (ppm)	pH
	---------------- *Before transplanting* ----------------				
Zero	157	6.1	1111	13	7.2
Half	132	4.4	984	13	7.2
Full	129	6.6	849	16	7.1
		Significance [Y]			
Treatment	*0.724*	*0.579*	*0.408*	*0.886*	*0.774*
Block	*0.314*	*0.708*	*0.802*	*0.134*	*0.344*
Treatment x Block	*0.579*	*0.460*	*0.452*	*0.993*	*0.546*
	-------------- *60 days after transplanting* ----------------				
Zero	165	68	934	19	7.2
Half	187	72	927	22	7.1
Full	186	53	901	20	7.0
		Significance [Y]			
Treatment	*0.812*	*0.200*	*0.922*	*0.906*	*0.675*
Block	*0.185*	*0.189*	*0.563*	*0.231*	*0.074*
Treatment x Block	*0.780*	*0.656*	*0.634*	*0.839*	*0.916*
	---------------- *103 days after transplanting* -----------------				
Zero	134	359.6	1022	17	7.7
Half	147	346.3	999	18	7.5
Full	151	270.5	988	19	7.4
		Significance [Z]			
Treatment	*0.884*	*0.644*	*0.971*	*0.973*	*0.711*
Block	*0.491*	*0.624*	*0.837*	*0.172*	*0.571*
Treatment x Block	*0.861*	*0.858*	*0.526*	*0.995*	*0.745*
Shapiro-Wik[X]	*0,255*	*0.141*	*0.125*	*0.344*	*0.245*

[Z] zero (0 lb P/acre), Half (80 lb P/acre) and Full (160 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A5.4. Field 3a – Spring 2006 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. (n-1 = 5)

P Fertilizer Rate[Z]	Plant Biomass (g/plant)	---------- Soil ---------- P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	pH
	---------------- *Before transplant* ----------------					
Zero	--	140	18	89	890	7.3
Half	--	180	22	140	1170	7.2
Full	--	149	18	123	1080	7.3
			Significance[Y]			
Treatment	--	0.457	0.343	0.534	0.534	0.435
Block	--	0.343	0.433	0.345	0.543	0.454
Treatment x Block	--	0.344	0.363	0.534	0.434	0.439
	---------------- *60 days after transplant* ----------------					
Zero	269	180	51	151	1140	7.5
Half	307	174	64	168	1210	7.6
Full	329	175	66	166	1160	7.6
			Significance[Y]			
Treatment	0.343	0.343	0.354	0.674	0.454	0.543
Block	0.735	0.564	0.533	0.364	0.343	0.545
Treatment x Block	0.353	0.378	0.344	0.443	0.345	0.565
	---------------- *120 days after transplant* ----------------					
Zero	405	161	12	136	1140	8.2
Half	448	172	9	163	1210	8.2
Full	457	173	9	179	1290	8.1
			Significance[Y]			
Treatment	0.545	0.536	0.544	0.687	0.334	0.542
Block	0.673	0.568	0.786	0.554	0.234	0.233
Treatment x Block	0.577	0.658	0.676	0.758	0.343	0.545
Shapiro-Wilk[X]	0.356	0.548	0.334	0.544	0.321	0.432

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A5.5. Farm 3a – Spring 2007 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. Samples were collected at planting (3 January 2007), and at 60 (30 March 2007), and 110 (21 May 2007) days after planting. (n-1 = 5)

P Fertilizer Rates[Z]	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	pH
			Before planting		
Zero	60.0	31.0	85.0	1170	7.50
Half	57.0	34.0	87.0	1080	7.30
Full	75.0	37.0	89.0	1100	7.20
			Significance[Y]		
Treatment	*0.748*	*0.486*	*0.738*	*0.485*	*0.846*
Block	*0.450*	*0.474*	*0.423*	*0.334*	*0.344*
Treatment x Block	*0.545*	*0.786*	*0.674*	*0.434*	*0.655*
			60 days after transplant		
Zero	54.5	49.0c c	103.5c c	985c c	7.20
Half	65.0	58.5b b	126.5b b	1055b b	7.20
Full	52.5	104.5a a	133.0a a	1245a a	7.10
			Significance[Y]		
Treatment	*0.828*	*<0.0001*	*<0.0001*	*<0.0001*	*0.931*
Block	*0.564*	*0.745*	*0.343*	*0.454*	*0.443*
Treatment x Block	*0.544*	*0.454*	*0.434*	*0.454*	*0.453*
			110 days after transplant		
Zero	58.5c c	80.0	130.0c c	920	7.30c c
Half	98.0a a	60.0	152.5b b	900	7.35b b
Full	89.5b b	96.0	165.0a a	955	7.50a a
			Significance[Y]		
Treatment	*<0.0001*	*0.630*	*<0.0001*	*0.957*	*<0.0001*
Block	*0.544*	*0.354*	*0.536*	*0.434*	*0.454*
Treatment x Block	*0.354*	*0.544*	*0.445*	*0.556*	*0.423*
Shapiro-Wilk[X]	*0.234*	*0.234*	*0.344*	*0.454*	*0.234*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A5.6. Farm 4 – Spring 2007 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. Samples were collected prior to planting (18 September 2007), and at 60 (20 November, 2007) and 120 (15 January, 2008) days after transplanting. (n-1 = 5)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	pH
	---------------- *Before transplant* ----------------				
Zero	31	28	183	1303	7.0
Half	31	32	185	1297	7.0
Full	31	35	185	1297	7.0
			Significance[Y]		
Treatment	*0.960*	*0.559*	*0.994*	*0.997*	*0.444*
Block	*0.983*	*0.843*	*0.345*	*0.536*	*0.434*
Treatment x Block	*0.978*	*0.784*	*0.543*	*0.545*	*0.454*
	---------------- *60 days after transplant* ----------------				
Zero	80	23	182	800 b b	7.0
Half	44	43	183	1130 a a	7.1
Full	85	36	189	850 ab ab	7.3
			Significance[Y]		
Treatment	*0.208*	*0.329*	*0.729*	*0.001*	*0.588*
Block	*0.454*	*0.434*	*0.453*	*0.233*	*0.544*
Treatment x Block	*0.354*	*0.478*	*0.544*	*0.334*	*0.454*
	---------------- *120 days after transplant* ----------------				
Zero	48	43	198	1337	7.3b b
Half	34	41	206	1273	7.6a a
Full	65	51	196	1410	7.3b b
			Significance[Y]		
Treatment	*0.315*	*0.373*	*0.633*	*0.170*	*0.033*
Block	*0.454*	*0.343*	*0.978*	*0.874*	*0.454*
Treatment x Block	*0.544*	*0.234*	*0.978*	*0.748*	*0.443*
Shapiro-Wilk[X]	*0.233*	*0.978*	*0.234*	*0.312*	*0.235*

[Z] zero (0 lb P/acre), Half (56 lb P/acre) and Full (112 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Appendix 6 Tomato Plant Biomass Data

Note: limited biomass data was collected for Farm 1 – Spring 2006. Data collected appears on Table A5.1.

Table A6.1. Farm 1 – Fall 2006 Tomato Biomass. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected at 60 (2 January 2007) and 120 (2 March 2007) DAT. (n-1 = 8)

P Fertilizer Rate[Z]	Plant + fruit dry wt (g/plant)	Plant + fruit dry wt (oz/plant)	Fruit dry wt (g/plant)	Plant dry wt (g/plant)	Fruit fresh wt (lb/plant)
		----------------60 days after transplant---------------			
Zero	1051	282	854	197	1.9
Half	1108	293	905	202	2.0
Full	1246	301	1049	196	2.3
		Significance[Y]			
Treatment	*0.226*	*0.327*	*0.222*	*0.577*	*0.208*
Block	*0.345*	*0.635*	*0.434*	*0.568*	*0.554*
Treatment x Block	*0.233*	*0.544*	*0.343*	*0.554*	*0.532*
		----------------120 days after transplant---------------			
Zero	3384	619	3071	312	5.3
Half	3030	607	2692	337	6.0
Full	2717	576	2377	339	6.8
		Significance[Y]			
Treatment	*0.647*	*0.875*	*0.614*	*0.542*	*0.614*
Block	*0.443*	*0.655*	*0.785*	*0.786*	*0.678*
Treatment x Block	*0.433*	*0.765*	*0.656*	*0.656*	*0.654*
Shapiro-Wilk[X]	*0.342*	*0.443*	*0.322*	*0.112*	*0.212*

[Z] zero (0 lb P/acre), Half (84 lb P/acre) and Full (168 lb P/acre)

[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.

