THESIS

POTATO TUBER YIELD, QUALITY, MINERAL NUTRIENT CONCENTRATION, SOIL HEALTH AND SOIL FOOD WEB IN CONVENTIONAL AND ORGANIC POTATO SYSTEMS

Submitted by

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ABSTRACT

POTATO TUBER YIELD, QUALITY, MINERAL NUTRIENT CONCENTRATION, SOIL HEALTH AND SOIL FOOD WEB IN CONVENTIONAL AND ORGANIC POTATO SYSTEMS

Field grown tubers from two conventional and two organic potato farms were compared to determine genotypic and environmental effects on tuber yield, quality, and tuber mineral content. Rhizosphere and bulk soil from the same conventional and organic farms were compared to determine genotypic and environmental effects on soil bacteria, fungi, protozoa, nematodes and soil health.

Analyses of variance revealed a significant effect of the interaction between genotype and location on total tuber yield as well as the <4oz, ≥4oz, and ≥10oz tuber weight ranges ($p<0.05$). Total yields were grouped the tightest with CO00291-5R, and showed the greatest variability in 'Fortress Russet'. In the greater than or equal to 10oz tuber weight range CO97087-2RU, 'Fortress Russet,' and'Sangre-S10' each exhibited much greater yields at one of the conventional locations with 'Fortress Russet' showing the greatest variability across locations. Tubers from conventionally managed locations had significantly greater total yield, ≥4oz tubers, ≥6oz tubers, and ≥10oz tubers. There were also significant effects of location within management for all weight ranges, significant effects of genotype for all weight ranges, and significant interaction effects for all weight ranges except ≥6oz tubers.

There was a significant effect of the interaction of genotype and location on specific gravity ($p<0.05$). CO00291-5R and 'Sangre-S10' had low variability across locations, while

CO97087-2RU had the greatest variability across locations. There was a significant effect of location on specific gravity ($p<0.05$) with location one of the organic locations having the highest specific gravity at 1.086 and the two conventional locations having the lowest values at 1.079 and 1.080, respectively. There was a significant effect of genotype on specific gravity.

'Fortress Russet' was the only clone in which location had a significant impact on the prevalence of hollow heart (chi-square=9.881 df=3, p=0.0196) with a maximum of 10.7% of total yield exhibiting hollow heart. 'Fortress Russet' was also significantly impacted by location with regard to growth cracks (chi-square=8.309, df=3, p=0.0400) with a maximum of 5.6% of total yield as was Sangre-S10 (chi-square=12.500, df=3, p=0.0059) with a maximum of 6.1% of total yield. No clones were significantly impacted by location with regard to brown center, knobs, or misshapes.

The interaction between genotype and location had a significant effect on tuber potassium concentration (p=0.0127), but not tuber iron or zinc (p=0.3526 and p=0.5259, respectively). CO97087-2RU exhibited much higher levels of tuber potassium at one of the conventional locations than the other locations. 'Fortress Russet' and 'Sangre-S10' exhibited a larger range of tuber potassium concentrations across all four locations compared to the remaining clones. Tuber mineral iron and zinc concentrations were significantly different between tubers from conventionally versus organically managed fields ($p<0.05$). Tubers from conventionally managed fields had on average 1.91 % dry weight K, 122.8 mg/kg Fe, and 17.4 mg/kg Zn. Tubers from organically managed fields had on average 1.91 % dry weight K, 100.1 mg/kg Fe, and 14.0 mg/kg Zn. There was a significant main effect of location on tuber mineral potassium, iron, and zinc concentrations. There was a significant main effect of genotype on tuber mineral potassium, iron, and zinc concentrations.

There was a significant interaction effect between genotype and location for soil bacteria and fungi biomass ($p<0.05$). ‘Sangre-S10’ showed little variation in soil bacteria between locations, whereas CO97087-2RU and ‘Fortress Russet’ did. CO97087-2RU showed much greater differences in soil fungi between conventional and organic locations, as did ‘Fortress Russet’ and ‘Sangre-S10’. There was a significant difference in soil fungi, amoebae, and ciliate biomass between management regimes ($p<0.0001$ for each). Organically managed soils averaged 254 µg fungi /g soil, while conventionally managed soils averaged 142 µg fungi /g soil. Organically managed soils averaged 236,265 amoebae/g soil, while conventionally managed soils averaged 50,872 amoebae/g soil. Organically managed soils averaged 525 ciliates/g soil, while conventionally managed soils averaged 32 ciliates/g soil. There is a significant effect of location on all soil food web constituents except for flagellates ($p<0.05$). There was a significant effect of clone on soil fungi and ciliates ($p<0.05$).

There were significant differences in soil respiration, organic carbon, and organic nitrogen between management ($p<0.05$). Soil from organically managed locations had mean soil respiration of 22.1 ppm CO_2/24hrs compared to conventionally managed locations with 16.9 ppm CO_2/24hrs. Soil from organically managed locations had mean soil organic carbon pools of 140 ppm compared to conventionally managed locations with a mean of 97 ppm. Soil from organically managed locations had mean soil organic nitrogen pools of 31.8 ppm compared to conventionally managed locations with a mean of 24.4 ppm. There was a significant main effect of location on soil respiration, organic carbon, and organic nitrogen ($p<0.05$).

The purposes of this study were to identify breeding material that may be used to improve yield and mineral nutrient concentrations of potatoes in conventional and organic systems. There were no clones that performed better in organic systems than conventional, but

CO00291-5R did have the least variability in tuber yield across locations. CO00291-2RU was identified as a good candidate for improving potato potassium and zinc concentrations; CO97087-2RU as a good candidate for improving potato iron and potassium concentrations; and Sangre-S10 as a good candidate for improving potato iron concentration. While yield was reduced under organic management, tuber specific gravity was increased compared to conventional management. Organic management also improved soil food web structure and soil health by increasing soil fungal, amoebae, and ciliate biomass, microbial activity, and carbon and nitrogen concentrations.

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CHAPTER 1: LITERATURE REVIEW

1.1 General Introduction

The potato (*Solanum tuberosum*) is the third most consumed crop globally behind rice and wheat (International Potato Center 2013). Potatoes are a versatile crop that can be cultivated in diverse environments and are currently grown in 100 different countries (United States Potato Board 2015). Potato crops can yield 9.2M calories per acre, which is more than that of maize (7.5M), rice (7.4M), wheat (3M), and soybean (2.8M) (Ensminger et al. 1994). Potatoes are an excellent candidate for biofortification to address malnourishment in developing countries, feed a growing global population, and fit into a healthy part of the American diet.

In 2014, the United States harvested 1.0 million acres yielding 44.7 billion pounds of potatoes (National Potato Council 2015). In 2013, Colorado ranked sixth in potato production with 2.0 billion pounds valued at 3.9 billion dollars (National Potato Council 2015).

Colorado's San Luis Valley is the state's predominant center of potato production. Conventionally managed potato farms typically follow a two year rotation of potato and grain using either malting barley or sorghum-sudangrass to control nematode populations (Stark 2003, p. 83). Pre-planting herbicides are typically applied to control pigweed, kochia, and volunteer barley (Hoffsteen et al. 2003). Various chemical insecticides are applied throughout the season to control aphids, potato psyllids, thrips, and cabbage loopers. Nematicides are often applied to control plant parasitic nematodes whose damage is often only seen in the tuber so are applied as a precaution. Fungicides are applied throughout the season to control for early blight, silver scurf, fusarium, and powdery scab. Potatoes are typically planted in the spring in April or May and harvested in the fall in September or October. In the San Luis Valley, potatoes are irrigated using center-pivot sprinklers supplying 14-18” of water throughout the season. Two to three weeks before harvest potato vines are typically killed with a chemical desiccant.

Organic agriculture relies on cultural and biological methods for pest management and utilizes crop rotation, animal manure, and compost to build soil fertility (USDA National Organic Program 2015). Organically managed potato fields often follow a longer rotational strategy utilizing green manures and other crops specifically chosen for soil improvement and pest and disease management (Seaman 2015). Cattle often graze green manures, and biological amendments such as composts, manures, and compost teas are relied upon for meeting fertility needs. Weeds are typically managed using tine weeders (Seaman 2015). USDA certified organic farmers may use materials approved by the Organic Materials Review Institute (OMRI) for pest control. Various compounds including biological inocula, botanical and mineral oils, coppers, and hydrogen dioxides are utilized for control of early blight, silver scurf, fusarium, and powdery scab. Few pesticides are available for management of nematodes are available and minimally effective (Seaman 2015). Insecticides composed of compounds such as biological, botanic, iron phosphate, oil, soap, sulphur are available for managing aphids and mites (Seaman 2015). Because pesticide options available to the organic grower are limited and often less effective than conventional options, choosing certified seed varieties that are early emerging to compete with weeds and have virus and insect resistances are of utmost importance.

In the United States the organic agriculture market captured an estimated 35 billion dollars in sales in 2014, an increase in nearly 300% from 2005 (USDA ERS 2013). Total organic cropland has increased from 638,500 acres in 1995 to 3,084,989 acres in 2011, an increase of 383% (USDA ERS 2013a). As a percentage of total cropland, organic farming is small but growing quickly. In 2005 organic cropland represented 0.46% of total cropland, and in 2011 represented 0.83% (USDA ERS 2013a). Potatoes have seen a more dramatic increase with 0.59% of potato cropland grown organically in 2005 and 1.21% in 2011 (USDA ERS 2013a). From 1997 to 2011, with the exception of 2008, Colorado has had the second highest organic potato acreage in the United States, second to California (USDA ERS 2013b).

Organic agricultural practices are being increasingly encouraged to integrate into our food system by global scientists as a means to address a changing future climate (Smith et al. 2014; Borron 2006). With many types of agriculture currently addressing issues of feeding a growing population as well as managing the planet in a sustainable way, it is important to consider focused breeding efforts to perform better in these new target environments.

1.2 Yield and Tuber Quality

In 2014 Colorado averaged 397 cwt/acre compared to the national average of 426 cwt/acre (USDA NASS 2015). The most recently available statistics comparing conventional and organic potato production in 2008 show the average yield for organic potatoes was 263 cwt/acre in Colorado compared to the national average of 284 cwt/acre (USDA Census of Agriculture 2008) whereas the average yield for conventional potatoes was 384 cwt/acre in Colorado compared to the national average of 396 cwt/acre (USDA NASS 2015).

A 2007 study by Murphy et al. showed up to 31% yield increases in organic wheat could be achieved when genotypes were directly selected for within organic systems. This suggests that the yield gap may be due varieties being better adapted to conventional than organic production systems.

1.3 Potato Tuber Mineral Nutrients

Potatoes are a great source of Vitamin C and potassium, offering 45% and 18% of the recommended daily value respectively per 5.3 ounce potato with skin on (United States Potato

Board 2015). Compared to other vegetables commonly found in grocery stores, potatoes are the largest and most affordable source of potassium (Drewnowski et al. 2011). With zero mg of sodium per serving, and 2 g of fiber, potatoes are receiving more and more attention as a food source for biofortification to be a more complete nutrient source for the American diet as well as developing nations.

Iron deficiency is one of the most prevalent forms of malnutrition and is ranked as the ninth most common risk factor for disability adjusted life years, the number of years lost due to poor health or disability (Stoltzfus 2003; Ezzati et al. 2002). It is relatively common in toddlers, adolescent girls, and women of childbearing age in the United States (Looker et al. 1997). Approximately 8% of women, 5% of men, and 7% of children in North America suffer from anemia as a result of iron deficiency (Stoltzfus 2003). African, Latin America, Eastern Mediterranean and Asia can see seven to eight times the numbers seen in the North America.

Zinc deficiency is ranked eleventh as a risk factor for disability adjusted life years (Ezzati et al. 2002). It occurs mostly in the world’s poor populations, and can be attributed to abnormal cognitive development (Gibson 2006). Zinc supplementation has been shown to have therapeutic effects on children with diarrhea, pneumonia, measles, and malaria (Gibson 2006).

Recent studies have shown potato mineral iron and zinc is heritable and therefore can be increased through breeding (Brown et al. 2010; Brown et al. 2011). However, it is also important to understand how environment influences tuber nutrient concentration. Previous studies have explored how conventional and organic management systems can impact potato nutritional aspects. Hajslova et al. 2005 found both potato variety and management (conventional versus organic) played a role in potato tuber mineral nutrient concentration, nitrates, glycoalkaloids, and dry matter content.

