CDFA Fertilizer Research and Education Program 2014 Project

A. Project Information:

2014 CDFA/FREP Summary Report, 2014 cropping year (May – Dec, 2014).

Project Title:

PHOSPHOROUS AND BORON FERTILIZER IMPACTS ON SWEETPOTATO PRODUCTION AND LONG-TERM STORAGE

project #13-0266-SA.
GTS No. Y13 - 2034
Principal Investigator/Project Director: Scott Stoddard,
SUBJECT: Phosphorous and Boron Fertilizer Impacts on Sweetpotato Production and Storage , **Sponsored by:** CAL DFA DIVISION OF PEST PREVENTION AND PLANT HEALTH SERVICES
Agreement Number: 13-0266-SA . **Amount:** $8,576.00

Project Leader:

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B. Objectives:

1. Evaluate different rates of soil applied phosphorous on sweetpotato crop response in soil, leaves, and roots to determine P rate recommendations for this crop.
2. Evaluate different rates of boron fertilizer on sweetpotato roots to determine impacts on yield and skin color after long-term storage.

C. Abstract

The last documented fertilizer trial conducted in California for phosphorus on sweetpotatoes was in 1974, and no trials evaluating crop response to fertilizer boron have ever been conducted in the state. The industry has changed substantially in the last 40 years, with increased use of compost, new varieties, drip irrigation, and much greater emphasis on long-term storage in order to meet customer expectations of having availability to sweetpotatoes year-round. Therefore, an on-farm fertilizer test was conducted in Merced County in 2014 to evaluate the response of sweetpotato cultivar ‘Covington’ to phosphorus and boron fertilizers. Treatment design was a randomized block split-plot with 4 replications. Phosphorus rates were the main plots; Boron rate was the split plot. Split size plot size was 6 rows (20 feet) by 30 feet long. The trial was transplanted on 6-May-2014 with the cultivar “Covington”. Phosphorus fertilizer, as MAP (11-52-0) was applied on 12-May by shanking in the dry fertilizer as a band on either side of the drip tape in the center of the bed to establish P_2O_5 treatments of 0, 50, 100, and 150 lbs/A. Ammonium sulfate and potassium sulfate were also added to each plot as appropriate so that applied N and K were

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equivalent. Boron fertilizer, as Granubor 14.3% B, was applied by hand down the center of the bed under the drip tape on 28-May and lightly incorporated. The amount of B varied by plot to establish treatment rates of 0, 1, 2, and 3 lbs B/A. Additional nitrogen and potassium fertilizer was applied through the drip tape during the growing season (liquid 10-0-10). Plots were harvested with a commercial mechanical harvester and sorted into #1, medium, and jumbo size categories. Means separations on the various response factors were done using Fishers protected LSD at p=0.05.

Pretreatment soil samples contained 46 ppm Olsen-P and 0.06 ppm B in the upper two feet of the profile, which would indicate that a response to additional P fertilizer would be unlikely, but that boron levels were low. Early season growth was reduced in the 0 lb/A phosphorous and boron plots as compared to the others plots, though this effect disappeared as the season progressed. In-season plant samples taken for B and P analysis showed some increased crop uptake of these nutrients as the rate increased, however the response was weakly polynomial with regression correlation coefficients (R^2) of only 0.3 – 0.56. There was a greater effect on leaf boron levels as fertilizer B increased as compared to phosphorous, but there was no significant effect on the plant canopy biomass from the boron treatments. Canopy biomass at harvest significantly increased from 20,000 lbs/A to 30,000 lbs/A in the plots with the highest rate of P (150 lbs P_2O_5 per acre), and all fertilizer rates had greater P concentration in the canopy compared to the 0 rate. Fall soil samples showed few differences, however, to the different rates of applied P or B, and and there was no correlation between fall soil test values and yield. Overall yields were very good in this field, with total marketable yield averaging over 56 bins/A, but only the jumbo size category displayed a significant response to added P, with more jumbos at 150 lbs P_2O_5 per acre as compared to the 0 rate. As a result, there was a significant inverse relationship observed in the economically important No. 1 category, with the highest percentage of No. 1's (60.3%) at the 0 lb/acre P rate. On average, P removal by the harvested roots was 1.3 lbs P_2O_5 per 1000 lbs (1 bin). At this location, the amount of P partitioned between the canopy and roots was 25.0 lbs P_2O_5 and 75 lbs P_2O_5 per acre, respectively. In general, the lack of response in this trial indicates that additional work on the method of application, especially for boron, is needed. Samples are being evaluated for treatment effects in storage.

D. Introduction

Sweetpotatoes are a growing industry in the U.S. They have received much positive publicity in the last few years regarding their nutritional benefits; additionally the production of sweetpotato fries has been a consumer success that is growing each year. In 2012, California was the second top producing state, harvesting approximately 21% of the national production from 18,500 acres (approximately 650 million pounds). The estimated farm value of the sweetpotato crop in 2011 was nearly $130 million. This project addresses two issues currently facing the industry in California: 1) very little information regarding phosphorous requirements for this crop; and 2) a skin discoloration problem in the main cultivar that Extension Specialists in other states have suggested appears to be boron deficiency.