[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A6.2. Farm 1 – Fall 2007 Tomato Biomass. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected on at 60 (28 December 2007) and 120 (8 February 2008) DAT. (n-1 = 8)

P Fertilizer Rate[Z]	**Plant Dry Wt** (g/plant)	**Fruit Fresh Wt** **(lb/plant)**
----------------60 days after transplant--------------		
Zero	190	1.8 b b
Half	183	1.6 a b
Full	158	2.3 a a
	Significance[Y]	
Treatment	*0.272*	*0.008*
Block	*0.120*	*0.001*
Treatment x Block	*0.445*	*0.001*
----------103 days after transplant----------		
Zero	297	4.9
Half	316	5.4
Full	225	3.3
	Significance[Y]	
Treatment	*0.129*	*0.185*
Block	*0.641*	*0.227*
Treatment x Block	*0.769*	*0.481*
Shapiro-Wilk[X]	0.690	0.196

[Z] zero (0 lb P/acre), Half (80 lb P/acre) and Full (160 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Note: limited biomass data was collected for Farm 3a – Spring 2006. Data collected appears on Table A5.4.

Table A6.3. Farm 3a – Spring 2007 Tomato Biomass. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected at 60 (30 March 2007), 90 (27 April 2007) and 110 (21 May 2007) DAT. (n-1 = 5)

P Fertilizer Rate[Z]	Plant + Fruit dry wt (g/plant)	Plant fresh wt (g/plant)	Fruit fresh wt (g/plant)	Fruit fresh wt (oz/plant)	Plant + fruit dry wt (oz/plant)	Plant dry wt (oz/plant)	Fruit dry wt (lb/plant)
			--------------60 days after transplant--------------				
Zero	171.2 b b	152.5	189.9 c c	6.70 c c	6.04 c c	5.38	0.42 c c
Half	222.3 a a	163.3	590.8 a a	20.84 a a	7.84 a a	5.76	1.30 a a
Full	189.4 ab ab	153.4	360.9 b b	12.73 b b	6.68 b b	5.41	0.80 b b
				Significance[Y]			
Treatment	*<0.0001*	*0.920*	*<0.0001*	*<0.0001*	*<0.0001*	*0.920*	*<0.0001*
Block	*0.823*	*0.645*	*0.965*	*0.564*	*0.785*	*0.544*	*0.274*
Treatment x Block	*0.674*	*0.658*	*0.543*	*0.233*	*0.234*	*0.223*	*0.774*
			--------------90 days after transplant--------------				
Zero	988.8	269.9	7189.6	253.6	34.88	9.52	15.85
Half	928.2	267.1	6611.2	233.2	32.74	9.42	14.58
Full	1081.0	309.9	7711.2	272.0	38.13	10.93	17.00
				Significance[Y]			
Treatment	*0.920*	*0.915*	*0.923*	*0.923*	*0.920*	*0.915*	*0.923*
Block	*0.786*	*0.578*	*0.565*	*0.346*	*0.546*	*0.347*	*0.554*
Treatment x Block	*0.343*	*0.869*	*0.678*	*0.673*	*0.434*	*0.654*	*0.766*
			--------------110 days after transplant--------------				
Zero	673.6	315.3	3583.4 a a	126.4 a a	23.76	11.12	7.9 b b
Half	821.0	304.5	5166.5 a a	182.2 a a	28.96	10.74	11.4 a a
Full	630.8	294.3	3368.0 b b	118.8 b b	22.25	10.38	7.4 b b
				Significance[Z]			
Treatment	*0.544*	*0.947*	*<0.0001*	*<0.0001*	*0.544*	*0.947*	*<0.0001*
Block	*0.443*	*0.857*	*0.575*	*0.785*	*0.564*	*0.734*	*0.655*
Treatment x Block	*0.674*	*0.634*	*0.454*	*0.445*	*0.674*	*0.896*	*0.352*
Shapiro-Wilk[X]	*0.312*	*0.322*	*0.328*	*0.214*	*0.343*	*0.134*	*0.217*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)

[Y] Treatment, block, or interactions are considered significantly different at $P \le 0.05$ (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.

[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \le 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A6.4. Farm 4 – Spring 2007 Tomato Biomass. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected on at 60 (20 November 2006) and 120 (15 January 2007) DAT. (n-1 =8)

P Fertilizer Rate[Z]	Plant + fruit dry wt (g/plant)	Fruit fresh wt (g/plant)	Plant dry wt (g/plant)	Plant + fruit dry wt (oz/plant)	Fruit fresh wt (oz/plant)	Plant dry wt (oz/plant)
			---------60 days after transplant----------			
Zero	478	1734	305	16.9	61.2	10.8
Half	450	1519	298	15.9	53.6	10.5
Full	457	1550	302	16.1	54.7	10.7
			Significance[Y]			
Treatment	*0.584*	*0.732*	*0.919*	*0.584*	*0.732*	*0.919*
Block	*0.344*	*0.356*	*0.346*	*0.554*	*0.564*	*0.675*
Treatment x Block	*0.444*	*0.575*	*0.545*	*0.673*	*0.557*	*0.758*
			--------------120 days after transplant--------------			
Zero	259	--[Y]	259	9.1	--	9.1
Half	253	--	253	8.9	--	8.9
Full	258	--	258	9.1	--	9.1
			Significance[Y]			
Treatment	*0.778*		*0.778*	*0.729*		*0.778*
Block	*0.434*		*0.674*	*0.546*		*0.452*
Treatment x Block	*0.445*		*0.544*	*0.675*		*0.544*
Shapiro-Wilk[X]	*0.324*		*0.445*	*0.323*		*0.312*

[Z] zero (0 lb P/acre), Half (56 lb P/acre) and Full (112 lb P/acre)

[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.

[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Appendix 7 Tomato Leaf Sample Data

Table A7.1. Farm 1 – Spring 2006 Tomato Leaf Tissue Elemental Content. Content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 30 (18 December 2005), 60 (17 January 2006) and 150 (17 April 2006) days after transplanting. Final leaf tissue concentrations are based on dry weight. (n-1 = 8)

P Fertilizer Rate[Z]	N (%)	S (%)	P (%)	K (%)	Mg (%)	Ca (%)
		---------------- *30 days after transplant* ----------------				
Zero	6.1 b b	1.24 b b	0.78 b b	4.4	0.42 b b	2.12
Half	6.5 a a	1.29 b b	0.88 ab ab	4.2	0.41 b b	2.18
Full	6.0 b b	1.39 a a	0.94 a a	4.5	0.49 a a	2.22
			Significance[Y]			
Treatment	*0.043*	*0.012*	*0.027*	*0.557*	*0.025*	*0.611*
Block	*0.972*	*0.565*	*0.436*	*0.554*	*0.675*	*0.655*
Treatment x Block	*0.356*	*0.232*	*0.324*	*0.434*	*0.322*	*0.456*
		---------------- *60 days after transplant* ----------------				
Zero	5.2	2.43	0.70	5.5	0.47	2.10
Half	5.5	2.43	0.77	5.3	0.46	2.05
Full	5.4	1.17	0.80	5.3	0.49	2.15
			Significance[Y]			
Treatment	*0.378*	*0.501*	*0.211*	*0.796*	*0.608*	*0.604*
Block	*0.244*	*0.457*	*0.544*	*0674*	*0.343*	*0.654*
Treatment x Block	*0.454*	*0.675*	*0.326*	*0.437*	*0.434*	*0.343*
		---------------- *150 days after transplant* ----------------				
Zero	3.4	1.33 b b	0.44 b a	3.3	0.51	1.77
Half	3.4	1.34 b b	0.48 a a	3.6	0.56	1.88
Full	3.1	1.43 a a	0.51 a a	3.5	0.61	2.07
			Significance[Y]			
Treatment	*0.056*	*0.047*	*0.009*	*0.153*	*0.107*	*0.071*
Block	*0.434*	*0.456*	*0.658*	*0.463*	*0.675*	*0.565*
Treatment x Block	*0.362*	*0.523*	*0.343*	*0.231*	*0.323*	*0.312*
Shapiro-Wilk[X]	*0.323*	*0.135*	*0.222*	*0.334*	*0.122*	*0.463*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)

[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.