1.4 Soil Food Web and Soil Health

Organic agriculture relies on microbially-mediated mineralization processes to meet soil fertility needs, whereas conventional systems supply soluble nutrients to feed plants. Organic agriculture utilizes practices that purposely affect microbial communities. Organic amendments are added to provide microbes with carbon and nitrogen, thus increasing microbial biomass and activity and microbes themselves are sometimes added in the form of biological amendments. Organically managed soils, thus, have a soil ecosystem unique from conventionally managed farming systems.

Organically managed soils have been shown to have higher microbial biodiversity (Mäder et al. 2002; Fließbach et al. 2007) and have higher levels of soil organic matter (Marriott et al. 2006) than their conventional counterparts. Genotype likely plays a role in recruiting soil microbiome (Badri et al. 2009; Manter et al. 2009), and perhaps clones can be better selected to perform well in respective soil ecosystems (Bakker et al. 2012).

1.5 Objectives

These studies focused on comparing conventional and organic production systems to determine 1) how genotype and management influence tuber yield and quality, 2) how genotype and management influence tuber mineral nutrient concentration, and 3) how genotype and management influence soil health and the soil food web. The clones from the Colorado Potato Breeding and Selection Program have never been evaluated for differences between conventional and organic farm systems. The objectives of this study are to identify breeding material for improved yield and tuber quality across both conventional and organic management systems; to identify breeding material which exhibits high tuber potassium, iron, and zinc concentrations across both conventional and organic management systems; and to identify differences in soil food web and soil health of conventional and organic potato systems.

CHAPTER 2: YIELD AND TUBER QUALITY OF POTATOES GROWN IN CONVENTIONAL AND ORGANIC SYSTEMS

2.1 Introduction

Potato yields are steadily increasing globally. In 2014 Colorado averaged 397 cwt/acre compared to the national average of 426 cwt/acre (USDA NASS 2015). The most recently available statistics comparing conventional and organic potato production in 2008 show the average yield for organic potatoes was 263 cwt/acre in Colorado compared to the national average of 284 cwt/acre (USDA Census of Agriculture 2008) whereas the average yield for conventional potatoes was 384 cwt/acre in Colorado compared to the national average of 396 cwt/acre (USDA NASS 2015).

Many studies have found yield gaps in organic versus conventional farming systems. Poneisio et al. (2015) conducted a meta-analysis of studies comparing conventional and organic yields, and found agricultural diversification, multi-cropping, and crop rotations in organic farms decreased the yield gap with conventional farms to 4-9%, suggesting agro-ecological approaches may be key.

A 2007 study by Murphy et al. showed that up to 31% yield increases in organic wheat could be achieved when genotypes were directly selected for within organic systems. This suggests that the yield gap between organic and conventional systems may be due to varieties being bred to perform best in conventionally managed systems. In fact, there has been a recent slurry of literature supporting the notion that varieties bred specifically for organic agriculture are needed and have proven successful: sweet corn in Wisconsin (Shelton et al. 2015); tomato in Oregon (Horneburg et al. 2012); and brassicas in Oregon (Myers et al. 2012).

Low-input and organic systems are often a necessity in developing countries. In order for potatoes to be a viable option for feeding the worlds growing population, this major discrepancy in yield may be resolved through breeding and a better understanding of genotype by management interactions.

Common external defects in potatoes are growth cracks, knobs, and misshapes. Growth cracks often form under irregular environmental conditions such as soil moisture, soil temperature, and air temperature (Hiller et al. 2008). Common internal defects in potatoes include brown center and hollow heart, both of which are physiological disorders. Both commonly occur with environmental fluctuations in soil moisture and soil temperature resulting in rapid growth of the tuber (Zotarelli et al. 2015). High specific gravity is desirable in potatoes. Low specific gravity can often be caused by excess of nitrogen or potassium, or deficiency in phosphorous (Bohl et al. 2010).

The purpose of this study was to evaluate the effects of genotype and management on potato tuber yield and quality when grown in conventionally and organically managed farms. This was done to identify breeding material that may be used to improve specific performance of potatoes in respective management systems.

2.2 Materials and Methods

This research was conducted in Colorado’s San Luis Valley. Field grown tubers in 2014 were evaluated for yield, internal defects, external defects, and specific gravity.

Plant Material

Five potato genotypes were grown in the summer of 2014: ‘Fortress Russet’, a russet variety released by the Colorado Potato Breeding and Selection Program in 2014 known to have resistance to PVY; ‘All Blue’, an heirloom blue skin blue flesh variety; ‘CO00291-5R’, a red skin white fleshed selection from the Colorado Potato Breeding and Selection Program; ‘CO97087-2RU’, a russet selection from the Colorado Potato Breeding and Selection Program; and ‘Sangre-S10’, a red skin white fleshed variety from the Colorado Potato Breeding and Selection Program.

Experimental Design

Tubers were grown during the summer of 2014 in the Colorado’s San Luis Valley. Plots of fifteen plants per clone spaced 12 inches apart on 34 inch centers were replicated four times at each location in a randomized complete block design for a total of 60 plants per clone at all four locations.

Locations

All five clones were grown at four locations in the San Luis Valley. Management of each of the four locations varied in an attempt to cover a wide spectrum but were broadly grouped into two categories: conventional and organic. Conventionally managed locations utilized synthetic fertilizers to meet fertility needs and various pesticides and rotational strategies for pest management. CONV-1, a research farm, utilized best management practices determined by most recent research to apply fertilizer and pesticides effectively. CONV-2, a commercial farm, represented average commercial management. Organically managed locations generally utilized organic amendments to meet fertility needs and cultural practices for pest management including a two-year rotational strategy with one year in cash crop and the second year in a green manure. ORG-1 grew a companion mix of legumes within the potato crop, rotated the potato crop with a multi-species green manure crop, applied compost and biological inocula to meet fertility needs and control pests, and grew strips of a multi-species flower mix in the center and borders of the fields to attract beneficial insects for pest control. ORG-2 was a certified organic farm representing more typical management growing in a potato monoculture rotated with a green manure and applying compost and compost teas to meet fertility needs and control pests. The specific locations and rotation managements are described further in Table 2.1.

Table 2.1: Locations of 2014 study and information on management and rotation strategies of each location.

Identity	Location	Management	Rotation
CONV-1	Center, CO	Conventional	Potato, barley
ORG-1	Center, CO	Organic	Potato companion mix [b], green manure [c]
CONV-2	Mosca, CO	Conventional	Potato, sorghum sudangrass
ORG-2	Mosca, CO	Organic [a]	Potato, green manure [d], quinoa, green manure [e]

[a] USDA Certified Organic

[b] Companion mix comprised of potatoes with chickling vetch, field pea, and buckwheat intercropped.

[c] Green manure mix comprised of spring lentils, chickling vetch, peas, chick pea, oats, pearl millet, brown top millet, graze corn, broadleaf mustard, tillage radish, and collards; grazed.

[d] Green manure mix comprised of field pea and wheat.

[e] Green manure of clover, grazed at least one time during season.

Tuber Yield and Size Distribution

Plots were harvested one week after vine kill, approximately 100 days after planting. Tubers from each plot were separated into the following weight distribution ranges: less than 4oz; greater than or equal to 4oz, less than 6oz; greater than or equal to 6oz, less than 8oz; greater than or equal to 8oz, less than 10oz; greater than or equal to 10oz, less than 12oz; greater than or equal to12oz, less than 14oz,; greater than or equal to 14oz, less than 16oz; and greater than 16oz. Weights are reported as cwt/acre. For yield analysis tubers were combined into the following weight ranges: less than 4oz; greater than or equal to 4oz; greater than or equal to 6oz; greater than or equal to 10oz; and total yield.

Tuber External Defects

Tubers from each plot with growth cracks, knobs, and misshapes were weighed and reported as a percent of the total yield.

Tuber Internal Defects

The five largest tubers from each plot were cut open to identify hollow heart and brown center. For every tuber identified with a defect, five more of the largest tubers were cut open until five cut tubers revealed no internal defects consecutively. Tubers with defects were weighed and reported as a percent of total yield.

Tuber Specific Gravity

Ten 8-10oz tubers from each plot were scrubbed clean of soil using a dish brush in tap water. Specific gravity was measured using the tuber weight in air and the tuber weight in water method: weight in air/(weight in air – weight in water).

Statistical Analysis

All statistical analyses were performed using SAS Statistical Analysis System Studio, v 3.2 Enterprise Edition (SAS Institute Inc., Cary, NC, USA). Yield, internal defects, external defects, and specific gravity were transformed to the natural logarithm to meet assumptions of normality for all analyses. Analyses of variance were conducted to determine the effect of location, the effect of genotype, and the effect of the interaction of genotype and location treating locations as fixed using the type 3 Mixed Procedure. Because there were no significant differences between reps the data were analysed as a completely randomized design. Least squares means estimates were calculated to determine differences between management. Kruskal-Wallis non-parametric alternative to one-way analyses of variance were conducted to determine influence of location on tuber internal and external defects of each clone using the exact Wilcoxon two-sample test.

2.3 Results

2.3.1 Yield

There was a significant effect of the interaction between genotype and location on total tuber yield as well as the <4oz, ≥4oz, and ≥10oz tuber weight ranges (Figure 2.1). In total yield, all clones except CO00291-5R ranked CONV-1, CONV-2, ORG-2, and ORG-1 from highest to lowest. With CO00291-5R the ORG-2 location outperformed the CONV-2 location. Total yields were most similar across locations with CO00291-5R, whereas Fortress Russet had the greatest variability across locations. In the less than 4oz tuber weight range, 'All Blue' produced a greater yield in CONV-2 than other locations and CO97087-2RU also produced a greater yield in CONV-2 than other locations. In the greater than or equal to 4oz tuber weight range all clones ranked CONV-1, CONV-2, ORG-2, and ORG-1 from highest to lowest, however, with CO97087-2RU the ORG-2 location outperformed the CONV-2 location. In the greater than or equal to 10oz tuber weight range CO97087-2RU, 'Fortress Russet,' and'Sangre-S10' each exhibited much greater yields at CONV-1 with 'Fortress Russet' showing the greatest variability across locations.

Total yield in conventionally managed locations averaged 406 cwt/acre and organic locations averaged 251 cwt/acre (Figure 2.2). There was a significant difference ($p<0.05$) in mean total yield and all tuber weight ranges except for <4oz tubers between conventional and organic managements.

There was a significant main effect of location on all tuber weight ranges ($p<0.05$). Location CONV-1 yielded the greatest total tuber yield with 450 cwt/acre and location ORG-1 yielded the lowest with 225 cwt/acre (Figure 2.3). CONV-1 yielded the greatest in all of the weight ranges except the <4oz.