Multi-year fertilizer trials conducted with sweetpotatoes, including one such FREP sponsored trial in 2001 – 02, with nitrogen and potassium have provided information regarding rates, timing, source, and impacts on storage quality (the most recent report is in the 2009 Sweetpotato Research Progress Report, available online at http://cemerced.ucdavis.edu). Since that first work ten years ago, the industry has changed substantially, with increased use of compost, new varieties, and much greater emphasis on long-term storage in order to meet customer expectations of having availability to sweetpotatoes year-round. Additional issues within the industry include:

- Phosphorous rate determination and nutrient removal in the stored crop. The last documented fertilizer trial conducted in California for P on sweetpotatoes was in 1974. No yield response was observed, however, soil P levels were not determined. In the Fertilizer Guide for California Vegetable Crops[2], the suggested phosphorous rate for sweetpotatoes is 60 – 120 lbs P_2O_5 per acre. Based on root analyses from my own work, phosphorous is removed at the rate of 1.0 lb P_2O_5 per 1000 pounds of harvested roots. Average yields are about 31,000 lbs/A; high yielding fields are 60,000 lbs/A. Thus the current recommendation may be too high.
- Boron impacts on root quality and long-term storage. A new variety, Covington, now the dominant variety used in California, has problems after 6 months of storage with darkening of skin ("tea staining") and dark spot formation that suggests boron deficiency (Figures 1 and 2, below). No Boron recommendations are made for sweetpotatoes in California, but fertilizer guidelines from other states suggest 0.5 – 1.0 lbs B per acre (NC Sweetpotatoes, Borax 2012).

Because of the lack of information on these two nutrients in California, a fertilizer rate trial was conducted in a commercial sweetpotato field in 2014. This project addresses two of FREPs priority research areas: Demonstrating agronomically sound uses of fertilizing materials at the field scale, and developing best management practices and education materials.

Figure 1 (left): dark spots on the left suggest B deficiencies, though the biotic pathogen Scurf may also be involved. **Figure 2 (right):** though subtle, this root is turning dark and becoming unmarketable in storage.

E. Description:

Project was located within a commercial sweetpotato field on the north east corner of Linwood Road and the Turlock main canal, near Delhi on the Merced-Stanislaus county line. Initial fertilizer treatments were on May 2, 2014, with the application of pre-plant, banded 8-8-8 fertilizer by Simplot at 60 gpa to certain plots within the project site. The fertilizer was applied as two bands, about 9" deep and 9" off-center in the bed. This application established the baseline P fertilizer levels at 50 lbs P_2O_5 per acre throughout most of the plot area except the untreated control. Additional P fertilizer, as MAP (11-52-0) was applied on May 12, 2014, by shanking in the dry fertilizer as a band on either side of the drip tape in the center of the bed (Figure 3). The amount of MAP applied varied by plot to establish P_2O_5 treatments of 0, 50, 100, and 150 lbs/A. These rates were slightly higher than originally proposed to better match current industry practices. Ammonium sulfate and potassium sulfate were also added to each plot as appropriate so that N and K were equivalent (season total 170 lbs N and 250 lbs K_2O per acre equivalent).

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[2] Tyler, K.B., and O.A. Lorenz. 1981. Department of Vegetable Crops, University of California.

Boron fertilizer, as Granubor 14.3% B, was applied by hand down the center of the bed on May 28 and lightly incorporated, after which the drip tape placed on top (Figure 4). The amount of B varied by plot to establish B treatment rates of 0, 1, 2, and 3 lbs/A. These rates were higher than originally proposed based on discussions with growers and currently used rates that vary from 0.5 to 6 lbs B/A. Additional nitrogen and potassium fertilizer were added by the grower through the drip tape throughout the growing season (approximately 100 lbs per acre by mid August from 10-0-10 liquid formulation).

Treatment design is a randomized block split-plot with 4 replications. Phosphorous rates are the main plots; Boron rate is the split plot. Split-plot size is 6 rows (20 feet) by 30 feet. All data (plant and soil samples, yield) were taken from the center 2 rows. There were 64 total plots, and total trial size is 0.88 acres. Sweetpotato variety "Covington" was planted on May 6 using the growers labor and equipment at standard 12" plant spacing (about 13,000 plants per acre). This variety has had more problems with long-term storage and possible B deficiencies than other cultivars. The field was drip irrigated by the grower to maximize production (water was not a limiting factor) from transplanting until the end of August.

Irrigation water samples and the first leaf samples were taken on June 23. Leaf and petiole samples consisted of 20 leaves selected randomly from the center 2 rows of the plot, 6^{th} leaf back from the growing tip. These were air dried at 50° C for one week, then submitted to ANR labs at UC Davis for nutrient analysis (P & B) using standard lab methodology. A second leaf sampling was done on July 28 using the same procedure. One-half of the plots were soil sampled (0-12") on August 15, air dried, and submitted to ANR labs for P (Olsen P determination) and B analysis. To estimate the amount of nutrients in the canopy by the end of the season, whole plant canopy samples were taken from selected plots (16, such that there were samples from all four P and B rates) on August 29 by cutting a 35 ft^2 area from the center plot. The canopy was removed at ground level and weighed, then a sub-sample taken for moisture content and lab analysis (Figures 5 and 6).