[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A7.2. Farm 1 – Fall 2006 Tomato Leaf Tissue Elemental Content. Content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 60 (2 January 2006) and 120 (2 March 2006) days after transplanting. Final leaf tissue concentrations are based on dry weight. (n-1 =8)

P Fertilizer RateZ	N (%)	S (%)	P (%)	K (%)	Mg (%)	Ca (%)
			---------------- *60 days after transplant* ----------------			
Zero	4.93	1.44	0.83	5.05	0.51	1.94
Half	5.23	1.59	0.93	4.86	0.48	2.18
Full	5.07	1.53	0.71	4.88	0.51	2.07
			Significance[Y]			
Treatment	*0.301*	*0.562*	*0.606*	*0.687*	*0.729*	*0.166*
Block	*0.935*	*0.547*	*0.856*	*0.576*	*0.676*	*0.658*
Treatment x Block	*0.235*	*0.645*	*0.623*	*0.323*	*0.678*	*0.446*
			---------------- *120 days after transplant* ----------------			
Zero	1.50	1.91	0.39b b	2.43	0.69	0.84
Half	1.87	2.27	0.44ab ab	2.75	0.69	1.12
Grower	1.97	2.25	0.47a a	3.04	0.71	1.55
			Significance[Y]			
Treatment	*0.381*	*0.137*	*0.046*	*0.061*	*0.951*	*0.194*
Block	*0.676*	*0.676*	*0.344*	*0.845*	*0.545*	*0.463*
Treatment x Block	*0.364*	*0.454*	*0.536*	*0.549*	*0.845*	*0.364*
Shapiro-Wilk[X]	*0.443*	*0.323*	*0.132*	*0.124*	*0.341*	*0.236*

[Z] zero (0 lb P/acre), Half (84 lb P/acre) and Full (168 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A7.3. Farm 1 – Fall 2007 Tomato Leaf Tissue Elemental Content. Content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 60 (28 December, 2007) and 103 (8 February, 2008) days after transplanting. Final leaf tissue concentrations are based on dry weight. (n-1 = 8)

P Fertilizer Rate[Z]	N (%)	P (%)	K (%)
	----- *60 days after transplant* -------		
Zero	4.88	0.51	2.85
Half	5.22	0.51	3.01
Full	5.10	0.53	2.90
	Significance[Y]		
Treatment	*0.119*	*0.212*	*0.640*
Block	*0.004*	*0.489*	*0.042*
Treatment x Block	*0.128*	*0.075*	*0.624*
	----- *103 days after transplant* -------		
Zero	3.28	0.30	2.98
Half	3.54	0.36	3.02
Full	3.53	0.33	2.47
	Significance[Y]		
Treatment	*0.244*	*0.214*	*0.07*
Block	*0.005*	*0.212*	*0.98*
Treatment x Block	*0.39*	*0.591*	*0.95*
Shapiro-Wilk[X]	*0.851*	*0.103*	*0.310*

[Z] zero (0 lb P/acre), Half (80 lb P/acre) and Full (160 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A7.4. Farm 3a – Spring 2006 Tomato Leaf Tissue Elemental Content. Content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 60 (4 April 2006) and 120 (3 June 2006) days after transplanting. Final leaf tissue concentrations are based on dry weight. (n-1 = 5)

P Fertilizer Rate[Z]	N (%)	S (%)	P (%)	K (%)	Mg (%)	Ca (%)
	---------------- *60 days after transplant* ----------------					
Zero	4.25	1.18	0.51	4.72	0.73	2.85
Half	4.52	1.22	0.52	4.81	0.72	2.82
Full	4.59	1.29	0.54	5.25	0.79	2.86
			Significance[Y]			
Treatment	0.345	0.578	0.444	0.758	0.344	0.365
Block	0.367	0.765	0.564	0.434	0.765	0.786
Treatment x Block	0.349	0.674	0.546	0.553	0.554	0.344
	-------------- *120 days after transplant* -------------					
Zero	3.14	0.95	0.29	2.29	1.13	4.06
Half	3.25	1.05	0.33	2.37	1.16	3.91
Full	3.34	1.05	0.31	2.39	1.20	4.07
			Significance[Y]			
Treatment	0.545	0.334	0.434	0.345	0.435	0.674
Block	0.677	0.645	0.785	0.786	0.363	0.253
Treatment x Block	0.443	0.345	0.654	0.356	0.543	0.334
Shapiro- Wilk[X]	0.231	0.543	0.443	0.452	0.344	0.126

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A7.5. Farm 3a – Spring 2007 Tomato Leaf Tissue Elemental Content. Content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 60 (30 March 2007), 90 (27 April 2007) and 110 (21 May 2007) days after transplanting. Final leaf tissue concentrations are based on dry weight. (n-1 = 5)

P Fertilizer Rate^Z	N (%)	S (%)	P (%)	K (%)	Mg (%)	Ca (%)
			---------------- *60 days after transplant* ----------------			
Zero	4.40	0.815	0.670	3.93a a	0.355	1.10a a
Half	4.60	0.865	0.500	2.855c c	0.335	0.95b b
Full	4.15	0.890	0.480	3.605b b	0.335	0.90c c
			Significance^Y			
Treatment	*0.736*	*0.835*	*0.577*	*<0.0001*	*0.174*	*<0.0001*
Block	*0.844*	*0.554*	*0.653*	*0.644*	*0.564*	*0.565*
Treatment x Block	*0.545*	*0.564*	*0.543*	*0.544*	*0.574*	*0.324*
			---------------- *90 days after transplant* ----------------			
Zero	3.90c c	3.215	0.285c c	3.143	0.840	3.280
Half	3.95b b	2.715	0.335b b	3.470	0.880	3.090
Full	5.35a a	2.930	0.365a a	3.440	0.835	3.285
			Significance^Y			
Treatment	*<0.0001*	*0.846*	*<0.0001*	*0.293*	*0.930*	*0.809*
Block	*0.434*	*0.674*	*0.634*	*0.543*	*0.543*	*0.343*
Treatment x Block	*0.245*	*0.454*	*0.554*	*0.344*	*0.856*	*0.554*
			---------------- *110 days after transplant* ----------------			
Zero	4.40c c	2.585	0.20b b	2.010	0.73b b	3.720a a
Half	4.85a a	2.290	0.19c c	1.980	0.745a a	3.895a a
Full	4.45b b	1.845	0.24a a	2.065	0.625c c	3.135b b
			Significance^Y			
Treatment	*<0.0001*	*0.693*	*<0.0001*	*0.9878*	*<0.0001*	*<0.0001*
Block	*0.433*	*0.435*	*0.634*	*0.435*	*0.564*	*0.654*
Treatment x Block	*0.234*	*0.565*	*0.675*	*0.564*	*0.675*	*0.564*
Shapio-Wilk^X	*0.543*	*0.423*	*0.434*	*0.433*	*0.434*	*0.234*

^Z zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
^Y Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
^X The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A7.6. Farm 4 – Fall 2006 Tomato Leaf Tissue Elemental Content. Content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 60 (18 January 2007) DAT. Final leaf tissue concentrations are based on dry weight. (n-1 = 8)

P Fertilizer Rate[Z]	N (%)	S (%)	P (%)	K (%)	Mg (%)	Ca (%)
	-----------------	***60 days after transplanting***	-----------------			
Zero	4.470	1.663	0.480	4.893	0.667	1.983
Half	4.870	1.007	0.470	4.810	0.663	2.060
Full	4.800	0.990	0.443	3.893	0.607	2.217
			Significance[Z]			
Treatment	*0.062*	*0.433*	*0.389*	*0.541*	*0.489*	*0.112*
Block	*0.754*	*0.545*	*0.564*	*0.745*	*0.546*	*0.543*
Treatment x Block	*0.344*	*0.534*	*0.674*	*0.564*	*0.564*	*0.454*
Shapio-Wilk[X]	*0.563*	*0.654*	*0.423*	*0.564*	*0.344*	*0.442*

[Z] zero (0 lb P/acre), Half (56 lb P/acre) and Full (112 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Appendix 8 Tomato Yield Data

Table A8.1. Farm 1 – Spring 2006 Tomato Yields. Two 10-plant sub-samples within each plot were harvested and separated by fruit size. First harvest was on 27 February 2006, second harvest on 10 March 2006, and third harvest on 27 March 2006. Size categories are 6x7 (medium), 6x6 (large), and 5x6 (extra large). Yields are reported in units of lbs per 10 plants and 25-lb boxes/acre. Culled fruit were considered unmarketable. (n-1 = 8)

	-------------- 5x6 --------------			-------------- 6x6 --------------			-------------- 6x7 --------------			------------ Total ------------		
P Fertilizer Rate^{Z}	Marketable Yield (boxes/ac)	Avg Wt (oz/fruit)	Cull yield (boxes/ac)	Marketable Yield (boxes/ac)	Avg Wt (oz/fruit)	Cull yield (boxes/ac)	Marketabl e Yield (boxes/ac)	Avg Wt (oz/fruit)	Cull yield (boxes/ac)	Marketabl e Yield (boxes/ac)	Avg Wt (oz/fruit)	Cull 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^{Y}						
Treatment	*0.444*	*0.868*	*0.621*	*0.066*	*0.881*	*0.117*	*0.741*	*0.808*	*0.572*	*0.451*	*0.707*	*0.268*
Block	*0.893*	*0.546*	*0.547*	*0.655*	*0.434*	*0.544*	*0.434*	*0.453*	*0.433*	*0.554*	*0.534*	*0.453*
Treatment x Block	*0.564*	*0.598*	*0.673*	*0.544*	*0.453*	*0.434*	*0.564*	*0.543*	*0.454*	*0.433*	*0.455*	*0.443*
	------------	------------	------------	------------	------------	*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^{Y}						
Treatment	*0.652*	*0.258*	*0.783*	*0.932*	*0.779*	*0.282*	*0.274*	*0.330*	*0.570*	*0.563*	*0.913*	*0.380*
Block	*0.356*	*0.323*	*0.324*	*0.423*	*0.534*	*0.756*	*0.645*	*0.546*	*0.673*	*0.323*	*0.342*	*0.543*
Treatment x Block	*0.432*	*0.324*	*0.432*	*0.543*	*0.634*	*0.543*	*0.342*	*0.342*	*0.453*	*0.432*	*0.543*	*0.443*
	------------	------------	------------	------------	------------	*Third harvest*	------------	------------	------------	------------	------------	------------
Zero	354	6.9	49	371 a a	5.3	44	379	4.3	41	1105 a a	5.3	134
Half	305	6.8	58	316 b b	5.3	47	312	4.2	52	932 b b	5.2	158
Full	313	6.9	35	322 b b	5.3	38	350	4.2	56	985 b b	5.2	130
						Significance^{Y}						