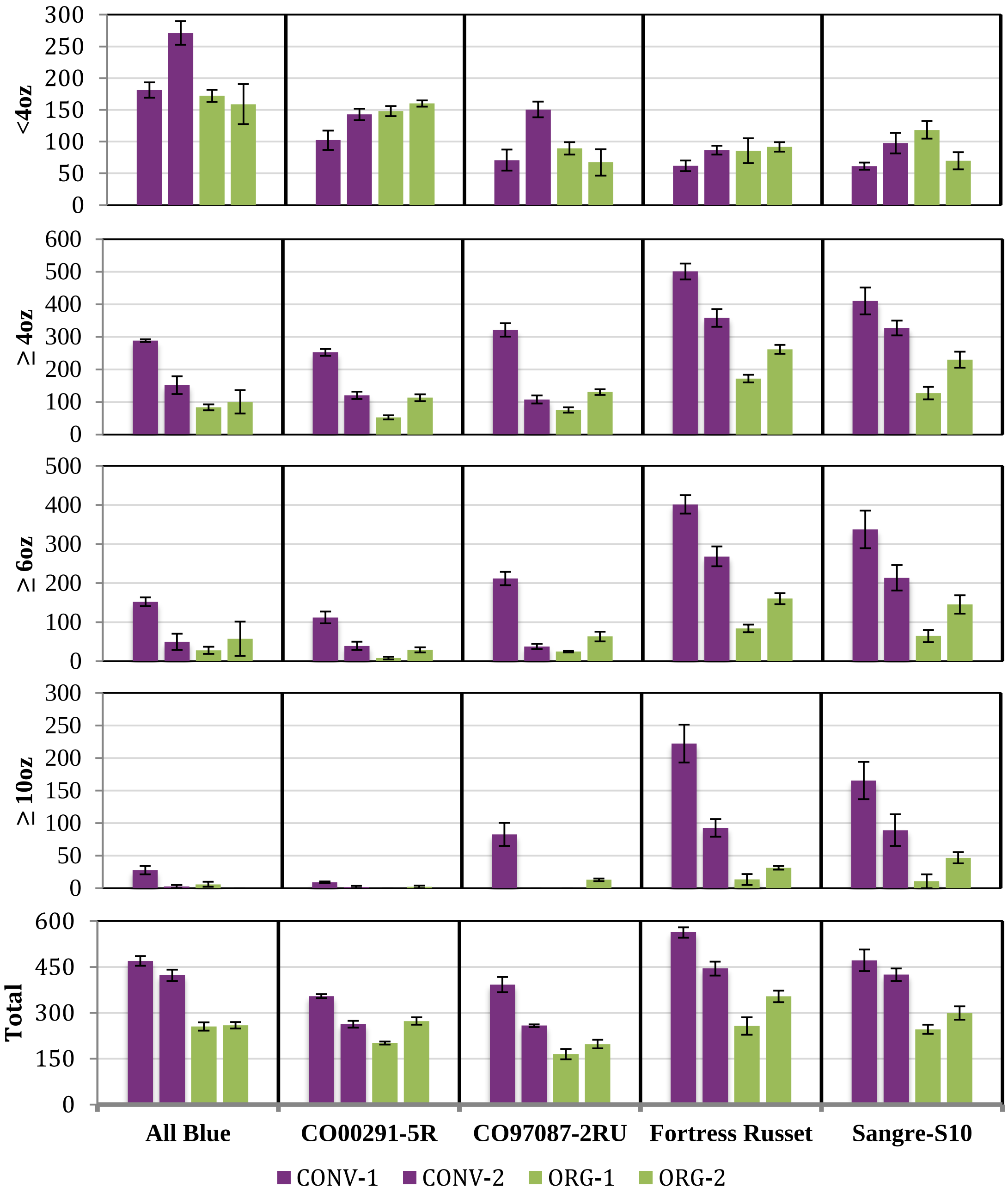

Figure 2.1: Tuber yield in cwt/acre by clone and by location. All tuber weight ranges had significant clone and location effects ($p<0.05$). Total yield, <4oz, ≥4oz and ≥10oz tuber weight ranges had significant interactions between clone and location. Error bars represent standard error of the mean (n=4). Purple bars represent conventionally managed locations; green bars represent organically managed locations.

There was a significant main effect of genotype on all tuber weight ranges ($p<0.05$).

'Fortress Russet' yielded the greatest total tuber yield with 405 cwt/acre while CO00291-5R and

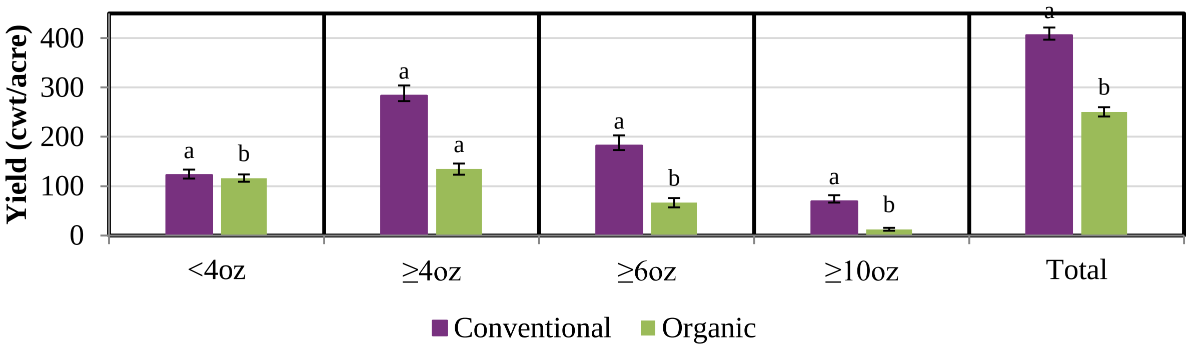

Figure 2.2: Mean yield (cwt/acre) by management. Means with the same letter within the same tuber weight range are not significantly different between managements (p>0.05). Error bars represent standard error of the mean (n=40). Purple bars are conventionally managed locations; green bars are organically managed locations.

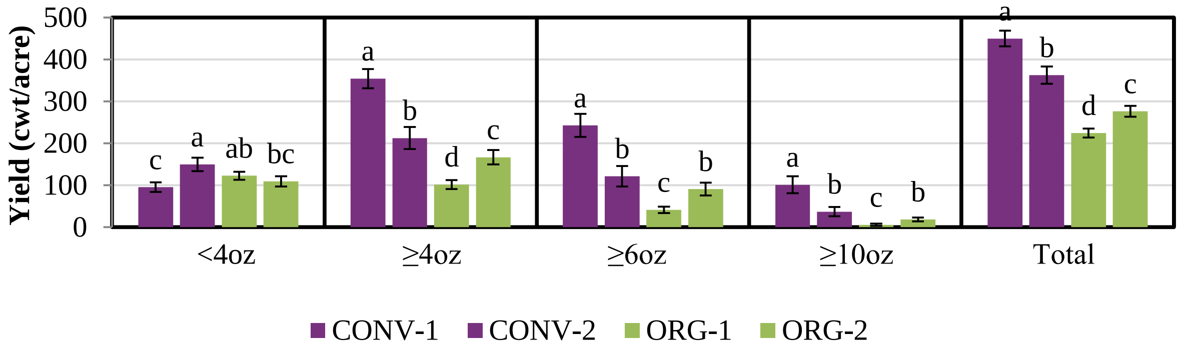

Figure 2.3: Mean yield (cwt/acre) by location. Means with the same letter within the same tuber weight range are not significantly different between locations (p>0.05). Error bars represent standard error of the mean (n=20). Purple bars represent conventional locations; green bars represent organic locations.

CO97087-2RU yielded the lowest total tuber yield with 273 and 253 cwt/acre, respectively (Figure 2.4).

2.3.2 Tuber Internal and External Defects

'Fortress Russet' was the only clone in which location had a significant impact on the prevalence of hollow heart (chi-square=9.881 df=3, p=0.0196) with an average of 6.8% of total yield exhibiting hollow heart at ORG-2, 1.2% at CONV-1, 0.7% at ORG-1, and 0.0% at CONV-2 (see Appendices F and G.). 'Fortress Russet' was significantly impacted by location with

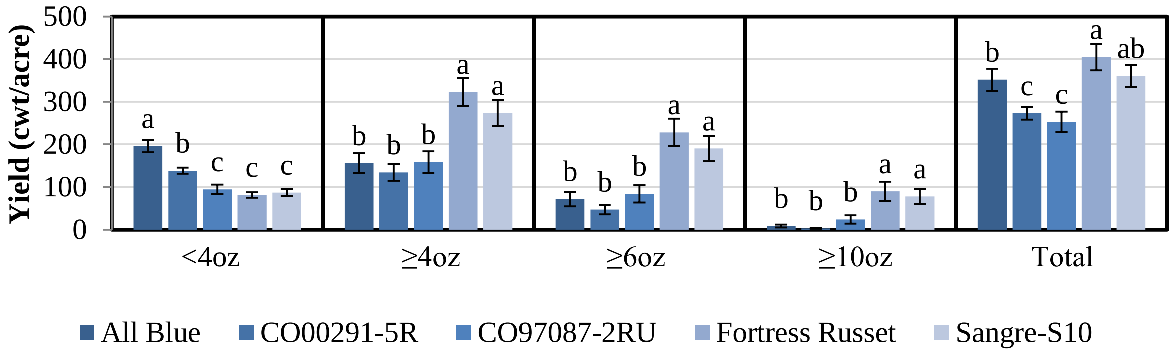

Figure 2.4: Mean yield (cwt/acre) by clone. Means with the same letter within the same tuber weight range are not significantly different between genotypes (p>0.05). Error bars represent standard error of the mean (n=16).

regard to growth cracks (chi-square=8.309, df=3, p=0.0400) (with a mean of 3.6% of total yield at ORG-2 exhibiting growth cracks, 0.38% at CONV-1, and 0.0% at both ORG-1 and CONV-2) as was Sangre-S10 (chi-square=12.500, df=3, p=0.0059) with a mean of 3.5% of total yield at ORG-2 exhibiting growth cracks, 2.4% at CONV-1, 0.2% at ORG-1, and 0.0% at CONV-2. No clones were significantly impacted by location with regard to brown center, knobs, or misshapes.

2.3.3 Specific Gravity

There was a significant effect of the interaction of genotype and location on specific gravity (p<0.05) (Figure 2.5). CO00291-5R and ‘Sangre-S10’ had low variability of specific gravity across locations, while CO97087-2RU had the greatest variability across locations.

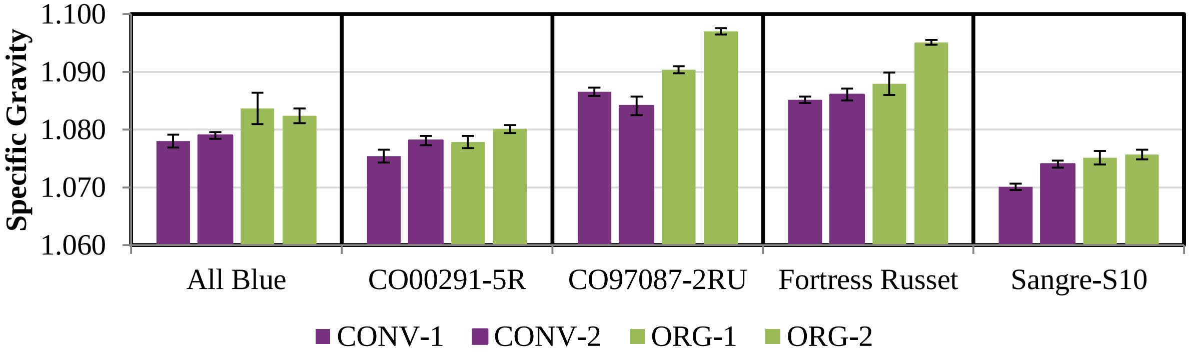

Figure 2.5: Mean specific gravity by clone and by location. Purple bars represent conventional locations; green bars represent organic locations. The effect of the interaction between clone and location is significant (p<0.05). Error bars represent standard error of the mean (n=4).

There was a significant difference in tuber specific gravity between management ($p<0.05$). Specific gravity averaged 1.080 in tubers grown in conventional management, and 1.084 in tubers grown in organic management (Figure 2.6).

There was a significant effect of location on specific gravity ($p<0.05$) with location ORG-2 having the highest specific gravity at 1.086 and CONV-1 and CONV-2 having the lowest values at 1.079 and 1.080, respectively (Figure 2.7).

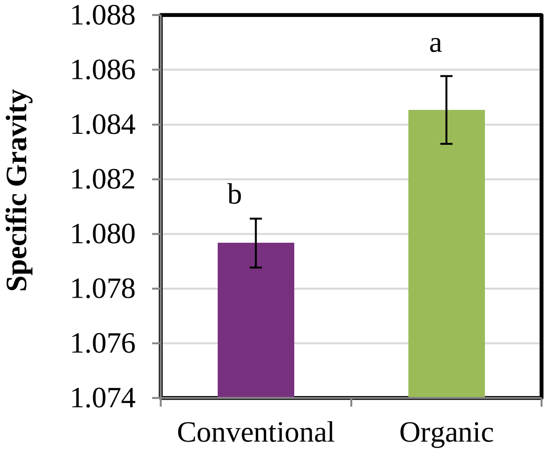

Figure 2.6: Mean tuber specific gravity by management. Means with the same letter are not significantly different between managements ($p>0.05$). Error bars represent standard error of the mean (n=40).

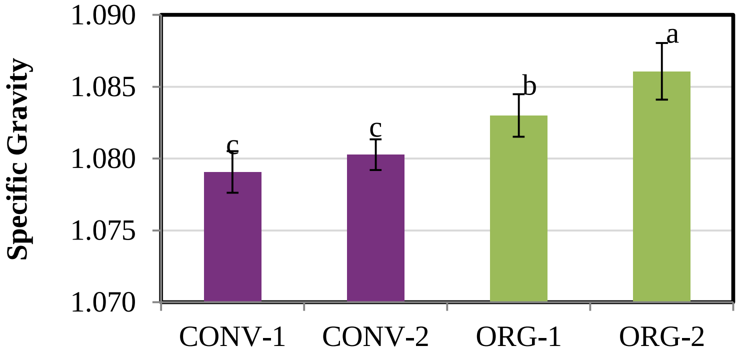

Figure 2.7: Mean tuber specific gravity by location. Purple bars represent conventional locations; green bars represent organic locations. Means with the same letter are not significantly different between locations ($p>0.05$). Error bars represent standard error of the mean (n=20).