Plots were harvested with a commercial mechanical harvester on Sept 25 – 26, 2014, and sorted into #1, medium, and jumbo size categories. A 30 lb storage sample was taken at this time, and a 10-root lab sample was also taken to determine crop nutrient removal. At the lab, the samples were washed very thoroughly and left to dry overnight, then sliced with a 3mm slicing blade in a food processor, spread out on a wire rack and dried in a forced air oven at 55 ºC. They dried perfectly in 2 days without cooking and about 75% loss in weight. The dried samples were then ground through a large Wiley mill.

Means separations on the various response factors were done using Fishers protected LSD at p=0.05. Storage samples were weighed at harvest again in February; additional storage data is planned for May.


Figures 3 (left) and 4 (right). Phosphorous treatments were shanked into the soil at 8" depth between the drip line and row of transplants. Boron was added later to each plot by hand to the center of the bed where the water from the drip tape could move it to the roots.


Figures 5 (left) and 6 (right). Canopy nutrient use estimates were made at the end of the season by weighing the vine from a 35ft^2 section of the plot, then taking a 1 lb sub-sample for nutrient analysis.

F. Results and Discussion:

The field location was selected for its proximity to canal water (TID), cultivar (Covington), and cooperator involvement. The site was typical for soil used for sweetpotatoes: sandy, low CEC, low E.C. and pH. Pretreatment soil samples contained 46 ppm Olsen-P and 0.06 ppm B in the upper two feet of the profile, which would indicate that a response to additional P fertilizer would be unlikely, but that boron levels were low. The water, being from the irrigation district, had no significant contribution to the nutrient status of this test. Initial soil test information and irrigation water quality are shown in Tables 1 and 2.

Early season growth was reduced in the 0 lb/A phosphorous and boron plots as compared to the other plots, though this was no longer apparent in August. Leaf, whole canopy, and root sampling results for P and B are shown in Table 3. Phosphorus and boron levels in the leaves were significantly increased as fertilizer rates increased on both sampling dates. Leaf tissue showed a strong linear correlation to applied boron, but this was weak with phosphorus (Figure 7).

No significant P fertilizer effect was observed in the whole canopy concentrations for phosphorus, though canopy biomass did significantly increase as P fertilizer increased. There was no biomass response to boron fertilizer, in either the canopy or the roots, but canopy concentrations did significantly increase as rates increased. The root analyses gave similar results: as fertilizer P and B increased, the concentration of these nutrients in the roots also significantly increased. In almost every case, there was no significant P x B interaction for any of the measurements made in this test. Adding phosphorus increased P in the plants, but had no effect on boron levels, and boron fertilizer increased B in the plants, but had no effect on phosphorus levels.

While P fertilizer rate had no significant effect on the canopy concentration of this nutrient, it did increase the amount of biomass at the end of the season. The overall affect was an increase in whole canopy phosphorus as P rates increased. In this trial and year, the crop canopy contained about 28 lbs of P_2O_5 per acre in the 150 lbs P_2O_5 per acre fertilizer treatment. Similarly, boron increased in the canopy, up to 0.2 lbs per acre (Figure 8).

Soil samples taken near the end of the growing season showed a significant increase in boron at the highest rate (only the 0 and 3 lb per acre rate were sampled), but no response to added phosphorous (Table 4). Results for phosphorus ranged from 25 – 45 ppm – well above the sufficiency level suggested for this crop.

Root yields and the estimated nutrient removal by the harvested roots were modestly affected by the fertilizer treatments in this study (Table 5). The No. 1 grade, which returns the most money to the grower, actually decreased as the P fertilizer rate increased, though the number of jumbos significantly increased and as a result, total yields were highest in the plots that received 150 lbs P_2O_5 per acre. The rate of boron did not have an effect yield. P removal in the roots was not significantly increased as the fertilizer rate increased, and averaged 75 lbs P_2O_5 per acre across all treatments. The lack of yield response is not surprising, given the high amount of P in the soil at this location, but yield responses to P in sweetpotatoes has been found to rarely occur in other trial locations across the U.S.

No correlation between P and B content in the roots and weight loss in storage was observed after 5 months (Table 5), however, some roots were already beginning to develop similar storage problems (blister, tea staining) that initiated this trial in the first place.

The amount of P_2O_5 removed by the roots was determined to be about 1.3 lbs per 1000 lbs of marketable yield (Figure 9). This figure compares favorably with other studies in the US that have shown P_2O_5 removal ranges from 1.0 – 1.5 lbs per 1000 lbs of harvested roots.

G. Discussion and Conclusions

In general, there was a crop response to increasing rates of both P and B fertilizer in this trial: as rates increased, so did the amount of these nutrients in the canopy and roots. However, there was no significant total marketable yield response, and therefore no optimal rate of either nutrient could be determined. The lack of yield response was likely because this site location had high soil test P levels well above established guidelines for either warm season (> 12 ppm Olsen P) or cool season (>25 ppm Olsen P) crops.

It is difficult to interpret the boron results. Clearly the plants were picking up the additional B as rates increased (Figures 7 and 8), however the amount found in the roots was very low, less than 10 ppm regardless of treatment, and the estimated amount in the roots (0.1 lbs per acre) and canopy (0.2 lbs per acre) is far less than what was applied. Further adding to the puzzle is the end of season soil B test in the untreated plots was far higher than the initial soil tests (0.47 vs 0.06 ppm), which is within the sufficiency range for most crops.