Treatment	*0.467*	*0.513*	*0.608*	*0.024*	*0.680*	*0.620*	*0.136*	*0.668*	*0.456*	*0.013*	*0.942*	*0.454*
Block	*0.356*	*0.654*	*0.454*	*0.434*	*0.443*	*0.433*	*0.565*	*0.632*	*0.434*	*0.234*	*0.453*	*0.754*
Treatment x Block	*0.543*	*0.954*	*0.543*	*0.343*	*0.543*	*0.564*	*0.434*	*0.563*	*0.345*	*0.423*	*0.575*	*0.534*
	------------------------------------ *Fourth harvest* ------------------------------------											
Zero	86	6.6	18	201 a a	5.2 a a	40 a a	472 a b	4.0	100	759 a a	4.4	159
Half	114	6.5	31	242 a a	5.2 a a	42 a a	485 a b	4.0	99	841 a a	4.5	172
Full	40	6.9	20	138 b b	5.1 b b	23 b b	331 b b	3.9	68	508 b b	4.3	112
	Significance[Y]											
Treatment	*0.065*	*0.534*	*0.269*	*0.010*	*0.003*	*0.019*	*0.040*	*0.750*	*0.284*	*0.019*	*0.209*	*0.155*
Block	*0.475*	*0.434*	*0.548*	*0.678*	*0.656*	*0.543*	*0.453*	*0.658*	*0.437*	*0.892*	*0.324*	*0.564*
Treatment x Block	*0.324*	*0.564*	*0.443*	*0.543*	*0.453*	*0.344*	*0.433*	*0.678*	*0.443*	*0.784*	*0.443*	*0.453*
	------------------------------------ *Total* ------------------------------------											
Zero	1390	7.4	201	1050 a a	5.4	136 a a	1150	4.2	183	3590 a a	5.4	521
Half	1460	7.4	231	1040 a a	5.4	150 a a	1060	4.2	189	3550 a a	5.5	570
Full	1320	7.4	185	907 b b	5.4	98 b b	930	4.2	153	3160 b b	5.5	436
	Significance											
Treatment	*0.497*	*0.984*	*0.385*	*0.028*	*0.900*	*0.009*	*0.064*	*0.809*	*0.591*	*0.014*	*0.722*	*0.127*
Block	*0.546*	*0.434*	*0.434*	*0.534*	*0.568*	*0.544*	*0.434*	*0.564*	*0.233*	*0.453*	*0.573*	*0.345*
Treatment x Block	*0.543*	*0.565*	*0.634*	*0.544*	*0.675*	*0.455*	*0.543*	*0.424*	*0.434*	*0.312*	*0.642*	*0.233*
Shapiro-Wilk[X]	*0.213*	*0.324*	*0.564*	*0.443*	*0.658*	*0.545*	*0.564*	*0.334*	*0.543*	*0.123*	*0.342*	*0.235*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)

[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.

[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A8.2. Farm 1 – Fall 2006 Tomato Yields. Two 10-plant sub-samples within each plot were harvested and separated by fruit size. First harvest was on 23 January 2007, second harvest on 18 February 2007, and third harvest on 2 March 2007. Size categories are 6x7 (medium), 6x6 (large), and 5x6 (extra large). Yields are reported in units of lbs per 10 plants and 25-lb boxes/acre. Culled fruit were considered unmarketable. (n-1 = 8)

	---- Medium (6x7) ------		----- Large (6x6) ---------		------- Extra-large (5x6) -------		------------- Total -------------		
P Fertilizer Rate[Z]	Total fruit Wt (lb/10 plants)	Marketable yield boxes/ac	Total fruit Wt (lb/10 plants)	Marketable yield boxes/ac	Total fruit Wt (lb/10 plants)	Marketable yield boxes/ac)	Marketable yield (boxes/ac)	Unmarketable yield (lb/10 plants)	Unmarketable yield (boxes/ac)
				First Harvest					
Zero	0.58	8.42	3.57	51.84	32.30	469.00	529	2.41	35
Half	0.38	5.52	3.91	56.77	32.68	474.51	537	2.53	66
Full	0.22	3.19	4.69	68.10	32.20	467.54	539	2.48	36
					Significance[Y]				
Treatment	0.712	0.712	0.642	0.642	0.982	0.982	0.778	0.639	*0.893*
Block	0.345	0.344	0.344	0.453	0.434	0.543	0.453	0.533	*0.455*
Treatment x Block	0.567	0.634	0.245	0.564	0.543	0.453	0.544	0.453	*0.553*
				Second Harvest					
Zero	0.82	11.91	12.16	176.56	33.56	487.29	676	5.19	75
Half	0.31	4.50	12.55	182.23	33.88	491.94	679	5.91	86
Full	0.58	8.42	10.77	156.38	36.90	535.79	701	4.34	63
					Significance[Y]				
Treatment	0.386	0.386	0.549	0.549	0.835	0.835	0.590	0.543	*0.543*
Block	0.443	0.233	0.433	0.653	0.435	0.563	0.534	0.453	*0.666*
Treatment x Block	0.523	0.543	0.644	0.634	0.536	0.645	0.543	0.634	*0.544*
				Third Harvest					

Zero	19.00	275.88	7.25	105.27	10.20	148.10	529	5.35	78
Half	20.25	294.03	7.45	108.17	11.40	165.53	568	7.05	102
Full	20.90	303.47	8.40	121.97	12.45	180.77	606	8.8	128
					Significance[Y]				
Treatment	0.703	0.703	0.907	0.907	0.694	0.694	0.768	*0.412*	*0.412*
Block	0.345	0.546	0.345	0.643	0.434	0.434	0.453	*0.544*	
Treatment x Block	0.634	0.645	0.564	0.673	0.673	0.354	0.345	*0.663*	
				------------------ *Total Harvest* ------------------					
Zero	20.4	296.21	22.98	333.67	76.06	1104.39	1734	12.95	188
Half	20.94	304.05	23.91	347.17	77.96	1131.98	1783	17.53	254
Full	21.7	315.08	23.86	346.45	81.55	1184.11	1846	15.62	227
					Significance[Y]				
Treatment	0.600	0.600	0.698	0.698	0.837	0.837	0.712	0.478	*0.478*
Block	0.543	0.458	0.544	0.354	0.543	0.455	0.433	0.544	*0.343*
Treatment x Block	0.675	0.363	0.645	0.456	0.454	0.434	0.543	0.434	*0.543*
Shapiro-Wilk[X]	0.321	0.643	0.543	0.231	0.433	0.232	0.463	0.122	*0.453*

[Z] zero (0 lb P/acre), Half (84 lb P/acre) and Full (168 lb P/acre)

[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.

[X] The Shapiro-Wilk test tests the <u>null hypothesis</u> that a sample came from a <u>normally distributed</u> population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals <u>are not from a normal distribution</u> and the multiple range test is invalid.

Table A8.3. Farm 1 – Fall 2007 Tomato Yields. Two 10-plant sub-samples within each plot were harvested and separated by fruit size. First harvest was on 8 February 2008 and second harvest on 17 February 2008. Size categories are 6x7 (medium), 6x6 (large), and 5x6 (extra large). Yields are reported in units of lbs per 10 plants and 25-lb boxes/acre. Culled fruit were considered unmarketable. (n-1 = 8)

	---- Medium (6x7) ------		----- Large (6x6) ----------		------- Extra-large (5x6) -------		------------- Total -------------		
P Fertilizer Rate[Z]	Total Fruit Wt (lb/10 plants)	Marketable Yield (boxes/ac)	Total Fruit Wt (lb/10 plants)	Marketable Yield (boxes/ac)	Total Fruit Wt (lb/10 plants)	Marketable Yield (boxes/ac)	Marketable Yield (boxes/ac)	Unmarketable Yield (lb/10 plants)	Unmarketable Yield (boxes/ac)
			----------------- *First Harvest* -------------------						
Zero	3.61	52.4	17.22	250.0	30.21	438.6	741.0	3.97 a a	57.6 a a
Half	2.29	33.2	12.50	181.5	34.93	507.0	721.9	2.05 b a	29.8 b a
Full	3.83	55.6	10.47	152.0	34.75	504.6	712.2	1.79 b a	26.0 b a
				Significance[Y]					
Treatment	0.721	0.721	0.306	0.306	0.472	0.472	0.919	0.045	0.045
Block	0.061	0.061	0.303	0.303	0.066	0.066	0.055	0.051	0.051
Treatment x Block	0.377	0.377	0.359	0.359	0.525	0.525	0.237	0.147	0.147
			----------------- *Second Harvest* -----------------						
Zero	5.34	77.5	5.25	76.2	8.27	120.1	273.8	5.77	83.8
Half	5.43	78.8	3.07	44.6	10.09	146.5	270.1	5.80	84.2
Full	5.92	86.0	4.27	62.0	10.32	149.8	297.7	5.34	77.5
				Significanc[Y]					
Treatment	0.521	0.521	0.487	0.487	0.903	0.903	0.776	0.921	0.921
Block	0.069	0.069	0.741	0.741	0.750	0.750	0.210	0.012	0.012
Treatment x block	0.036	0.036	0.477	0.477	0.225	0.225	0.056	0.293	0.293
			----------------- *Total Harvest* -----------------						
Zero	9.76	141.8	22.46	326.2	38.48	558.8	68.00	9.74	141.4