There was a significant effect of genotype on specific gravity ($p<0.05$) with clones CO97087-2RU and 'Fortress Russet' having the highest at 1.089 and 1.088, respectively and 'All Blue,' CO00291-5R, and 'Sangre-S10' having the lowest at 1.080, 1.077, and 1.073, respectively (Figure 2.8).

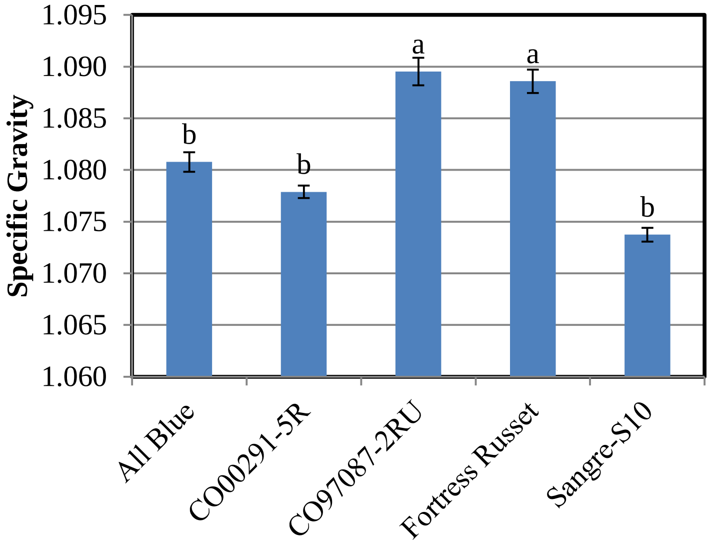

Figure 2.8: Mean tuber specific gravity by clone. Means with the same letter are not significantly different between genotypes ($p>0.05$). Error bars represent standard error of the mean (n=16).

2.4 Discussion

The conventional and organic total yields observed (406 cwt/acre and 251 cwt/acre, respectively) were commensurate with yields observed statewide in 2014 (384 cwt/acre and 263 cwt/acre, respectively). Organic systems yielded approximately 65% of their conventional counterparts which is commensurate with trials conducted in Kimberly, Idaho during 2009 reported by Moore et al. 2013. Nitrogen applications rates reported by farmers of the experimental locations and soil fertility tests from conventionally managed locations indicated a total of 150 lbs nitrate/acre whereas nitrogen applications rates reported by farmers of the experimental locations and soil fertility tests from organically managed sties indicated an average of 100 lbs nitrate/acre.

The significant main effect of location was not surprising, as the four locations were intentionally selected to represent various ends on each management spectrum. It was interesting that the organically managed locations had a disproportionately larger amount of less than 4 oz tubers. This is likely explained by early maturation of tubers, which is then not sustained because plant available nitrogen is not applied throughout the season as in conventional systems.

Fortress Russet and Sangre-S10 had higher yields overall and yielded more large tubers than then other clones but were also highly variable across locations. ‘Fortress Russet’ had the greatest average yield in all tuber sizes except the less than 4oz size. This is to be expected as this variety produces larger tubers. ‘All Blue’ had the greatest yield of <4oz size tubers. This also was not surprising as this variety typically produces small tubers. ‘Fortress Russet’ and ‘Sangre-S10’ produced the most ≥10oz tubers.

‘Fortress Russet,’ while yielding the greatest mean total yield across both managements, consistently exhibited large yield increases in each tuber size category (except the less than 4oz) when grown in conventionally managed locations, but also performed above average in all size categories (except less than 4oz) in organically managed locations. ‘Fortress Russet’ also had the greatest variability in ≥10oz tuber yield across locations making it not a good candidate for organic management if the goal is large tubers. CO00291-5R had a consistent mean total yield across managements. None of the clones yielded greater in organic management than in conventional management, though clones with stable responses may be promising for broader application. CO00291-5R had had low variability in all weight categories.

‘Fortress Russet’ was one of the only clones to be significantly impacted by location with regard to hollow heart and growth cracks. Growth cracks are typically the result from rapid growth rates, which would be better promoted by conventional management which supplies plant-available nitrogen through synthetic fertilizer applications rather than organically managed fields which supplies slower release of mineralized nitrogen leading to slower growth speeds. Unexpectedly, the greatest occurrence of both growth cracks and hollow heart were both in the ORG-2 location

Tubers from organic management consistently had higher specific gravity, which is a desirable trait in the potato industry. This is perhaps due to excessive nitrogen applications in conventional locations that may delay maturity and reduce specific gravity. It is interesting that specific gravity of tubers grown in conventional management did not differ significantly between locations, but the specific gravity of tubers grown in organic management did. While ‘All Blue,’ CO00291-5R and ‘Sangre-S10’ exhibited the lowest specific gravities, they had the smallest amount of variability across locations compared to CO97087-2RU and ‘Fortress Russet.’ Russet varieties typically have higher specific gravities than reds and specialties, which is commensurate with these data.

2.5 Conclusions

The five clones from this experiment showed great differences in yield and tuber quality. What is interesting is finding genotypes that respond well under a broad range of management practices. ‘Fortress Russet’ revealed to be significantly impacted by management and location; however, its PVY resistance and consistent high yields make this a great candidate variety for all growers. More research needs to be done to find varieties that perform consistently well under conventional versus organic management practices. These data should support integrating organic trials into breeding programs to produce more robust and broadly successful varieties.

CHAPTER 3: TUBER MINERAL NUTRIENT CONCENTRATIONS OF POTATOES GROWN IN CONVENTIONAL AND ORGANIC SYSTEMS

3.1 Introduction

Iron deficiency is one of the most prevalent forms of malnutrition and is ranked as the ninth most common risk factor for disability-adjusted life years (Stoltzfus 2003; Ezzati et al. 2002). It is relatively common in toddlers, adolescent girls, and women of childbearing age in the United States (Looker et al. 1997). Approximately 8% of women, 5% of men, and 7% of children in North America suffer from anemia as a result of iron deficiency (Stoltzfus 2003). African, Latin America, Eastern Mediterranean and Asia can see seven to eight times the numbers seen in the North America.

Zinc deficiency is ranked eleventh as a risk factor for disability adjusted life years, the number of years lost due to poor health or disability (Ezzati et al. 2002). It occurs mostly in the world’s poor populations, and can be attributed to abnormal cognitive development (Gibson 2006). Zinc supplementation has been shown to have therapeutic effects on children with diarrhea, pneumonia, measles, and malaria (Gibson 2006).

Recent studies have shown potato mineral iron and zinc is heritable and therefore can be increased through breeding (Brown et al. 2010; Brown et al. 2011). Additionally, there exists considerable genetic variation within potatoes to improve micronutrient content (Haynes et al. 2013). However, it is also important to understand how environment influences tuber nutrient concentration. Previous studies have explored how conventional and organic management systems can impact potato nutritional aspects. Hajslova et al. 2005 found both potato variety and management (conventional versus organic) played a role in potato tuber mineral nutrient content, nitrates, glycoalkaloids, and dry matter content.

The purpose of this study was to evaluate the effects of genotype and management on tuber mineral iron, zinc, and potassium concentrations when grown in conventionally and organically managed farms. This was done to identify breeding material that may be used to improve tuber mineral concentration as well as evaluate performance of genotypes in conventionally and organically managed farms.

3.2 Materials and Methods

This research was conducted in Colorado's San Luis Valley. Field grown tubers were evaluated for all mineral nutrients, but the focus of this study is on iron, zinc and potassium (See Appendix C for data on all mineral nutrients). In the summer of 2013, twenty-four genotypes were evaluated at four farms and analyzed for tuber mineral nutrient concentration. Five clones from the 2013 evaluation with high levels of tuber iron, zinc, and potassium were studied again in 2014.

Plant Material

Twenty-four potato genotypes representing major market classes were grown in the summer of 2013 to screen for tuber iron, zinc, and potassium concentrations. Eleven clones were from the Colorado Potato Breeding and Selection Program, thirteen clones were commercially available varieties including 'All Blue', 'Canela Russet', 'Centennial Russet', 'Colorado Rose', 'Mesa Russet', 'Mountain Rose', 'Norland', 'Ranger Russet', 'Rio Grande Russet', 'Russet Nugget', 'Sangre-S10', and 'Yukon Gold' (see Appendix A for complete clone list)**.**

Five potato genotypes were grown in the summer of 2014: 'Fortress Russet', a russet variety released by the Colorado Potato Breeding and Selection Program in 2014 known to have resistance to PVY; ‘All Blue’, an heirloom blue skin blue flesh variety; ‘CO00291-5R’, a red skin white fleshed selection from the Colorado Potato Breeding and Selection Program; ‘CO97087-2RU’, a russet selection from the Colorado Potato Breeding and Selection Program; and ‘Sangre-S10’, a red skin white fleshed variety from the Colorado Potato Breeding and Selection Program.

Experimental Design

In the summer of 2013 plots of ten plants per clone spaced 12 inches apart in rows on 34 in centers were replicated one time in a completely randomized design at each of four locations in order to screen for mineral nutrient concentration.

In the summer of 2014, plots of fifteen plants per clone spaced 12 inches apart on 34 inch centers were replicated four times at each location in a randomized complete block design for a total of 60 plants per clone at all four locations. All five clones were also grown in Springlake, TX and Delta, CO but were not included in the conventional versus organic nutrient analyses to control geographical effects. See Appendices B and C for data from these locations.

Locations

In the summer of 2013 twenty-four clones were grown on four farms in the following locations: one farm in Springlake, TX; one farm in Delta, CO; two farms in Center, CO.

All five clones were grown at four locations in the San Luis Valley. Management of each of the four locations varied in an attempt to cover a wide spectrum but were broadly grouped into two categories: conventional and organic. Conventionally managed locations utilized synthetic fertilizers to meet fertility needs and various pesticides and rotational strategies for pest management. CONV-1, a research farm, utilized best management practices determined by most recent research to apply fertilizer and pesticides effectively. CONV-2, a commercial farm, represented a more liberal use of fertilizer and pesticide application rates. Organically managed locations generally utilized organic amendments to meet fertility needs and cultural practices for pest management including a two-year rotational strategy with one year in cash crop and the second year in a green manure. ORG-1 grew a companion mix of legumes within the potato crop, rotated the potato crop with a multi-species green manure crop, applied compost and biological inocula to meet fertility needs and control pests, and grew strips of a multi-species flower mix in the center and borders of the fields to attract beneficial insects for pest control. ORG-2 was a certified organic farm representing more typical management growing in a potato monoculture rotated with a green manure and applying compost and compost teas to meet fertility needs and control pests. The locations and management are described in Table 3.1.

Table 3.1: Locations of 2014 study and information on management and rotation strategies of each location.

Identity	Location	Management	Rotation
CONV-1	Center, CO	Conventional	Potato, barley
ORG-1	Center, CO	Organic	Potato companion mix [b], green manure [c]
CONV-2	Mosca, CO	Conventional	Potato, barley
ORG-2	Mosca, CO	Organic [a]	Potato, green manure [d], quinoa, green manure [e]

[a] USDA Certified Organic

[b] Companion mix comprised of potatoes with chickling vetch, field pea, and buckwheat intercropped.

[c] Green manure mix comprised of spring lentils, chickling vetch, peas, chick pea, oats, pearl millet, brown top millet, graze corn, broadleaf mustard, tillage radish, and collards.

[d] Green manure mix comprised of field pea and wheat.

[e] Green manure of clover, grazed at least one time during season.

Nutrient Analysis

Ten 8-10oz tubers from each plot were soaked in water and scrubbed to remove soil from the skins. Tubers were cut into pieces and placed in a drying oven at a temperature of 87 degrees Fahrenheit for up to 7 days. Dry tubers were ground using a Wiley Mill with a 1mm screen and collected into a single composite sample for each plot. Samples were sent to Servi-Tech Laboratories in Hastings, NE for full mineral nutrient analysis.

Statistical Analysis

All statistical analyses were performed using SAS Statistical Analysis System Studio, v 3.2 Enterprise Edition (SAS Institute Inc., Cary, NC, USA). Tuber iron and zinc were transformed to the natural logarithm to meet assumptions of normality for all analyses. Analyses of variance were conducted to determine the effect of location, the effect of genotype, and the effect of the interaction of genotype and location treating locations as fixed using the type 3 Mixed Procedure. Because there were no significant differences between reps the data were analysed as a completely randomized design. Least squares means estimates were calculated to determine differences between management using the lsmestimate procedure.