Overall yields were very good in this field, with total marketable averaging over 56 bins/A, but only the jumbo size category displayed a significant response to added P, with more jumbos at 150 lbs P_2O_5 per acre as compared to the 0 rate. As a result, there was a significant inverse relationship observed in % No. 1's, with the highest percentage of No. 1's (60.3%) at the 0 lb/acre P rate. On average, P removal by the harvested roots was 1.3 lbs P_2O_5 per 1000 lbs (1 bin). At this location, the amount of P partitioned between the canopy and roots was 25.0 lbs P_2O_5 and 75 lbs P_2O_5 per acre, respectively. In general, the lack of response in this trial indicates that additional work on the method of application, especially for boron, is needed. Samples are being evaluated for treatment effects in storage. At 5 months, weight loss was 8.5% and symptoms of boron deficiency were just starting to appear only in the 0 and 1 lb boron treatments (Figure 10).

H. Project Impacts

One of the main objectives of the trial was to evaluate the impact of different rates of boron on storage quality. Long-term storage data will not be available until June, 2015.

Other potential impacts. Nutrient needs of the crop for the canopy, and what is removed at harvest. This trial needs to be repeated to confirm, but the data suggest 100 lbs of P_2O_5 per acre are needed annually, of which 75 lbs per acre are being removed in an average yielding crop.

Project's contribution toward advancing safe and sound use of fertilizer: no yield response to fertilizer P is expected when soil tests levels are > 40 ppm Olsen-P. When needed, a reasonable P fertilizer application rate would be 60 – 75 lbs per acre, depending on expected yield. There may be an interaction between P and nitrogen and potassium, as the data also suggest that N and K in the plants increased as P fertilizer increased.

I. Outreach.

Results of this work were presented at the following events:
2014 FREP/WPHA Conference, October 30, 2014, Modesto, CA. Phosphorus and Boron Fertilizer Impacts on Sweetpotato Production. A 20 minute presentation giving preliminary results to about 120 people, mostly CCAs, university, and CDFA-FREP personnel.

National Sweetpotato Collaborators Group annual meeting, January 24-25, 2015, Nashville, TN. 15 minute summary presentation of production results. Attendance about 40, mostly university specialists, students, and advisors working with sweetpotatoes.

50th Annual Sweetpotato Meeting, February 3, 2015, Merced CA. Quick summary of main results of this trial was given at this annual meeting. About 60 people in attendance, mostly growers and PCAs.

2014 Research Progress Report. Annual report of my research activities. To be posted to the Merced County UCCE website at http://cemerced.ucanr.edu/Vegetable_Crops/

Literature Cited:

Tyler, K.B., and O.A. Lorenz. 1981. Fertilizer Guide for California Vegetable Crops. Department of Vegetable Crops, University of California

NC Sweetpotatoes, 2014. Soils and fertilization. http://www.ncsweetpotatoes.com/sweet-potato-industry/growing-sweet-potatoes-in-north-carolina/soils-and-fertilization/.

Borax, 2012. Boron in vegetables. http://www.borax.com/docs/crop-guides/rtm-cg-vegetables_final-feb2012.pdf?sfvrsn=2.

J. Factsheet Template

1. **Title**: Phosphorous and boron fertilizer impacts on sweetpotato production and long-term storage.
2. **Grant agreement #: 13-0266-SA**
3. **Project** Leader: Scott Stoddard, UC Cooperative Extension
4. **Project time frame**: April 2014 – May 2015
5. **Trial location**: North of Linwood and west of Vincent Rds, off the Turlock Main Canal near Delhi, CA. 10 S 695725 E 4150738 N
6. **County**: Merced, border with Stanislaus
7. **Project highlights**:
   - The amount of boron in leaf samples collected in June and July increased linearly as boron fertilizer (as Granubor) increased from 0 to 3 lbs per acre, however, very little boron was found in the roots and there was no significant effect on yield. Total boron removed at harvest was estimated at less than 0.1 lbs per acre.

   - Canopy weight and root yield increased as phosphorus fertilizer increased from 0 to 150 lbs P_2O_5 per acre, but the yield response was subtle -- only the jumbo size category significantly increased with applied fertilizer. Total marketable yields were 52, 57, 57, and 59 bins per acre at 0, 50, 100, and 150 lbs P_2O_5 per acre, respectively, but these results were not significantly different at the 95% confidence level. No significant boron by phosphorus interaction was observed.

   - The lack of a strong response to either of these two nutrients at this location means that developing a rate recommendation for sweetpotatoes is not possible at this time. The amount of P_2O_5 removed by harvest was determined to be 75 lbs per acre, while another 25 lbs remains in the shredded leaves and vines and returned to the soil. The amount of N, P_2O_5, and K_2O removed by the crop was found to be about 2.4, 1.3, and 5.25 lbs per 1000 pounds of harvested roots.