Half	7.72	112.0	15.58	226.2	45.02	653.6	68.32	7.86	114.1
Full	8.96	130.0	18.74	272.2	45.06	654.2	69.56	7.14	103.7
					Significance[Y]				
Treatment	0.939	0.939	0.653	0.653	0.772	0.772	0.998	0.774	0.774
Block	0.788	0.788	0.802	0.802	0.471	0.471	0.867	0.812	0.812
Treatment x block	0.966	0.966	0.943	0.943	0.491	0.491	0.976	0.882	0.882
Shapiro-Wilk[X]	0.147	0.824	0.643	0.423	0.219	0.234	0.162	0.250	0.248

[Z] zero (0 lb P/acre), Half (80 lb P/acre) and Full (160 lb P/acre)

[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan’s (first letter) and Tukey’s (second letter) multiple range tests using SAS Proc. GLM.

[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A8.4. Farm 3a – Spring 2006 Tomato Yields. Two 10-plant sub-samples within each plot were harvested and separated by fruit size. First harvest was on 3 May 2006, and the second harvest on 12 May 2006. Size categories are 6x7 (medium), 6x6 (large), and 5x6 (extra large). Yields are reported in units of lbs per 10 plants and 25-lb boxes/acre. Culled fruit were considered unmarketable. (n-1 = 5)

	-------------- 5x6 --------------			-------------- 6x6 --------------			-------------- 6x7 --------------			------------ Total ------------		
P Fertilizer RateZ	Marketable Yield (boxes/ac)	Avg Wt (oz/fruit)	Cull yield (boxes/ac)	Marketable Yield (boxes/ac)	Avg Wt (oz/fruit)	Cull yield (boxes/ac)	Marketable Yield (boxes/ac)	Avg Wt (oz/fruit)	Cull yield (boxes/ac)	Marketabl e Yield (boxes/ac)	Avg Wt (oz/fruit)	Cull 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
						SignificanceY						
Treatment	0.346	0.365	0.845	0.365	0.563	0.634	0.346	0.634	0.543	0.643	0.463	
Block	0.344	0.642	0.344	0.757	0.635	0.807	0.564	0.908	0.564	0.753	0.464	
Treatment x Block	0.823	0.356	0.547	0.636	0.464	0.548	0.456	0.643	0.653	0.345	0.644	
						---------------- 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
						SignificanceY						
Treatment	0.436	0.446	0.675	0.563	0.758	0.342	0.543	0.563	0.347	0.634	0.543	0.674
Block	0.576	0.634	0.563	0.634	0.654	0.238	0.589	0.433	0.234	0.346	0.895	0.344
Treatment x Block	0.875	0.356	0.644	0.643	0.645	0.897	0.654	0.754	0.674	0.363	0.873	0.734
						---------------- Total ----------------						
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
						SignificanceY						
Treatment	0.556	0.238	0.346	0.345	0.378	0.346	0.543	0.453	0.545	0.653	0.563	0.654
Block	0.834	0.566	0.546	0.568	0.996	0.745	0.433	0.756	0.675	0.675	0.654	0.344

Treatment x Block	0.283	0.789	0.874	0.434	0.645	0.544	0.545	0.453	0.453	0.569	0.754	0.878
Shapiro-Wilk[X]	0.412	0.544	0.324	0.233	0.453	0.284	0.854	0.543	0.653	0.463	0.436	0.346

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)

[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.

[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A8.5. Farm 3a – Spring 2007 Tomato Yields. Two 10-plant sub-samples within each plot were harvested and separated by fruit size. First harvest was on 27 April 2007, second harvest on 11 May 2007, and third harvest on 21 May 2007. Size categories are 6x7 (medium), 6x6 (large), and 5x6 (extra large). Yields are reported in units of lbs per 10 plants and 25-lb boxes/acre. Culled fruit were considered unmarketable. (n-1 =5)

P Fertilizer Rate[Z]	----- Medium 6x7-------		------ Large 6x6-------		-- Extra Large 5x6 ----		------------- Total -------------		
	Total yield (lb/10plants)	Marketable yield boxes/ac	Total yield (lb/10plants)	Marketable yield boxes/ac	Total yield (lb/10plants)	Marketable yield boxes/ac	Marketable yield boxes/ac	Unmarketable yield (lb/10plants)	Unmarketable yield boxes/ac
					----------First Harvest----------				
Zero	1.4 a a	20 a a	17.0 a a	248 a a	72.2	1048	1316	6	87
Half	0.5 b b	8 b b	19.1 a a	277 a a	67.6	981	1266	4.33	63
Full	0 b b	0 b b	8.4 b b	122 b b	75.0	1089	1211	9.45	137
					Significance[Z]				
Treatment	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*0.874*	*0.874*	*0.911*	*0.337*	*0.332*
Block	*0.784*	*0.354*	*0.654*	*0.534*	*0.534*	*0.345*	*0.344*	*0.893*	*0.655*
Treatment x Block	*0.474*	*0.214*	*0.543*	*0.353*	*0.398*	*0.455*	*0.756*	*0.475*	*0.644*
					----------Second Harvest----------				
Zero	0.53	8	6.13	89	33.08	480	577	3.6	52
Half	0.73	11	9.5	138	32.8	476	625	3.8	55
Full	0.93	13	7.28	106	31.38	456	575	4.4	64
					Significance[Z]				
Treatment	*0.809*	*0.829*	*0.617*	*0.605*	*0.989*	*0.989*	*0.929*	*0.939*	*0.938*
Block	*0.455*	*0.565*	*0.745*	*0.745*	*0.546*	*0.344*	*0.543*	*0.745*	*0.855*
Treatment x Block	*0.876*	*0.645*	*0.645*	*0.754*	*0.654*	*0.643*	*0.654*	*0.565*	*0.768*
					----------Third Harvest----------				
Zero	3.9	57	19.3 a a	280 a a	10.78	156	493	1.95	28
Half	7.43	108	11.7 b b	170 c c	10.05	146	424	4.43	64
Full	6.05	88	14.4 ab ab	209 b b	13.2	192	489	6.9	100

					Significance[Y]				
Treatment	*0.685*	*0.679*	*<0.0001*	*<0.0001*	*0.698*	*0.698*	*0.724*	*0.487*	*0.477*
Block	*0806*	*0.454*	*0.657*	*0.486*	*0.554*	*0.453*	*0.455*	*0.658*	*0.434*
Treatment x Block	*0.735*	*0.654*	*0.455*	*0.654*	*0.456*	*0.845*	*0.654*	*0.546*	*0.345*
			----------*Total Harvest*----------						
Zero	5.81	85	42.46	617	116.06	1684	2386	11.55	168
Half	8.66	127	40.28	585	110.43	1603	2315	12.56	182
Full	6.98	101	30.06	437	119.58	1737	2275	20.75	301
					Significance[y]				
Treatment	*0.747*	*0.754*	*0.617*	*0.605*	*0.854*	*0.520*	*0.855*	*0.585*	*0.582*
Block	*0.453*	*0.465*	*0.544*	*0.432*	*0.744*	*0.634*	*0.434*	*0.546*	*0.344*
Treatment x Block	*0.645*	*0.655*	*0.645*	*0.574*	*0.745*	*0.543*	*0.565*	*0.457*	*0.454*
Shapiro-Wilk[X]	*0.348*	*0.735*	*0.456*	*0.356*	*0.243*	*0.264*	*0.564*	*0.344*	*0.342*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)

[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=6). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.