3.3 Results

3.3.1 2013 Study

When averaged across all locations, CO00291-5R had the highest concentration of potassium with 2.46% dry weight (Table 3.2). Sangre-S10 had the highest concentration of zinc with 22.3 mg/kg dry weight, and CO00291-5R had the second highest concentration of zinc with 20.8 mg/kg dry weight. CO97087-2RU had the highest concentration of iron with 85.4 mg/kg dry weight. These three clones, along with Fortress Russet and All Blue were chosen for use in the 2014 study. See Appendix B for all tuber mineral nutrient concentration data.

3.3.2 2014 Study

The interaction between genotype and location had a significant effect on tuber potassium concentration (p=0.0127), but not tuber iron or zinc (p=0.3526 and p=0.5259, respectively) (Figure 3.1). CO97087-2RU exhibited much higher levels of tuber potassium at CONV-2 than the other locations. ‘Fortress Russet’ and ‘Sangre-S10’ exhibited a larger range of tuber potassium concentrations across all four locations compared to the remaining clones.

Table 3.2: Tuber mineral potassium, zinc, and iron concentrations averaged across four locations from 2013 study.

Clone	K (%)	Zn (mg/kg)	Fe (mg/kg)
CO00291-5R	2.46	20.8	57.3
CO02024-9W	2.10	18.7	54.2
CO02033-1W	1.93	16.2	56.5
CO04159-1R	2.17	20.3	54.1
CO95051-7W	2.10	15.1	65.5
CO97087-2RU	1.91	16.4	85.4
CO99045-1W/Y	2.03	12.1	62.7
VC0967-2R/Y	1.79	17.4	60.0
VC1002-3W/Y	2.18	15.2	58.2
All Blue	1.99	16.8	72.7
Canela Russet	1.78	17.6	69.8
Centennial Russet	2.08	15.3	78.0
Colorado Rose	1.78	14.7	55.0
Fortress Russet	2.14	13.8	68.8
Mesa Russet	2.04	15.3	74.8
Mountain Rose	1.55	15.4	47.8
Norland (DR)	1.89	16.8	69.8
Purple Majesty	1.77	13.7	43.6
Ranger Russet	1.91	14.1	62.7
Rio Grande Russet	2.04	14.8	73.9
Russet Nugget	1.88	18.6	80.4
Sangre-S10	2.01	22.3	54.8
Yukon Gold	2.06	13.3	59.1

Tubers from conventionally managed fields had on average 1.91 % dry weight K, 122.8 mg/kg Fe, and 17.4 mg/kg Zn (Figure 3.2). Tubers from organically managed fields had on average 1.91 % dry weight K, 100.1 mg/kg Fe, and 14.0 mg/kg Zn. Tuber mineral iron and zinc concentrations were significantly different between tubers from conventionally versus organically managed fields ($p<0.05$).

There was a significant main effect of location on tuber mineral potassium, iron, and zinc concentrations (Figure 3.3). Location CONV-2 produced tubers with the highest potassium concentration at 2.02% dry weight. Location CONV-1 produced tubers with the greatest iron concentration at 180.2 mg/kg dry weight. CONV-2 produced tubers with the highest zinc concentration at 20.4 mg/kg dry weight.

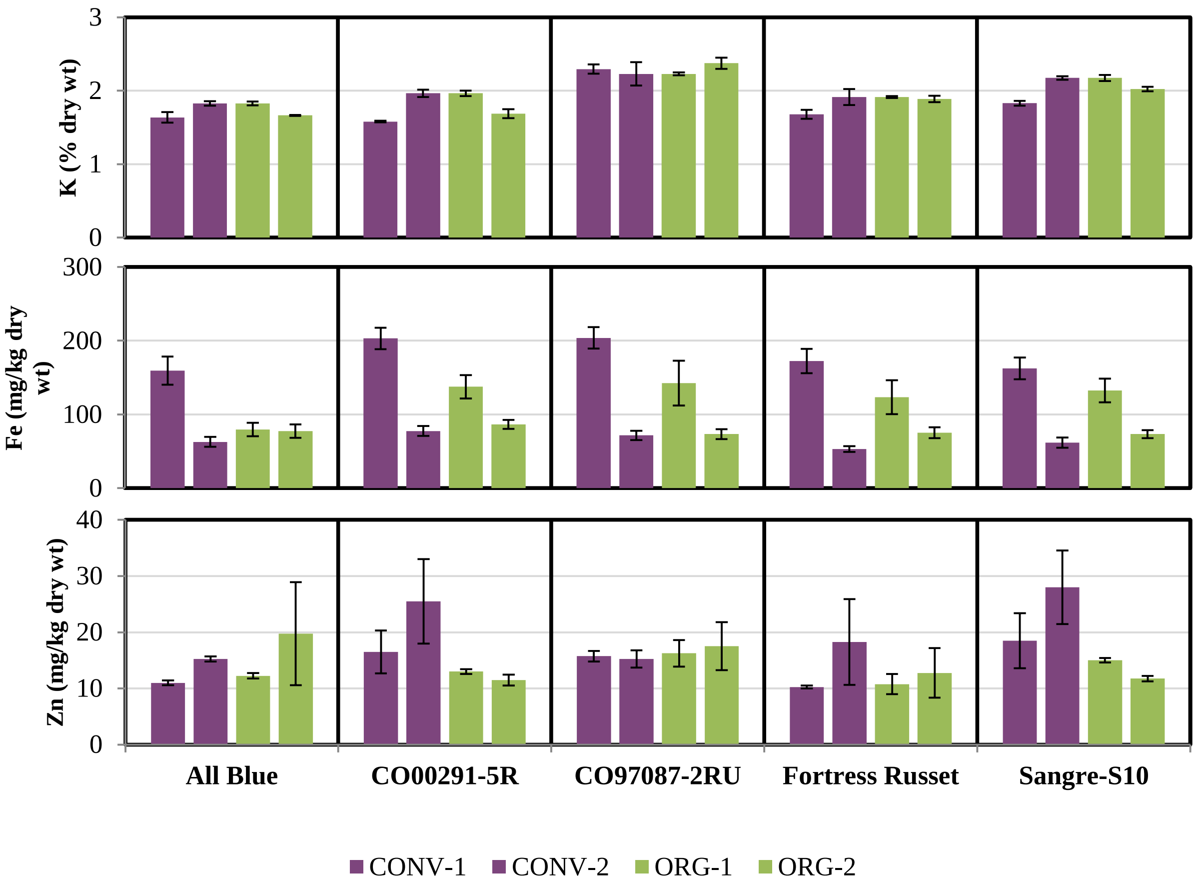

Figure 3.1: Mean tuber potassium, iron, and zinc concentrations by genotype and by location. Purple bars represent conventional locations; green bars represent organic locations. The effect of the interaction between clone and location is significant only for tuber potassium (p<0.05). Error bars represent standard error of the mean (n=4).

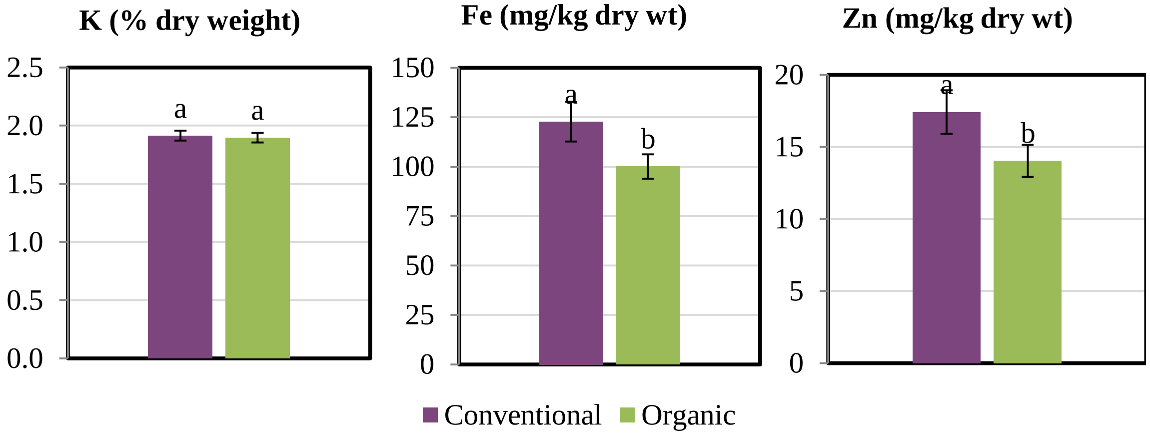

Figure 3.2: Mean tuber potassium (% dry weight), iron (mg/kg dry weight), and zinc (mg/kg dry weight) concentrations by management. Means with the same letter are not significantly different between managements (p>0.05). Error bars represent standard error of the mean (n=40).

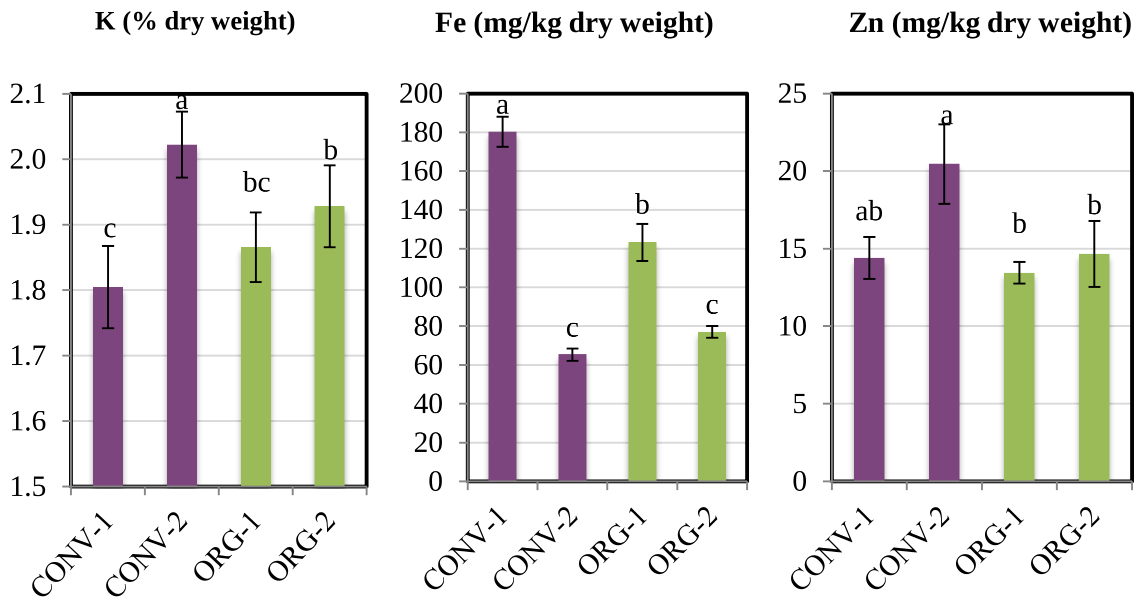

Figure 3.3: Mean tuber mineral nutrients by location. Purple bars represent conventional locations; green bars represent organic locations. Means with the same letter are not significantly different between locations (p>0.05). Error bars represent standard error of the mean (n=20).

There was a significant main effect of genotype on tuber mineral potassium, iron, and zinc concentrations (Figure 3.4). Among the five clones, CO00291-5R had the greatest tuber potassium concentration with 2.29% dry weight. CO00291-5R and CO97087-2RU had the greatest tuber iron concentrations with 122.8 and 126.2 mg/kg dry weight, respectively. Sangre-S10 had the greatest tuber zinc concentration with 18.3 mg/kg dry weight.

3.4 Discussion

Tuber mineral nutrients followed what was expected based on the 2013 trial results. CO00291-5R continued to exhibit high potassium levels. CO00291-5R and CO97087-2RU continued to exhibit high iron levels. CO00291-5R and Sangre-S10 continued to exhibit high zinc levels.