8. **Introduction**. In 2012, California was the second top producing state, harvesting approximately 21% of the national production from 18,500 acres (approximately 650 million pounds). The estimated farm value of the sweetpotato crop in 2011 was nearly $130 million. This project addresses two issues currently facing the industry in California: 1) very little information regarding phosphorous requirements for this crop; and 2) a skin discoloration problem in the main cultivar that Extension Specialists in other states have suggested appears to be boron deficiency. The last documented fertilizer trial conducted in California for phosphorus on sweetpotatoes was in 1974, and no trials evaluating crop response to fertilizer boron have ever been conducted in the state. The industry has changed substantially in the last 40 years, with increased use of compost, new varieties, drip irrigation, and much greater emphasis on long-term storage in order to meet customer expectations of having availability to sweetpotatoes year-round. Therefore, an on-farm fertilizer test was conducted in Merced County in 2014 to evaluate the response of sweetpotato cultivar ‘Covington’ to increasing rates of phosphorus and boron fertilizers.

9. **Methods**: Treatment design was a randomized block split-plot with 4 replications. Phosphorus rates were the main plots; Boron rate was the split plot. Split size plot size was 6 rows (20 feet) by 30 feet long. The trial was transplanted on 6-May-2014 with the cultivar “Covington”. Phosphorus fertilizer, as MAP (11-52-0) was applied on 12-May by shanking in the dry fertilizer as a band on either side of the drip tape in the center of the bed to establish P_2O_5 treatments of 0, 50, 100, and 150 lbs/A. Boron fertilizer, as Granubor 14.3% B, was

applied by hand down the center of the bed under the drip tape on 28-May and lightly incorporated. The amount of B varied by plot to establish treatment rates of 0, 1, 2, and 3 lbs B/A. Additional nitrogen and potassium fertilizer was applied through the drip tape during the growing season (approximately 100 lbs N/A). Plots were sampled for leaf and petiole analysis, canopy weight and nutrient content, soil analyses, and harvested with a commercial mechanical harvester and sorted into #1, medium, and jumbo size categories. A harvest sub-sample was also taken for storage evaluation. Means separations on the various response factors were done using Fishers protected LSD at p=0.05.

10. **Findings**. In general, there was a crop response to increasing rates of both P and B fertilizer in this trial: as rates increased, so did the amount of these nutrients in the canopy and roots. However, there was no significant total marketable yield response, and therefore no optimal rate of either nutrient could be determined. Overall yields were very good in this field, with total marketable averaging over 56 bins/A, but only the jumbo size category displayed a significant response to added P, with more jumbos at 150 lbs P_2O_5 per acre as compared to the 0 rate. On average, P removal by the harvested roots was 1.3 lbs P_2O_5 per 1000 lbs (1 bin). At this location, the amount of P partitioned between the canopy and roots was 25.0 and 75 lbs P_2O_5 per acre, respectively. In general, the lack of response in this trial indicates that additional work on the method of application, especially for boron, is needed. Samples are being evaluated for treatment effects in storage. At 5 months, weight loss was 8.5% and symptoms of boron deficiency had appeared in the 0 and 1 lb boron treatments.

Table 1. Sweetpotato P and B fertilizer trial, preplant soil samples (UC ANR analytical lab).

SAMPLE #	DESC	SP 200.02] %	pH 205.02]	EC 215.03] dS/m	Ca (SP) 235.04] meq/L	Mg (SP) 235.04] meq/L	Na (SP) 235.04] meq/L	Cl (SP) 227.02] meq/L	B (SP) 235.04] mg/L	NO3-N 312.03] ppm	Olsen-P 340.03] ppm	X-K 360.04] ppm	Zn (DTPA) 380.02] ppm	Mn (DTPA) 380.02] ppm	Cu (DTPA) 380.02] ppm	Fe (DTPA) 380.02] ppm
5	P trial 0-12"	23	6.21	0.62	4.54	1.01	0.56	0.93	0.06	6.50	44.1	39	2.9	13.5	4.8	62.9
6	P-Trial 12-24"	23	6.17	0.84	6.51	1.22	0.56	1.97	0.05	7.80	48.3	27	0.8	11.7	1.7	53.3

Table 2. Sweetpotato P and B fertilizer trial, Irrigation water analyses, June and July 2014.

SAMPLE #	DESC	NH4-N [SOP 847.03] mg/L	NO3-N [SOP 847.03] mg/L	pH [SOP 805.03]	EC [SOP 815.03] dS/m	SAR [SOP 840.02]	Ca (Soluble) [SOP 835.03] meq/L	Mg (Soluble) [SOP 835.03] meq/L	Na (Soluble) [SOP 835.03] meq/L	Cl [SOP 830.01] meq/L	B (Soluble) [SOP 835.03] mg/L
1	23-Jun	<0.05	<0.05	7.14	0.04	0.3	0.16	0.10	0.09	<0.10	<0.01
2	9-Jul	<0.05	<0.05	7.32	0.04	0.2	0.17	0.10	0.09	<0.10	<0.01
3	9-Jul	<0.05	0.05	7.34	0.04	0.3	0.17	0.10	0.09	<0.10	<0.01

Table 3. Phosphorus and boron content of sweetpotato leaves, canopy, and roots as affected by phosphorus and boron fertilzer treatment, 2014.