[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A8.6. Farm 4 – Spring 2007 Tomato Yields. Two 10-plant sub-samples within each plot were harvested and separated by fruit size. First harvest was on 23 January 2007, second harvest on 18 February 2007, and third harvest on 2 March 2007. Size categories are 6x7 (medium), 6x6 (large), and 5x6 (extra large). Yields are reported in units of lbs per 10 plants and 25-lb boxes/acre. Culled fruit were considered unmarketable. (n-1 = 8)

	---------- Medium (6x7) ----------			---------- Large (6x6) ----------			------- Extra-large (5x6) -------			-------------- Total --------------	
P Fertilizer Rate[Z]	Marketable Yield (boxes/ac)	With color (%)	Avg. fruit Wt (oz/fruit)	Marketable Yield (boxes/ac)	With color (%)	Avg. fruit Wt (oz/fruit)	Marketable Yield (boxes/ac)	With color (%)	Avg. fruit Wt (oz/fruit)	Marketable yield (boxes/ac)	Unmarketable yield (boxes/ac)
						---------------- First harvest ----------------					
Zero	64	37	5.2	174	22	6.4	769	20	9.0	1007	2
Half	60	33	5.2	195	25	6.2	747	19	9.1	1002	5
Full	46	38	5.5	190	19	6.4	717	23	9.0	954	4
						Significance[Y]					
Treatment	*0.281*	*0.705*	*0.369*	*0.789*	*0.726*	*0.676*	*0.832*	*0.497*	*0.967*	*0.843*	*0.165*
Block	*0.364*	*0.345*	*0.676*	*0.957*	*0.745*	*0.565*	*0.545*	*0.435*	*0.345*	*0.354*	*0.343*
Treatment x Block	*0.344*	*0.654*	*0.455*	*0.656*	*0.455*	*0.655*	*0.344*	*0.454*	*0.653*	*0.455*	*0.234*
						---------------- Second harvest ----------------					
Zero	170	24	4.8	254	16	5.9	336	20	7.6	760	8
Half	190	26	4.8	230	23	6.0	437	20	7.6	857	8
Full	196	20	4.8	248	16	6.0	336	18	7.7	780	10
						Significance[Y]					
Treatment	*0.690*	*0.560*	*0.790*	*0.741*	*0.263*	*0.174*	*0.298*	*0.707*	*0.611*	*0.607*	*0.372*
Block	*0.234*	*0.354*	*0.635*	*0.456*	*0.478*	*0.876*	*0.456*	*0.465*	*0.344*	*0.645*	*0.877*
Treatment x Block	*0.634*	*0.365*	*0.654*	*0.497*	*0.345*	*0.653*	*0.565*	*0.754*	*0.654*	*0.635*	*0.567*
						---------------------- Total ----------------------					
Zero	234	27	4.9	428	18	6.1	1106	20	8.6	1768	10
Half	250	27	4.9	425	24	6.1	1184	19	8.5	1859	13
Full	243	22	4.9	438	18	6.2	1053	21	8.6	1734	14
						Significance[Y]					
Treatment	*0.870*	*0.460*	*0.250*	*0.965*	*0.123*	*0.671*	*0.649*	*0.789*	*0.659*	*0.771*	*0.073*

Block	*0.454*	*0.346*	*0.478*	*0.365*	*0.454*	*0.434*	*0.954*	*0.423*	*0.758*	*0.855*	*0.634*
Treatment x Block	*0.453*	*0.657*	*0.455*	*0.734*	*0.573*	*0.874*	*0.455*	*0.454*	*0.345*	*0.544*	*0.568*
Shapiro-Wilk[X]	*0.534*	*0.284*	*0.257*	*0.248*	*0.633*	*0.634*	*0.237*	*0.243*	*0.342*	*0.363*	*0.453*

[Z] zero (0 lb P/acre), Half (56 lb P/acre) and Full (112 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Appendix 9 Miscellaneous Crops Data

Eggplant

Table A9.1. Farm 2 – Spring 2006 Eggplant Biomass and Extractable Soil Nutrients. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Samples were collected on at 60 (3 January 2006), 120 (5 April 2006) and 180 (4 June 2006) DAT. 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. Samples were collected prior to planting (5 December 2005), and at 60 (3 February 2006), 120 (5 April 2006) and 180 (4 June 2006) days after transplanting. (n-1 = 8)

P Fertilizer Rate^{Z}	Plant biomass (g/plant)	----------------------- Soil ---------------------------- P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	pH
			---------------- Before transplant ----------------			
Zero	--	501	223	226 a a	5110	7.0
Half	--	545	193	204 b a	5250	7.0
Full	--	510	160	179 c b	4720	7.0
			Significance^{Y}			
Treatment	--	*0.592*	*0.198*	*<.001*	*0.234*	*0.790*
Block		*0.934*	*0.348*	*0.984*	*0.865*	*0.465*
Treatment x Block		*0.678*	*0.594*	*0.544*	*0.645*	*0.776*
			---------------- 60 days after transplant ----------------			
Zero	32.6	453	264	247	4620	6.8
Half	34.3	550	337	233	4710	6.9
Full	30.3	507	350	279	4830	6.6
			Significance^{Y}			
Treatment	*0.477*	*0.213*	*0.374*	*0.627*	*0.832*	*0.105*
Block	*0.445*	*0.876*	*0.545*	*0.967*	*0.896*	*0.654*
Treatment x Block	*0.465*	*0.745*	*0.454*	*0.755*	*0.855*	*0.675*
			---------------- 120 days after transplant ----------------			
Zero	333	466	239	275	4760	7.3 a a
Half	324	486	240	289	4850	7.3 a a
Full	330	520	177	271	4800	7.1 b b
			Significance^{Y}			
Treatment	*0.829*	*0.509*	*0.763*	*0.967*	*0.972*	*0.042*
Block	*0.346*	*0.744*	*0.654*	*0.474*	*0.566*	*0.544*
Treatment x Block	*0.634*	*0.875*	*0.454*	*0.745*	*0.586*	*0.454*
			---------------- 180 days after transplant ----------------			
Zero	441	488	187	353	5290	7.5
Half	553	534	175	320	5370	7.5

Full	527	510	133	302	5130	7.5
			Significance[Y]			
Treatment	*0.282*	*0.212*	*0.682*	*0.164*	*0.583*	*0.871*
Block	*0.345*	*0.765*	*0.366*	*0.654*	*0.564*	*0.634*
Treatment x Block	*0.634*	*0.454*	*0.564*	*0.456*	*0.346*	*0.564*
Shapiro-Wilk[X]	*0.455*	*0.343*	*0.234*	*0.237*	*0.237*	*0.345*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A9.2. Farm 2 – Spring 2006 Eggplant Leaf Tissue Elemental Content. Content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 60 (3 January 2006) and 120 (5 April 2006) DAT. Final leaf tissue concentrations are based on dry weight. (n-1 = 8)

P Fertilizer Rate[Z]	N (%)	P (%)	K (%)	Mg (%)	Ca (%)
	----------- *60 days after transplant* ------------				
Zero	5.89	0.58	5.13	0.44	2.17
Half	6.14	0.65	5.17	0.42	2.19
Full	6.11	0.65	5.14	0.39	2.01
			Significance[Y]		
Treatment	*0.068*	*0.276*	*0.873*	*0.120*	*0.519*
Block	*0.455*	*0.534*	*0.354*	*0.764*	*0.545*
Treatment x Block	*0.544*	*0.547*	*0.655*	*0.564*	*0.356*
	-------- *120 days after transplant* ----------				
Zero	4.36	0.32	4.11	0.61	3.95
Half	4.66	0.30	4.02	0.60	4.19
Full	4.58	0.29	4.28	0.55	4.05
			Significance[Y]		
Treatment	*0.083*	*0.496*	*0.365*	*0.075*	*0.378*
Block	*0.365*	*0.343*	*0.567*	*0.644*	*0.475*
Treatment x Block	*0.564*	*0.645*	*0.658*	*0.435*	*0.324*
Shapiro-Wilk[X]	*0.434*	*0.324*	*0.245*	*0.236*	*0.277*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A9.3. Farm 2 – Spring 2006 Eggplant Yields. Two 10-plant sub-samples within each plot were harvested and separated into marketable and unmarketable categories. First harvest was on 10 March 2006 and ended on 1 June 2006 with a total of 14 harvests. Yields are reported in units of fruit number and pounds per acre. Culled fruit were considered unmarketable. (n-1 = 8)