There was a significant interaction effect of genotype and location on potassium. CO97087-2RU exhibited the greatest level of stability in potassium concentration across the four

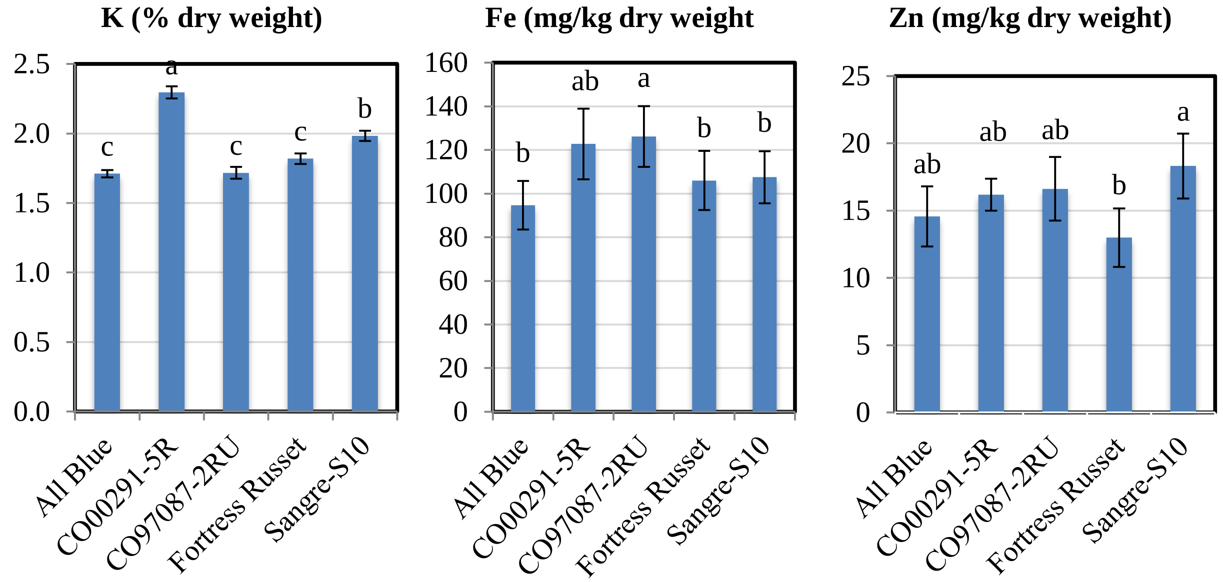

Figure 3.4: Mean tuber mineral nutrients by clone. Means with the same letter are not significantly different between genotypes (p>0.05). Error bars represent standard error of the mean (n=16).

locations and also exhibited the greatest level of stability in tuber zinc concentration across the four locations, thus, CO97087-2RU may be a good candidate for improved potassium and zinc concentrations across a range of management systems.

The main effect of location played a more important role in tuber mineral nutrient concentrations than management. Cultural management information reported by farmers along with pre-plant soil test reports (see Appendix G) indicated all locations had “very high” phosphorous values, “very high” potassium values, “adequate” zinc values, and “adequate” iron values (Self, 2010).

3.5 Conclusions

CO00291-2RU is a good candidate to use as breeding material for improving potato potassium and zinc concentrations. CO97087-2RU is a good candidate to use as breeding material for improving potato iron and potassium concentrations. Sangre-S10 is a good candidate to use as breeding material for improving potato iron concentration.

CHAPTER 4: SOIL FOOD WEB AND SOIL HEALTH OF CONVENTIONAL AND ORGANIC POTATO SYSTEMS

4.1 Introduction

Organic agriculture relies on microbially-mediated mineralization processes to meet soil fertility needs, whereas conventional systems supply soluble nutrients to feed plants. Organic agriculture utilizes practices that promote microbial biomass, diversity, and organic matter through diversified crop rotations, addition of carbon and nitrogen substrates, and microbial inocula. Organically managed soils, thus, have a soil ecosystem unique from conventionally managed farming systems.

Organically managed soils have been shown to have higher microbial biodiversity (Mäder et al. 2002; Fließbach et al. 2007) and have higher levels of soil organic matter (Marriott et al. 2006) than their conventional counterparts. Genotype likely plays a role in recruiting soil microbiome (Badri et al. 2009; Manter et al. 2009), and perhaps clones can be better selected to perform well in respective soil ecosystems (Bakker et al. 2012).

The purpose of this study was to evaluate the effects of genotype and environment on the soil food web composition and the capacity of the rhizosphere and bulk soil to support microbial life in conventionally and organically managed fields.

4.2 Materials and Methods

This research was conducted in Colorado’s San Luis Valley. Rhizosphere and bulk soil from field grown tubers were analyzed for soil food web composition and soil organic carbona nd nitrogen in fields managed conventionally and organically.

Plant Material

Five potato genotypes were grown in the summer of 2014: ‘Fortress Russet’, a russet variety released by the Colorado Potato Breeding and Selection Program in 2014 known to have resistance to PVY; ‘All Blue’, an heirloom blue skin blue flesh variety; ‘CO00291-5R’, a red skin white fleshed selection from the Colorado Potato Breeding and Selection Program; ‘CO97087-2RU’, a russet selection from the Colorado Potato Breeding and Selection Program; and ‘Sangre-S10’, a red skin white fleshed variety from the Colorado Potato Breeding and Selection Program.

Experimental Design

Tubers in this study were grown during the summer of 2014 in the San Luis Valley of Colorado. Plots of fifteen plants per clone spaced 12 inches apart on 34 inch centers were replicated four times at each location in a randomized complete block design for a total of 60 plants per clone at all four locations.

Locations

All five clones were grown on four locations in the San Luis Valley. Two locations were conventionally managed and located in Center, CO and Mosca, CO. Two locations were organically managed and located in Center, CO and Mosca, CO.

All five clones were grown at four locations in the San Luis Valley. Management of each of the four locations varied in an attempt to cover a wide spectrum but were broadly grouped into two categories: conventional and organic. Conventionally managed locations utilized synthetic fertilizers to meet fertility needs and various pesticides and rotational strategies for pest management. CONV-1, a research farm, utilized best management practices determined by most recent research to apply fertilizer and pesticides effectively. CONV-2, a commercial farm, represented a more liberal use of fertilizer and pesticide application rates. Organically managed locations generally utilized organic amendments to meet fertility needs and cultural practices for pest management including a two-year rotational strategy with one year in cash crop and the second year in a green manure. ORG-1 grew a companion mix of legumes within the potato crop, rotated the potato crop with a multi-species green manure crop, applied compost and biological inocula to meet fertility needs and control pests, and grew strips of a multi-species flower mix in the center and borders of the fields to attract beneficial insects for pest control. ORG-2 was a certified organic farm representing more typical management growing in a potato monoculture rotated with a green manure and applying compost and compost teas to meet fertility needs and control pests. The locations and management are described in Table 4.1. See Appendix H. for more management information.

Table 4.1: Locations of 2014 study and information on management and rotation strategies of each location.

Identity	Location	Management	Rotation
CONV-1	Center, CO	Conventional	Potato, barley
ORG-1	Center, CO	Organic	Potato companion mix [b], green manure [c]
CONV-2	Mosca, CO	Conventional	Potato, barley
ORG-2	Mosca, CO	Organic [a]	Potato, green manure [d], quinoa, green manure [e]

[a] USDA Certified Organic

[b] Companion mix comprised of potatoes with chickling vetch, field pea, and buckwheat intercropped.

[c] Green manure mix comprised of spring lentils, chickling vetch, peas, chick pea, oats, pearl millet, brown top millet, graze corn, broadleaf mustard, tillage radish, and collards.

[d] Green manure mix comprised of field pea and wheat.

[e] Green manure of clover, grazed at least one time during season.

Soil Food Web Analysis

Soil samples were taken from all four fields, all five clones, and three of the four replications. Ten 3-4" soil cores were taken from the base of plants throughout each plot and combined as a composite sample in a Ziploc bag. Samples were stored at 35°F for one week then shipped on ice overnight to Earthfort Labs in Corvallis, OR for an analysis of total soil bacteria, fungi, protozoa, and nematodes.

Samples were prepared and stained with fluorescein diacetate and bacteria (Babiuk & Paul 1970; Ingham & Horton 1987; Ingham 1994; Van Veen & Paul 1979) and fungi (Ingham 1995; Lodge & Ingham 1995a; Van Veen & Paul 1979) were quantified using microscopy. Ciliates, flagellates and amoeba were enumerated by direct counting of serial dilutions of the sample using microscopy (Darbyshire et al. 1974; Ekelund 1998; Ingham 1993; Ingham 1995c; Lee et al. 1985; Singh 1995; Stevik et al. 1998). Nematodes were extracted from samples using an enhanced Baermann funnel technique then identified using direct microscopy (Baermann 1917; Bongers 1988; Goodey 1963; Ingham 1995b; Mai & Lyon 1975). Nematodes were observed by species and further classified by feeding habit. Species that feed on root/tubers were classified as "bad" and species that feed on bacteria and fungi were classified as "good."

Soil food web constituents were interpreted by low to high value ranges designated by Earthfort Labs as follows: 300 – 600 µg bacteria/g soil; 300 – 600 µg fungi/g soil; 10000 – 100,000 flagellates/g soil; 10000-100,000 amoebae/g soil; 0-200 ciliates/g soil; 10-20 nematodes/g soil.

Soil Health Analysis

Soil samples were taken from all four fields, three clones ('All Blue', CO00291-5R, and 'Fortress Russet'), from three of the four replications. Ten 4-6" soil cores were taken from each plot and combined as a composite sample in a sealed plastic bag. Samples were stored at 35°F for one week then shipped on ice overnight to the USDA-ARS lab in Temple, TX for the Haney Soil Health Test assay which includes an analysis of microbial CO_2 release (Franzluebbers et al. 1996; Franzluebbers et al. 2000), soil organic carbon (water extractable carbon available for driving soil microbial activity), and soil organic nitrogen (water extractable organic nitrogen available for driving soil microbial activity).

Statistical Analysis

All statistical analyses were performed using SAS Statistical Analysis System Studio, v 3.2 Enterprise Edition (SAS Institute Inc., Cary, NC, USA). Total fungi, flagellates, amoebae, ciliates, nematodes and soil respiration were transformed to the natural logarithm to meet assumptions of normality for all analyses. Analyses of variance were conducted to determine the effect of location, the effect of genotype, and the effect of the interaction of genotype and location on soil food web constituents and soil health by treating locations as fixed using the type 3 Mixed Procedure. Because there were no significant differences between reps the data were analysed as a completely randomized design. Least squares means estimates were calculated to determine differences between management.

4.3 Results

4.3.1 Soil Food Web

There was a significant interaction effect between genotype and location for soil bacteria and fungi biomass ($p<0.05$) (Figure 4.1). ‘Sangre-S10’ showed little variation in soil bacteria between locations, whereas CO97087-2RU and ‘Fortress Russet’ did. CO97087-2RU showed much greater differences in soil fungi between conventional and organic locations, as did ‘Fortress Russet’ and ‘Sangre-S10’.

There was a significant difference in soil fungi, amoebae, and ciliate biomass between management ($p<0.0001$ for each). Organically managed soils averaged 254 µg fungi/g soil, while conventionally managed soils averaged 142 µg fungi/g soil (Figure 4.2). Organically managed soils averaged 236,265 amoebae/g soil, while conventionally managed soils averaged 50,872 amoebae/g soil. Organically managed soils averaged 525 ciliates/g soil, while conventionally managed soils averaged 32 ciliates/g soil.

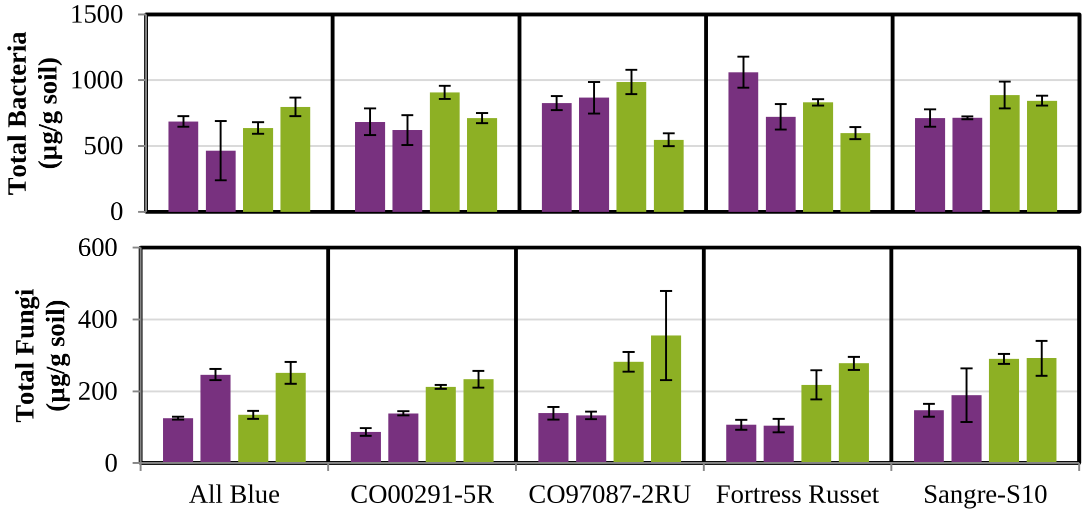

Figure 4.1: Mean soil bacteria and fungi biomass by clone and by location. Purple bars represent conventional locations; green bars represent organic locations. The effect of the interaction between clone and location is significant ($p<0.05$). Error bars represent standard error of the mean (n=4).