Treatment		June 24 leaf sampling		July 28 leaf sampling		Aug 29 Canopy (whole plant)			biomass		Sept 20 Roots		biomass	
Main Plot, P205 lbs/A		Total P, %	Total B, ppm	Total P, %	Total B, ppm	wt, lbs/A	Total P, %	Total B, ppm	P2O5 lbs/A	B lbs/A	Total P, %	Total B, ppm	P2O5 lbs/A	B lbs/A
1	0	0.37	61.9	0.34	60.4	20,399	0.28	---	21.1	---	0.23	6.6	69.0	0.09
2	50	0.38	49.7	0.34	46.4	25,072	0.27	---	25.8	---	0.23	6.4	74.2	0.09
3	100	0.41	49.9	0.35	55.2	24,954	0.28	---	27.2	---	0.23	6.4	75.8	0.09
4	150	0.42	44.1	0.37	39.2	30,747	0.27	---	28.1	---	0.25	6.2	82.2	0.09
Average		0.40	51.4	0.35	50.3	25,293	0.27	---	25.5	---	0.23	6.4	75.3	0.09
Variance		0.0025	131.7	0.0004	36.9	7.99E+06	0.0004	---	14.6	---	0.0002	0.26	184.0	0.00006
p-value		0.051	0.011	0.003	0.001	0.002	0.86	---	0.097	---	0.021	0.324	0.120	0.538
Split Plot, Boron lbs/A														
a	0.0	0.39	32.9	0.35	29.3	25,962	---	22.9	---	0.09	0.23	5.9	74.1	0.08
b	1.0	0.40	44.0	0.35	45.0	25,035	---	27.2	---	0.11	0.23	6.3	75.0	0.09
c	2.0	0.40	54.8	0.35	57.7	25,713	---	39.4	---	0.16	0.23	6.7	75.1	0.09
d	3.0	0.39	73.8	0.35	69.1	24,462	---	46.8	---	0.21	0.24	6.8	76.9	0.10
Average		0.40	51.4	0.35	50.3	25,293	---	34.1	---	0.14	0.23	6.4	75.3	0.09
Variance		0.0003	142.6	0.0001	100.3	2.55E+07	---	41.2	---	0.0015	0.0001	0.14	28.4	0.0004
p-value		0.339	0.001	0.896	0.001	0.97	---	0.001	---	0.004	0.351	0.001	0.521	0.001
P x B interaction p-value		0.066	0.08	0.108	0.106	---	---	---	---	---	0.717	0.618	0.797	0.161
CV, %		4.1	23.2	3.5	19.9	11.2	7.43	18.8	15	27.6	4.5	5.9	7.1	8.7

p-value = probability of significant treatment effect; values less than 0.05 indicate means are significantly different at the 95% confidence level.
--- not all plots were sampled, therefore these values could not be determined.
CV = coefficient of variation

Table 4. Treatment effects on soil P and B.

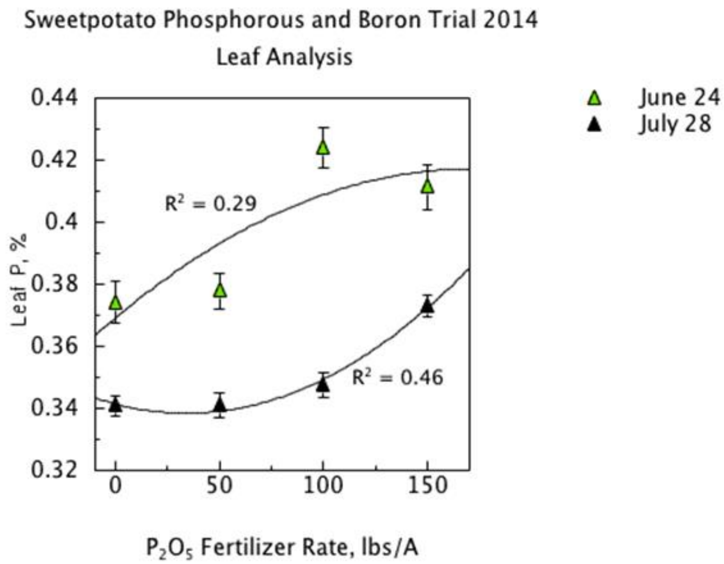
Treatment		Aug 15 soil sampling	
Main Plot, P205 lbs/A		Olsen P,ppm	B, mg/L
1	0	35.0	0.47
2	50	33.3	0.56
3	100	36.3	0.43
4	150	33.8	0.63
Average		34.60	0.52
Variance		21.1	0.08
p-value		0.586	0.532
Split Plot, Boron lbs/A			
a	0.0	34.9	0.38
b	1.0	---	---
c	2.0	---	---
d	3.0	34.3	0.67
Average		34.60	0.52
Variance		6.6	0.07
p-value		0.557	0.009
P x B interaction p-value		0.543	0.361
CV, %		7.4	51.1

p-value = probability of significant treatment effect; values less than 0.05 indicate means are significantly different at the 95% confidence level.
--- not all plots were sampled, therefore these values could not be determined.
CV = coefficient of variation

Table 5. Sweetpotato yield as affected by fertilizer treatments and estimated removal in crop, 2014