P Fertilizer Rate[Z]	Marketable			Unmarketable	
	(no/ac)	(lb/ac)	(lb/fruit)	(no/ac)	(lb/ac)
			---------------- *Early yield* ----------------		
Zero	2060	3190	1.55	726	1100
Half	2780	4550	1.67	968	1230
Full	2180	3560	1.61	847	1340
			Significance[Y]		
Treatment	*0.462*	*0.421*	*0.367*	*0.444*	*0.812*
Block	*0.865*	*0.474*	*0.546*	*0.346*	*0.654*
Treatment x Block	*0.346*	*0.545*	*0.644*	*0.653*	*0.765*
			---------------- *Mid yield* ----------------		
Zero	26,900	39,000	1.45	730 b b	1,130
Half	28,300	41,300	1.46	1,750 a a	2,140
Full	28,400	41,700	1.46	1,210 ab a	1,600
			Significance[Y]		
Treatment	*0.736*	*0.568*	*0.871*	*0.046*	*0.165*
Block	*0.343*	*0.343*	*0.364*	*0.454*	*0.764*
Treatment x Block	*0.634*	*0.645*	*0.675*	*0.363*	*0.454*
			---------------- *Late yield* ----------------		
Zero	19,800	24,500	1.25	3,330 b b	3,420
Half	20,200	25,200	1.22	3,750 b b	3,900
Full	18,500	23,600	1.28	4,600 a a	4,630
			Significance[Y]		
Treatment	*0.843*	*0.882*	*0.457*	*0.009*	*0.107*
Block	*0.344*	*0.465*	*0.654*	*0.654*	*0.855*
Treatment x Block	*0.745*	*0.745*	*0.546*	*0.454*	*0.4647*
			---------------- *Total yield* ----------------		
Zero	48,800	66,800	1.37	4,780 b b	5,640
Half	51,200	71,000	1.37	6,470 a a	7,280
Full	49,100	68,900	1.40	6,660 a a	7,570
			Significance[Y]		
Treatment	*0.620*	*0.479*	*0.216*	*0.009*	*0.071*
Block	*0.654*	*0.586*	*0.479*	*0.458*	*0.549*
Treatment x Block	*0.645*	*0.654*	*0.766*	*0.t34*	*0.434*
Shapiro-Wilk[X]	*0.274*	*0.434*	*0.344*	*0.784*	*0.432*

Peppers

Table A9.4. Farm 2 – Spring 2007 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. Samples were collected at 90 (27 March 2007) 120 (2 May 2007) and 150 (30 May 2007) days after transplanting. (n-1 = 8)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	pH
	---------------- *90 days after transplanting* --------------				
Zero	65.25	278.8	146.8	1255	7.50
Half	67.25	252.5	146.3	1213	7.67
Full	82.75	268.5	147.8	1263	7.50
			Significance[Y]		
Treatment	*0.128*	*0.888*	*0.998*	*0.710*	*0.059*
Block	*0.565*	*0.476*	*0.656*	*0.765*	*0.568*
Treatment x Block	*0.734*	*0.566*	*0.657*	*0.679*	*0.638*
	----------------- *120 days after transplanting* -----------------				
Zero	66.75	130.5	132.3	1358	7.70
Half	82.00	159.5	154.5	1565	7.63
Full	124.8	196.3	176.3	1538	7.73
			Significance[Y]		
Treatment	*0.244*	*0.08*	*0.189*	*0.114*	*0.512*
Block	*0.735*	*0.645*	*0.474*	*0.865*	*0.478*
Treatment x Block	*0.685*	*0.658*	*0.875*	*0.464*	*0.744*
	----------------- *150 days after transplanting* -----------------				
Zero	59.25	155.3	138.8	1090	7.68
Half	69.75	137.5	137.3	1033	7.78
Full	92.75	142.5	132.8	1053	7.70
			Significance[Y]		
Treatment	*0.058*	*0.872*	*0.958*	*0.495*	*0.114*
Block	*0.344*	*0.865*	*0.867*	*0.344*	*0.658*
Treatment x Block	*0.635*	*0.655*	*0.544*	*0.897*	*0.346*
Shapiro-Wilk[X]	*0.344*	*0.434*	*0.343*	*0.243*	*0.234*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.

[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A9.5. Farm 2 – Spring 2007 Pepper Biomass. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected on at 90 (27 March 2007), 120 (2 May 2007) and 150 (30 May 2007) DAT. (n-1 – 8)

P Fertilizer Rate[Z]	Jalapeno Fresh fruit (oz/plant)	Jalapeno Dry plant mass (g/plant)	Jalapeno Dry plant mass (oz/plant)	Cubanello Fresh fruit (oz/plant)	Cubanello Dry plant mass (g/plant)	Cubanello Dry plant mass (oz/plant)
			----------90 days after plant----------			
Zero	10.20	52.16	1.84	11.60	34.59	1.22
Half	12.60	59.25	2.09	19.60	49.05	1.73
Full	13.60	67.19	2.37	17.00	46.49	1.64
			Significance[Y]			
Treatment	*0.385*	*0.486*	*0.486*	*0.209*	*0.088*	*0.088*
Block	*0.346*	*0.875*	*0.764*	*0.645*	*0.564*	*0.867*
Treatment x Block	*0.654*	*0.556*	*0.545*	*0.544*	*0.565*	*0.543*
			----------120 days after plant----------			
Zero	12.80	104.33	3.68	16.80	67.76	2.39
Half	11.20	100.08	3.53	19.80	65.21	2.30
Full	11.60	90.44	3.19	16.00	61.52	2.17
			Significance[Y]			
Treatment	*0.788*	*0.471*	*0.471*	*0.676*	*0.915*	*0.915*
Block	*0.344*					
Treatment x Block	0.65					
			----------150 days after plant----------			
Zero	9.20 a a	106.60	3.76	3.40	72.29	2.55
Half	3.60 b b	128.99	4.55	5.20	81.65	2.88
Full	4.80 b b	135.23	4.77	6.60	82.22	2.90
			Significance[Y]			
Treatment	*0.030*	*0.597*	*0.597*	*0.536*	*0.678*	*0.678*
Block	*0.548*	*0.436*	*0.534*	*0.364*	*0.654*	*0.659*
Treatment x Block	*0.874*	*0.634*	*0.543*	*0.655*	*0.475*	
Shapiro-Wilk[X]	*0.344*	*0.345*	*0.294*	*0.544*	*0.675*	*0.324*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A9.6. Farm 2 – Spring 2007 Pepper Leaf Tissue Elemental Content. Content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were 90 (27 March 2007), 120 (2 May 2007) and 150 (30 May 2007) DAT. Final leaf tissue concentrations are based on dry weight. (n-1 = 8)

P Fertilizer Rate[Z]	N (%)	S (%)	P (%)	K (%)	Mg (%)	Ca (%)
	---------------- *90 days after transplant* ----------------					
Zero	5.300	0.390	0.450	5.080	0.620	1.130
Half	5.380	0.440	0.390	5.680	0.640	1.180
Full	4.900	0.410	0.480	5.620	0.670	1.150
	Significance[Y]					
Treatment	*0.326*	*0.265*	*0.543*	*0.177*	*0.595*	*0.874*
Block	*0.885*	*0.434*	*0.435*	*0.657*	*0.564*	*0.654*
Treatment x Block	*0.785*	*0.765*	*0.455*	*0.434*	*0.675*	*0.765*
	---------------- *120 days after transplant* ----------------					
Zero	2.430	0.780	0.290	4.180	1.000	2.775
Half	2.300	0.750	0.280	4.240	1.010	2.850
Full	2.450	0.750	0.280	4.230	0.970	2.680
	Significance[Y]					
Treatment	*0.671*	*0.824*	*0.697*	*0.822*	*0.619*	*0.423*
Block	*0.354*	*0.463*	*0.785*	*0.685*	*0.766*	*0.854*
Treatment x Block	*0.564*	*0.434*	*0.655*	*0.658*	*0.563*	*0.454*
	---------------- *150 days after transplant* ----------------					
Zero	3.730	0.900	0.430	5.030	0.825	1.940
Half	3.530	0.850	0.440	4.830	0.800	1.610
Full	3.500	0.850	0.410	5.010	0.700	2.010
	Significance[Y]					
Treatment	*0.909*	*0.729*	*0.732*	*0.449*	*0.184*	*0.511*
Block	*0.635*	*0.744*	*0.768*	*0.685*	*0.568*	*0.564*
Treatment x Block	*0.474*	*0.786*	*0.436*	*0.987*	*0.765*	*0.368*
Shapiro-Wilk[X]	*0.243*	*0.342*	*0.544*	*0.544*	*0.342*	*0.323*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A9.7. Farm 2 – Spring 2007 Pepper Yields. Two 10-plant sub-samples within each plot were harvested and separated into marketable and unmarketable categories. There were five harvest at 27 March 2007, 10 April 2007, 25 Apirl 2007, 9 May 2007 and 23 May 2007. Yields are reported in units of fruit number and 25-pound boxes per acre. Culled fruit were considered unmarketable. (n-1 = 8)