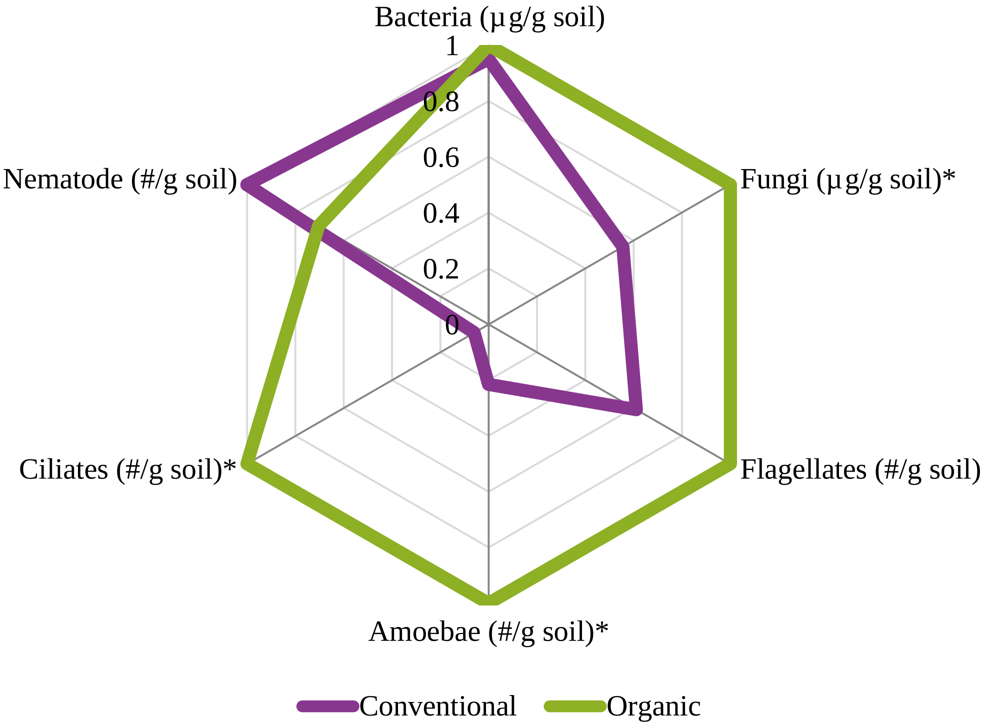

Figure 4.2: Mean soil food web constituents by management. Values have been normalized to the maximum, where the management practice with the highest value in a given category is assigned 1 and the remaining category value represents a percentage of that highest value (n=30). Constituents with an asterisk are significantly different between managements ($p<0.05$).

There was a significant effect of location on all soil food web constituents except for flagellates (p<0.05). No particular location stood out as having consistently greater soil food web constituents.

There was a significant effect of clone on soil fungi and ciliates (p<0.05), with genotype having a stronger effect on ciliates (p=0.0035) than fungi (p=0.0430). Soil samples taken from CO97087-2RU and 'Sangre-S10' had the greatest amount of fungi at 227 and 229 µg fungi /g soil, respectively (Table 4.2). Soil samples taken from CO97087-2RU also had the greatest average amount of ciliates with 606 ciliates/g soil.

Table 4.1: Mean soil food web constituents by location ± standard error of the mean (n=12). Means with the same letter within the same soil food web constituent are not significantly different between locations (p>0.05). There is a significant effect of location on all constituents except for flagellates (p<0.05).

Location	Bacteria (µg/g soil)	Fungi (µg/g soil)	Flagellates (#/g soil)
CONV-1	794 ± 49 ab	121 ± 8 a	6478 ± 1833 a
CONV-2	677 ± 61 b	162 ± 19 a	5226 ± 1891 a
ORG-1	850 ± 40 a	227 ± 18 b	5837 ± 832 a
ORG-2	699 ± 36 b	282 ± 26 b	13314 ± 3789 a

Location	Amoebae (#/g soil)	Ciliates (#/g soil)	Nematodes (#/g soil)
CONV-1	44698 ± 2866 a	27 ± 5 a	0.8 ± 0.1 a
CONV-2	57047 ± 8078 a	37 ± 20 a	6.0 ± 1.8 bc
ORG-1	289753 ± 42319 b	102 ± 23 b	2.9 ± 0.4 c
ORG-2	182777 ± 37104 ab	949 ± 380 c	1.9 ± 0.3 ac

There was no significant difference between management in terms of the proportion of good nematode species (DF=40, t-value=1.02, p=0.312). However, there was a significant effect of location on nematode species ratios (p<0.0001). CONV-2 and ORG-2 had the greatest proportion of good nematode species with 84.1% and 89.2% good species, respectively, while CONV-1 and ORG-1 had lower proportions of good nematode species with 69% and 58% good species, respectively.

Table 4.2: Mean soil food web constituents by clone ± standard error of the mean (n=15). Means with the same letter within the same soil food web constituent are not significantly different between clones (p>0.05). There was a significant effect of genotype on soil fungi and ciliates only (p<0.05).

Clone	Bacteria (µg/g soil)	Fungi (µg/g soil)	Flagellates (#/g soil)
All Blue	646 ± 64 a	189 ± 20 a	9655 ± 3039 a
CO00291-5R	731 ± 47 a	168 ± 19 a	3878 ± 841 a
CO97087-2RU	807 ± 60 a	227 ± 40 a	10462 ± 2928 a
Fortress Russet	802 ± 62 a	177 ± 25 a	8180 ± 3663 a
Sangre-S10	789 ± 36 a	229 ± 27 a	6394 ± 2312 a

Clone	Amoebae (#/g soil)	Ciliates (#/g soil)	Nematodes (#/g soil)
All Blue	152100 ± 42004 a	122 ± 41 ac	2.0 ± 0.3 a
CO00291-5R	163181 ± 53874 a	42 ± 12 c	2.9 ± 0.9 a
CO97087-2RU	167907 ± 43524 a	606 ± 420 ab	2.8 ± 0.8 a
Fortress Russet	157917 ± 45831 a	282 ± 197 ac	2.1 ± 0.9 a
Sangre-S10	76740 ± 23219 a	341 ± 256 c	4.7 ± 2.1 a

4.3.2 Soil Health

There was a significant main effect of location on soil respiration, organic carbon, and organic nitrogen (p<0.05). Location ORG-1 had the greatest soil respiration with 24.6 ppm CO_2/24 hrs (Figure 4.3). Location ORG-1 also had the greatest organic carbon pool with 159.9 ppm and the greatest organic nitrogen pool with 32.8 ppm. There was no significant main effect of genotype (p>0.05).

There were significant differences in soil respiration, organic carbon, and organic nitrogen between management (p<0.05). Soil from organically managed locations had mean soil respiration of 22.1 ppm CO_2/24hrs compared to conventionally managed locations with 16.9 ppm CO_2/24hrs. Soil from organically managed locations had mean soil organic carbon pools of 140 ppm compared to conventionally managed locations with a mean of 97 ppm. Soil from organically managed locations had mean soil organic nitrogen pools of 31.8 ppm compared to conventionally managed locations with a mean of 24.4 ppm.

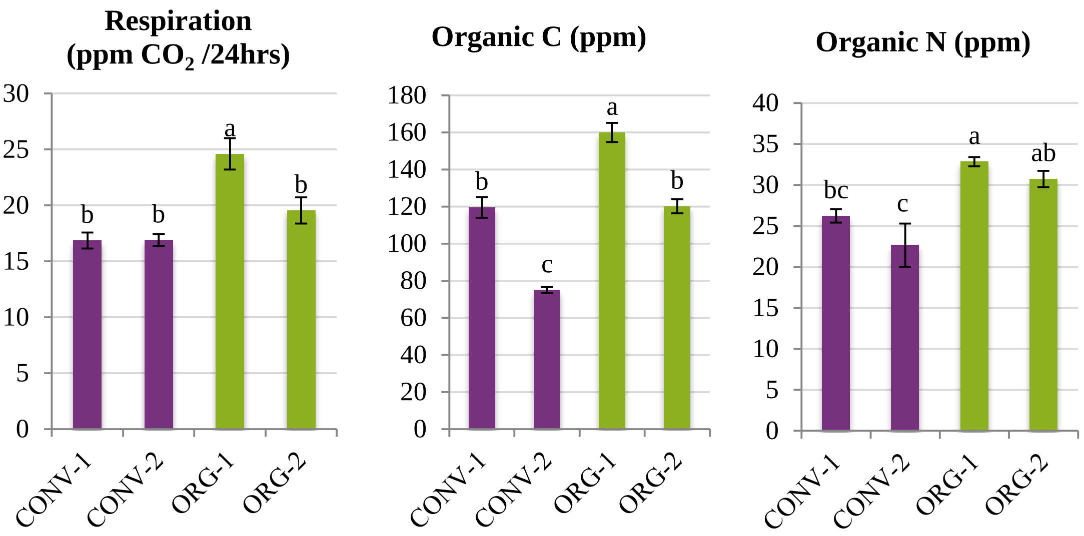

Figure 4.3: Mean respiration, organic carbon, and organic nitrogen by location. Purple bars represent conventional locations; green bars represent organic locations. Means with the same letter are not significantly different between locations ($p>0.05$). Error bars represent standard error of the mean ($n=9$).

4.4 Discussion

Conventional and organic soils differed significantly only in soil fungi, amoebae, and ciliates. Conventionally managed locations in this study utilized various fungicides, whereas the organically managed locations did not (see Appendix H). As fungicide applications have been shown to decrease soil fungal populations (Kuthubutheen et al. 1979), this may explain the differences observed in our study. Soil fungi have been known to support plant health by aiding in nutrient acquisition, protecting plant roots from pathogens, and acting as a buffer under stressful environmental conditions (Mohammadi et al. 2010; Coleman-Derr 2014). While the organic locations had greater fungal biomass compared to conventional locations, both soils were still bacterially dominated as expected in cultivated soils such as potato fields. CO97087-2RU and ‘Sangre-S10’ both had higher fungi biomass in their associated soil, which would be interesting to explore further with microscopy.

Soil bacterial biomass was very high relative to fungi and is typical in disturbed agricultural soils (Hendrix et al. 1986). Soil protozoa have been shown to exist in smaller numbers in soils with coarser texture such as the sandy soils found in the locations of this study (Rutherford & Juma 1991). Soil flagellates were at the low end of the given ranges for all locations and clones. Soil ciliate numbers were very high at the organic locations compared to the given ranges. Total nematodes were below the low end of the given range.

Organically managed locations generally had higher soil respiration, organic carbon and nitrogen pools suggesting organically managed soils can support more microbial life than conventionally managed soils. Location ORG-1, which grew a potato companion mix in addition to other means of increasing on farm biodiversity, consistently had the highest values for soil carbon and nitrogen. This is also reflected in the higher soil organic matter as indicated in the 2014 routine soil test results (Appendix H). McDaniel et al. (2014) observed a 3.6% increase in soil C, 5.3% increase in soil N by adding one crop to a monoculture rotation, and an 8.5% increase in soil C and a 12.8% increase in soil N when rotations included a cover crop. By increasing diversity in the rotations, they also dramatically increased soil microbial biomass. The potato companion crop and green manure rotation are likely increasing soil residue, thus, increasing soil organic matter.

Ranges of soil food web constituents given by Earthfort Labs are based on ranges that are typically seen in soil samples sent to their lab that have been taken from similar cropping schemes at similar times in the season. Currently there are no values that are recommended for agricultural soils as soil microbial populations are heavily influenced by soil texture, crop species, and tillage. These data then are only examined among the locations part of this study. It would be valuable to assay soil samples from many more locations throughout the San Luis Valley to establish a better understanding of the given range of microbial populations in that region as well as values from the Haney Soil Health Test.

4.5 Conclusions

Soil ecosystems differ dramatically between management and even within management. Soil fungi, amoebae, and ciliate biomass were decreased under conventional management. A better understanding of how plants relate to and alter the soil microbiome will help in breeding plants to perform better in certain ecosystems and potentially allow farmers to harness beneficial microbes to improve plant health.