Treatment		Yield, bins/A (bin = 1000 lbs)					Nutrient removal in roots, lbs/A				Feb-15
Main Plot, P205 lbs/A		#1's	Jumbo	Medium	TMY	% No. 1's	Root N	Root P2O5	Root K2O	Root B	wt loss, %
1	0	31.2	16.2	4.4	51.7	60.6	115.7	69.0	225.2	0.09	9.1
2	50	28.8	24.7	4.1	57.6	50.0	143.0	74.2	253.8	0.09	8.2
3	100	32.2	20.3	4.8	57.2	56.7	133.2	75.8	269.3	0.09	8.5
4	150	27.9	26.7	4.1	58.7	47.4	163.5	82.2	293.1	0.09	8.3
Average		30.0	22.0	4.3	56.3	53.6	138.8	75.3	260.4	0.09	8.5
Variance		9.5	32.9	1.3	70.2	41.4	639.5	184.0	2878.6	0.00006	0.62
p-value		0.052	0.003	0.362	0.157	0.001	0.003	0.120	0.034	0.538	0.040
Split Plot, Boron lbs/A											
a	0.0	30.5	20.4	4.2	55.2	55.8	141.2	74.1	253.2	0.08	8.7
b	1.0	30.0	22.8	4.1	56.9	53.0	137.9	75.0	257.3	0.09	8.7
c	2.0	30.4	21.4	4.5	56.4	54.4	134.6	75.1	262.0	0.09	8.4
d	3.0	29.0	23.2	4.5	56.7	51.4	141.6	76.9	269.0	0.10	8.3
Average		30.0	22.0	4.3	56.3	53.6	138.8	75.3	260.4	0.09	8.5
Variance		9.5	11.1	0.4	11.7	20.8	186.7	28.4	863.9	0.0004	0.86
p-value		0.496	0.09	0.182	0.493	0.055	0.447	0.521	0.479	0.001	0.419
P x B interaction p-value		0.402	0.034	0.074	0.224	0.097	0.801	0.797	0.221	0.161	0.389
CV, %		10.3	15.1	14.5	6.1	8.5	9.8	7.1	11.3	8.7	10.9

US #1's	Roots 2 to 3.5 inches in diameter, length 3 to 9 inches, well shaped and free of defects.
Medium	Roots 1 to 2 in diameter, 2 to 7 inches in length.
Jumbos	Roots that exceed the size requirements of above grades, but are marketable quality.
Mkt Yield	Total marketable yield is the sum of the above three categories.
bins/A	Standard unit of yield in the industry. 1 bin = 1000 lbs.
% US #1's	Weight of US #1's divided by total marketable yield.
p-value	probability of significant treatment effect; values less than 0.05 indicate means are significantly different at the 95% confidence level.
---	not all plots were sampled, therefore these values could not be determined.
CV	= coefficient of variation



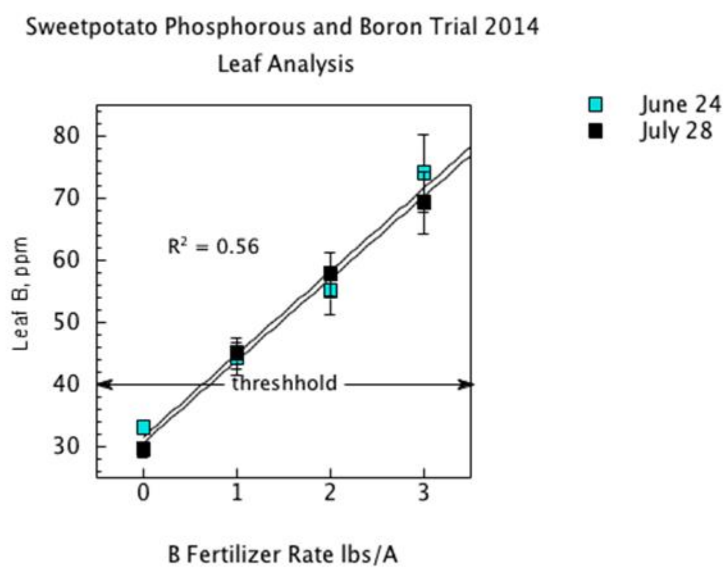


Figure 7. Phosphorus and boron levels in the leaves were increased as fertilizer rate increased on both evaluation dates. To improve clarity, data points show treatment average, however the regression was determined on individual plot data. Error bars show standard error of the mean.