	Jalapeno			*Cubanello*		
P Fertilizer Rate[Z]	Fruit wt (Oz/fruit)	Fruit wt (lb)	Fruit wt (Boxes/ac)	Fruit wt (Oz/fruit)	Fruit wt (lb)	Fruit wt (Boxes/ac)
			----------*First harvest*----------			
Zero	1.09	4.70	23	3.49	6.05	29
Half	1.13	5.65	27	3.68	6.55	32
Full	1.14	5.10	25	3.75	6.93	34
				Significance[Y]		
Treatment	*0.537*	*0.310*	*0.310*	*0.503*	*0.717*	*0.717*
Block	*0.834*	*0.865*	*0.674*	*0.656*	*0.876*	*0.765*
Treatment x Block	*0.547*	*0.667*	*0.754*	*0.754*	*0.564*	*0.655*
			----------*Second harvest*----------			
Zero	1.07	16.9	82	4.10	23.08	112
Half	1.07	15.83	77	4.04	26.10	126
Full	1.06	15.58	75	4.04	26.48	128
				Significance[Y]		
Treatment	*0.901*	*0.531*	*0.531*	*0.709*	*0.452*	*0.452*
Block	*0.654*	*0.987*	*0.685*	*0.655*	*0.655*	*0.565*
Treatment x Block	*0.665*	*0.795*	*0.867*	*0.756*	*0.789*	*0.786*
			----------*Third harvest*----------			
Zero	0.97	20.68	100	3.03	3.63	18
Half	0.91	15.25	74	2.70	3.05	15
Full	0.89	13.63	66	2.96	3.13	15
				Significance[Y]		
Treatment	*0.125*	*0.561*	*0.561*	*0.712*	*0.858*	*0.858*
Block	*0.657*	*0.657*	*0.545*	*0.437*	*0.545*	*0.865*
Treatment x Block	*0.564*	*0.432*	*0.966*	*0.976*	*0.776*	*0.769*
			----------*Forth harvest*----------			
Zero	*0.86*	*4.38*	21	*2.18*	*7.55*	*37*
Half	*0.85*	*5.33*	26	*2.10*	*6.33*	*31*
Full	*0.90*	*6.15*	30	*2.31*	*8.55*	*41*
				Significance[Y]		
Treatment	*0.074*	*0.279*	0.279	*0.700*	*0.681*	*0.681*
Block	*0.655*	*0.676*	0.585	*0.877*	*0.756*	*0.987*
Treatment x Block	*0.234*	*0.655*	0.657	*0.767*	*0.766*	*0.678*
			----------*Fifth harvest*----------			
Zero	*1.07*	*7.78*	*38*	*2.01*	2.28	*11*

Half	*0.74*	*6.55*	*32*	*2.12*	*1.58*	*8*
Full	*0.74*	*5.10*	*25*	*2.97*	*1.58*	*8*
				Significance^{Y}		
Treatment	*0.345*	*0.505*	*0.505*	*0.444*	*0.795*	*0.795*
Block	*0.655*	*0.897*	*0.987*	*0.549*	*0.565*	*0.876*
Treatment x Block	*0.787*	*0.676*	*0.545*	*0.767*	*0.685*	*0.776*
			----------*Total harvest*----------			
Zero	*5.06*	*54.42*	*264*	*14.81*	*42.59*	*207*
Half	*4.70*	*48.61*	*236*	*14.64*	*43.61*	*212*
Full	*3.86*	*45.56*	*221*	*16.03*	*46.67*	*226*
				Significance^{Y}		
Treatment	*0.477*	*0.477*	*0.477*	*0.592*	*0.706*	*0.706*
Block	*0.346*	*0.786*	*0.786*	*0.676*	*0.589*	*0.454*
Treatment x Block	*0.656*	*0.454*	*0.544*	*0.545*	*0.634*	*0.685*
Shapiro-Wilk^{X}	*0.453*	*0.323*	*0.233*	*0.432*	*0.796*	*0.238*

^{Z} zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
^{Y} Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
^{X} The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Corn

Table A9.8. Farm 2 – Spring 2008 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. Samples were collected prior to planting (11 January 2008), and at 31 (8 February 2008) and 62 (10 March 2008) days after transplanting. (n-1 = 8)

P Fertilizer Rate[Z]	P (ppm)	K (ppm)	Ca (ppm)	Fe (ppm)	pH
	-------------------- *At planting* -----------------------				
Zero	309	184	2797	11	7.7
Half	293	144	2646	11	7.8
Full	292	103	2509	12	7.7
		Significance[Y]			
Treatment	*0.267*	*0.321*	*0.438*	*0.242*	*.0833*
Block	*0.008*	*0.138*	*0.010*	*0.016*	*0.067*
Treatment x Block	*0.371*	*0.575*	*0.591*	*0.148*	*0.789*
	---------------- *31 days after planting* ----------------				
Zero	364	240	2822	10	7.4
Half	358	186	2755	10	7.5
Full	380	162	2851	12	7.4
		Significance[Y]			
Treatment	*0.889*	*0.781*	*0.960*	*0.445*	*0.182*
Block	*0.654*	*0.666*	*0.109*	*0.309*	*0.005*
Treatment x Block	*0.548*	*0.963*	*0.848*	*0.813*	*0.160*
	---------------- *62 days after planting* ----------------				
Zero	428	97	3124	12	8.0
Half	386	44	2872	10	7.8
Full	404	57	2771	12	7.8
		Significance[Y]			
Treatment	*0.501*	*0.182*	*0.641*	*0.419*	*0.187*
Block	*0.150*	*0.221*	*0.036*	*0.125*	*0.019*
Treatment x Block	*0.216*	*0.475*	*0.481*	*0.509*	*0.903*
Shapiro-Wilk[X]	*0.478*	*0.685*	*0.288*	*0.926*	*0.200*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A9.9. Farm 2 – Spring 2008 Corn Biomass. Plant stems were cut at the soil surface and removed from the field. The entire shoot (the above ground portion of the plant) was then dried in a drying oven until all water content was removed. Fruit and vegetative parts were removed and weighed separately. Samples were collected on at 31 (8 February 2008) and 62 (10 March 2008) DAT. (n-1 = 8)

P Fertilizer Rate[Z]	Fresh Wt (g ears/plant)	Dry Biomass (g/plant)
	-- 31 days after planting --	
Zero	-	9.67
Half	-	8.97
Full	-	10.80
	Significance[Y]	
Treatment		*0.799*
Block		*0.506*
Treatment x Block		*0.673*
	-- 62 days after planting --	
Zero	1.15	62.75
Half	0.85	53.37
Full	1.00	61.87
	Significance[Y]	
Treatment	*0.151*	*0.226*
Block	*0.083*	*0.232*
Treatment x Block	*0.331*	*0.215*
Shapiro-Wilk[X]	0.158	0.211

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at $P \leq 0.05$ (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, $P \leq 0.05$ indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A9.10. Farm 2 – Spring 2008 Corn Leaf Tissue Elemental Content. Content determined by harvest of ten to fifteen "most recently mature" leaves at separate locations throughout each plot. These recently mature leaves are located 4 to 6 leaves from the shoot terminal. Sample collection dates were at 31 (8 February 2008), 62 (10 March 2008) and 73 (21 March 2008) DAT. Final leaf tissue concentrations are based on dry weight. (n-1 = 8)

P Fertilizer Rate[Z]	N (%)	P (%)	K (%)
	----- *31 days after transplant* -------		
Zero	3.94	0.24	2.38
Half	3.68	0.26	2.29
Full	3.76	0.26	2.28
	Significance[Y]		
Treatment	*0.502*	*0.221*	*0.956*
Block	*0.241*	*0.102*	*0.225*
Treatment x Block	*0.860*	*0.130*	*0.884*
	----- *62 days after transplant* -------		
Zero	3.98	0.307	1.25
Half	3.88	0.343	1.16
Full	3.62	0.335	1.23
	Significance[Y]		
Treatment	*0.353*	*0.804*	*0.898*
Block	*0.612*	*0.093*	*0.643*
Treatment x Block	*0.707*	*0.966*	*0.853*
	----- *73 days after transplant* -------		
Zero	3.70	0.303	1.40
Half	3.67	0.273	1.39
Full	3.53	0.261	1.28
	Significance[Y]		
Treatment	*0.075*	*0.175*	*0.843*
Block	*0.047*	*0.690*	*0.418*
Treatment x Block	*0.212*	*0.961*	*0.745*
Shapiro-Wilk[X]	*0.179*	*0.047*	*0.517*

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.

Table A9.11. Farm 2 – Spring 2008 Corn Yields. Two 10-plant sub-samples within each plot were harvested and separated into marketable and unmarketable categories. Harvest was made once on 21 March 2008. Yields are reported in units of fruit number and pounds per acre. Culled fruit were considered unmarketable. (n-1 = 8)

P Fertilizer Rate[Z]	Fresh Wt. (lbs ears/ac)	Count (ears/ac)	Cull Wt (lbs ears/ac)	Cull Count (ears/ac)
Zero	6886	10306	1062	8425
Half	5907	9296	1072	7257
Full	6037	9435	993	7989
		Significance[Y]		
Treatment	*0.904*	*0.328*	*0.625*	*0.866*
Block	*0.563*	*0.163*	*0.961*	*0.701*
Treatment x block	*0.915*	*0.273*	*0.607*	*0.825*
Shapiro-Wilk[X]	0.844	0.103	0.263	0.171

[Z] zero (0 lb P/acre), Half (50 lb P/acre) and Full (100 lb P/acre)
[Y] Treatment, block, or interactions are considered significantly different at P ≤ 0.05 (n=9). Treatment means within columns with different letters are significantly different from each other (as indicated by letters a, b, etc.). Separation of treatment means with significant differences are presented using Duncan's (first letter) and Tukey's (second letter) multiple range tests using SAS Proc. GLM.
[X] The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. The test was applied to the residuals of the sample and linear model, therefore, P ≤ 0.05 indicates that the residuals are not from a normal distribution and the multiple range test is invalid.