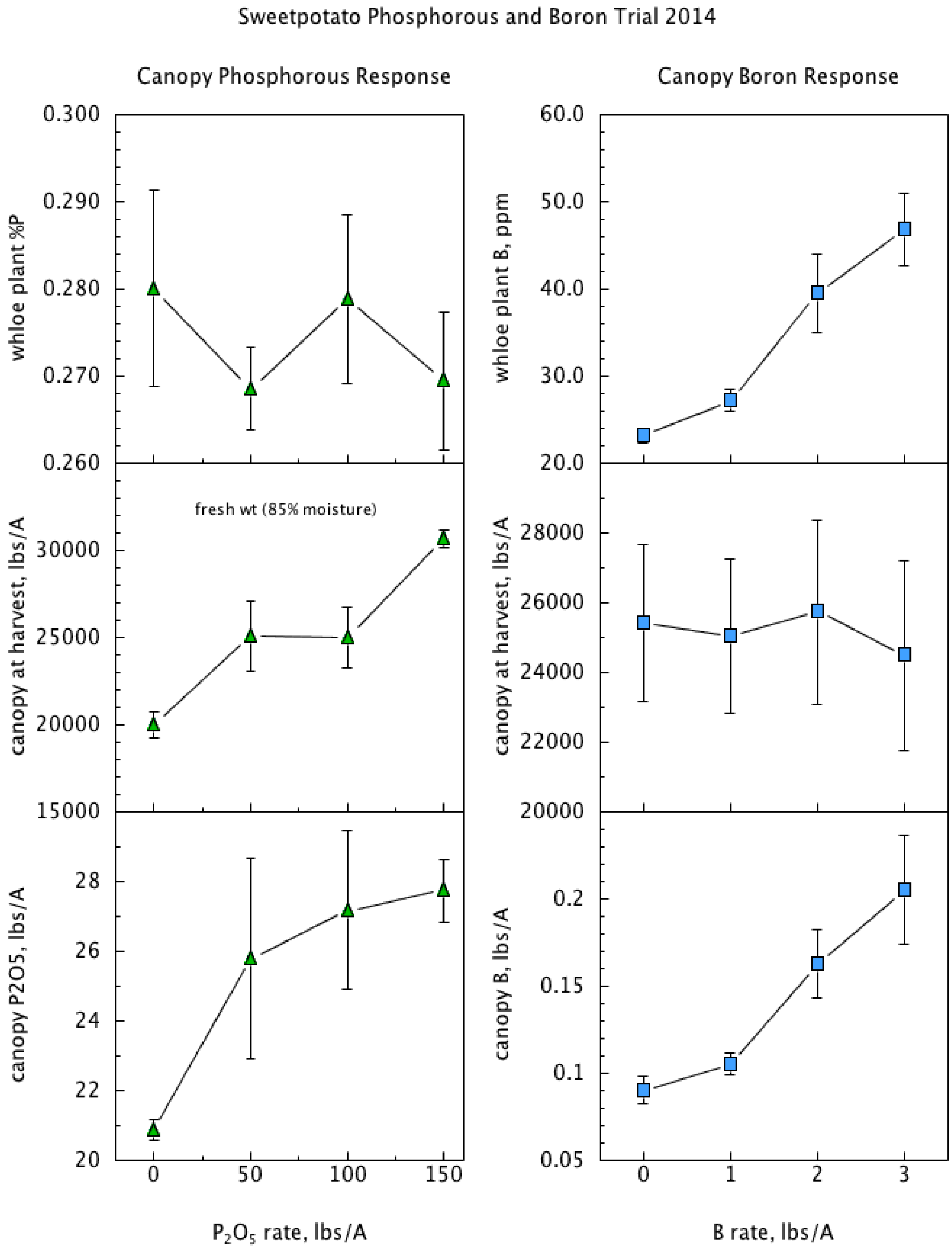


Figure 8. Whole plant P and B, canopy biomass, and canopy P and B nutrient content as effected by fertilizer rate. Error bars show standard error of the mean.

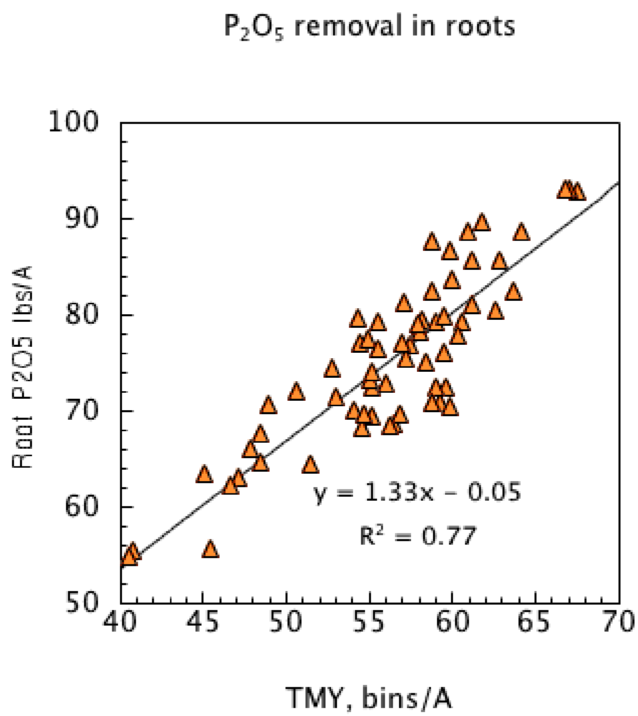


Figure 9. The relationship between total yield (TMY) and the amount of P_2O_5 in the roots was fairly well correlated, with 1.33 lbs removed per bin (1000 lbs).

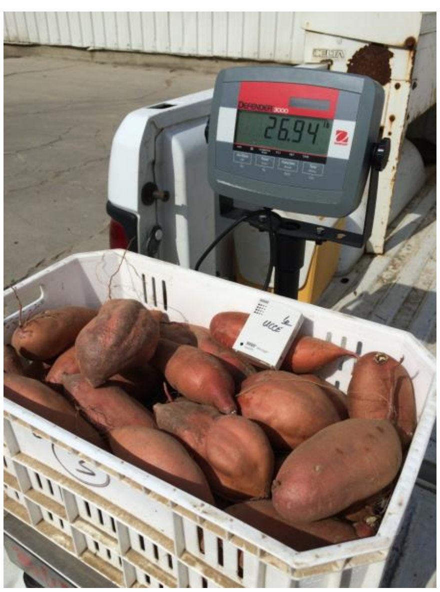


Figure 10. Darkening and blister were beginning to appear after 5 months in storage.