CHAPTER 5: GENERAL DISCUSSION AND CONCLUSION

5.1 General Discussion

The potato (*Solanum tuberosum*) is the third most consumed crop globally behind rice and wheat (International Potato Center, 2013). Potatoes are a versatile crop that can be cultivated in diverse environments and are currently grown in 100 different countries (United States Potato Board, 2015). Potato crops can yield 9.2M calories per acre, which is more than that of maize (7.5M), rice (7.4M), wheat (3M), and soybean (2.8M) (Ensminger et al. 1994). Potatoes are an excellent candidate for biofortification to address malnourishment in developing countries, feed a growing global population, and fit into a healthy part of the American diet.

These studies focused on comparing conventional and organic production systems and 1) how genotype and management influence tuber yield and quality, 2) how genotype and management influence tuber mineral nutrient concentration, and 3) how genotype and management influence soil health and the soil food web. The clones from the Colorado Potato Breeding and Selection Program have never been evaluated for differences between conventional and organic farm systems.

The first study concluded that management does in fact affect tuber yield and tuber quality. All five genotypes yielded higher when grown in conventional versus organic systems, which are likely attributed to greater nitrate availability. However, previous studies suggest breeding varieties specifically for organic systems can lessen the yield gap. The study also revealed that organically grown tubers had higher specific gravity than conventionally grown tubers. This may be important to consider especially for processing potatoes.

The second study revealed that location and clone have larger impact on tuber mineral nutrients than does management. When breeding for increased micronutrients, it is therefore important to evaluate tuber nutrients at various locations across managements.

The last study revealed that soil ecosystems differ between organic and conventionally managed farms. Organic soils have greater soil microbial biomass as well as organic carbon and organic nitrogen to support microbial life. Organic systems rely on microbially-mediated nutrient mineralization and so are dependent on an ecosystem to support this. The nuances of plant-microbe interactions are not yet fully understood, but may very likely be an important way to improve plant health and crop production regardless of management system. A recent study showed potato microbiome constituents were positively correlated with tuber mineral Zn, N, P, and Mg (Barnett et al. 2014).

5.2 Future Research

Future work needs to be done towards breeding specifically for organic systems. As organic acreage grows, and consumer demand for organic products continues to grow, better varieties are needed to address the unique needs of organic farmers – varieties that are better adapted to organic soil ecosystems.

More research should be done on improvement of potato mineral nutrient concentration. As a crop, potato shows plenty of promise for biofortification given the existing genetic diversity and heritability of mineral nutrient concentrations. Because of the strong effect of location on tuber mineral nutrients, more studies exploring the role the environment plays in tuber mineral nutrient concentration is also needed to compliment any genetic gains.

An economic analysis of conventional versus organic systems should be done to determine the viability of organic agriculture methods. Organic agriculture has been shown to produce lower crop yields, but money saved on other inputs, reduction of environmental impacts, and increasing soil carbon content, which may be rewarded through carbon credits in the future, should be taken into account.

LITERATURE CITED

Abreu, P., A. Relva, S. Matthew, Z. Gomes, and Z. Morais. 2007. High-performance liquid chromatographic determination of glycoalkaloids in potatoes from conventional, integrated, and organic crop systems. *Food Control* 18:40-44.

Badri, D.V., N. Quintana, E.G. El Kassis, H.K. Kim, Y.H. Choi, A. Sugiyama, R. Verpoorte, E. Martinoia, D.K. Manter, and J.M. Vivanco. 2009. An ABC transporter mutation alters root exudation of phytochemicals that provoke an overhaul of natural soil microbiota. *Plant Physiology* 151: 2006–2017.

Baermann, G. 1917. Eine einfache methode zur Auffindung von Ankylostomum (Nematoden) Larven inErdproben. *Mededelingen uit het Geneeskundig Laboratorium te Weltevreden* 41-47.

Bakker, M. G., D. K. Manter, A. M. Sheflin, T. L. Weir, and J. M. Vivanco. 2012. Harnessing the rhizosphere microbiome through plant breeding and agricultural management. *Plant and Soil* 360:1-13.

Barnett, B., D.G. Holm, J. Koym, R. Wilson, and D. Manter, D. 2014. Site and Clone Effects on the Potato Root-Associated Core Microbiome and its Relationship to Tuber Yield and Nutrients. *American Journal of Potato Research* 1-9.

Babiuk, L.A., and E.A. Paul. 1970. The use of fluorescein isothiocyanate in the determination of the bacterial biomass of a grassland soil. *Canadian Journal of Microbiology* 16: 57-62.

Bohl, W. H., and S. B. Johnson. 2010. Commercial Potato Production in North America: The Potato Association of America Handbook. Washington D.C: The Potato Association of America.

Bongers, T. 1988. De nematoden van Nederland. Pirola Schoorl. Natuurhist. Biblioth. KNNV nr. 46. Wageningen Agricultural University, The Netherlands.

Borron, S. 2006. Building Resilience for an Unpredictable Future: How Organic Agriculture can Help Farmers Adapt to Climate Change. Food and Agriculture Organization of the United States. Rome, August 2006.

Brown, C. R., K. G. Haynes, M. Moore, M. J. Pavek, D. C. Hane, S. L. Love, R. G. Novy, and J. C. Miller. 2010. Stability and broad-sense heritability of mineral content in potato: Iron. *American Journal of Potato Research* 87:390-396.

Brown, C. R., K. G. Haynes, M. Moore, M. J. Pavek, D. C. Hane, S. L. Love, and J. C. Miller. 2011. Stability and broad-sense heritability of mineral content in potato: Zinc. *American Journal of Potato Research* 88:238-244.

Coleman-Derr, D., S.G. Tringe. 2014. Building the crops of tomorrow: advantages of symbiont-based approaches to improving abiotic stress tolerance. *Frontiers in Microbiology* 5:283.

Darbyshire, J.F., R.E. Wheatley, M.P. Greaves, and R.H.E. Inkson. 1974. A rapid micromethod for estimating bacterial and protozoan populations in soil. Ecology 61: 764-771.

Drewnwski A. 2013. New metrics of affordable nutrition: which vegetables provide most nutrients for least cost? *Journal of the Academy of Nutrition and Dietetics* 113:1182-7.

Ekelund, F. 1998. Enumeration and abundance of mycophagous protozoa in soil, with special emphasis on heterotrophic flagellates. *Soil Biology and Biochemistry* 30:1343-1347.

Ensminger, A., M. E. Ensminger, and J. E. Konlande. 1994. Foods & Nutrition Encyclopedia. CTC Press.

Ezzati, M., A. D. Lopez, A. Rodgers, H. S. Vander, C. J. Murray. 2002. Selected major risk factors and global and regional burden of disease. *Lancet* 360(9343):1347–60.

Fließbach, A., H. Oberholzer, L. Gunst, and P. Mäder. 2007. Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. *Agriculture, Ecosystems & Environment* 118(1-4):273-284.

Franzluebbers, A.J., R. L. Haney, F. M. Hons, and D. A. Zuberer. 1996. Determination of soil microbial biomass and nitrogen mineralization following rewetting of dried soil. *Soil Science Society of America Journal* 60:1133- 1139.

Franzluebbers, A.J., R. L. Haney, C. W. Honeycutt, H. H. Schomberg, and F. M. Hons. 2000. Flush of CO2 following rewetting of dried soil relates to active organic pools. *Soil Science Society of America Journal* 64:613- 623.

Gibson, R. S. 2006. Zinc: the missing link in combating micronutrient malnutrition in developing countries. *Proceedings of the Nutrition Society* 65: 51–60.

Goodey, T. 1963. Soil and freshwater nematodes. John Wiley and Sons, New York, NY. Second edition revised by J.B. Goodey.

Griffiths, A. M., Cook, D. M., Eggett, D. L., & Christensen, M. J. 2011. A retail market study of organic and conventional potatoes (Solanum tuberosum): mineral content and nutritional implications. *International Journal of Food Sciences and Nutrition*, *63*(4), 393–401. http://doi.org/10.3109/09637486.2011.629602

Haynes, K. G., G. C. Yencho, M. E. Clough, M. R. Henninger, and S. B. Sterrett. 2013. Genetic variation for potato tuber micronutrient content and implications for biofortification of potatoes to reduce micronutrient malnutrition. *American Journal of Potato Research* 89: 192-198.

Hajslova, J., V. Schulzova, P. Slanina, K. Janne, K. E. Hellenas, and C. H. Andersson. 2005. Quality of organically and conventionally grown potatoes: Four-year study of micronutrients, metals, secondary metabolites, enzymic browning and organoleptic properties. *Food Additives and Contaminants* 22(6):514-534.

Hendrix, P.F., R.W. Parmallee, D.A. Crossley, D.C. Coleman, E.P. Odum, P.M. Groffman. 1986. Detritus Food Webs in Conventional and No-tillage Agroecosystems. *BioScience* 36(6):374-380.

Hiller, L.K., and R. E. Thornton. 2008. "Managing Physiological Disorders." In *Potato Health Management: Plant Health Management Series*, edited by D. A. Johnson, 235–245. St. Paul, MN: The American Phytopathological Society.

Hoffsteen, L., L. Downey. 2003. Crop Profile for Potatoes in Colorado. S. McDonald, Ed.

Horneburg, B. and J.R. Myers. 2012. Tomato: Breeding for Improved Disease Resistance in Fresh Market and Home Garden Varieties. In: Lammerts van Bueren, E.T., and Myers, J.R. (eds.) Organic Crop Breeding. Wiley-Blackwell. 239-250.

Ingham, E.R. 1993. In Bottomley, P. (ed) Methods in Soil Agronomy. Agronomy Society of America, Madison, WI.

Ingham, E.R. 1994. Standard Operating Procedure for Total Bacteria. USEPA Global Climate Change Program. Corvallis Environmental Research Lab.

Ingham, E.R. 1995a. Standard Operating Procedure for Microbial Population Dynamics. USEPA Global Climate Change Program. Corvallis Environmental Research Lab.

Ingham, E.R. 1995b. Standard Operating Procedure for Nematode Population and Community Structure. USEPA Global Climate Change Program. Corvallis Environmental Research Lab.

Ingham, E.R. 1995c. Standard Operating Procedure for Protozoan Population and Community Structure. USEPA Global Climate Change Program. Corvallis Environmental Research Lab.

Ingham, E.R. and K.A. Horton. 1987. Bacterial, fungal and protozoan responses to chloroform fumigation in stored prairie soil. *Soil Biology and Biochemistry* 19:545-550.

International Potato Center. 2013. *Potato Facts and Figures*. Retrieved December 2014, from http://cipotato.org/potato/facts/.

Kuthubutheen, A.J., G.J.F. Pugh. 1979. The effects of fungicides on soil fungal populations. *Soil Biology and Biochemistry* 11(3):297-303.

Lee, J.J., S.H. Hutner, and E.D. Bovee. 1985. An Illustrated Guide to the Protozoa. Society of Protozoologists, Lawrence, Kansas. 629pp.

Lodge, D.J. and E.R. Ingham. 1991. A comparison of agar film techniques for estimating fungal biovolumes in litter and soil. Methods in Soil Ecology. Elsevier, The Netherlands.

Looker, A.C., P.R. Dallman, M.D. Carroll, E.W. Gunter, and C.L. Johnson. 1997. Prevalence of iron deficiency in the United States. *Journal of American Medical Association* 12:973-6.

Mäder, P., A. Fliessbach, D. Dubois, L. Gunst, P. Fried, and U. Niggli. 2002. Soil fertility and biodiversity in organic farming. *Science* 296(5573):1694-1697.

Mai, W.F. and H.H. Lyon. 1975. Pictorial key to genera of plant-parasitic nematodes. Fourth edition, revised. Comstock Publishing Associates, Ithaca and London. 219 pp.

Manter, D.K., J.A. Delgado, D.G. Holm, and R.A. Stong. 2010. Pyrosequencing reveals a highly diverse and cultivar-specific bacterial endophyte community in potato roots. Microbial Ecology 60: 157–166.

Marriott, E. E., and M. M. Wander. 2006. Total and labile soil organic matter in organic and conventional farming systems. *Soil Science Society of America Journal* 70(3):950-959.

McDaniel, M., L. Tiemann, and A. Grandy. 2014. Does agricultural crop diversity enhance soil microbial biomass and organic matter dynamics? A meta-analysis. *Ecological Applications* 560-570.

Mohammadi, K., S. Khalesro, Y. Sohrabi, G. Heidari. 2011. A Review: Beneficial Effects of the Mycorrhizal Fungi for Plant Growth. *Journal of Applied Environmental and Biological Scienes* 1(90):310-319.

Moore, A., N. Olsen, M. Satterwhite, M. J. Frazier. 2013. Organic Potato Production in Idaho: Nutrient Management and variety selection: Bulletin 885. Moscow, Idaho. University of Idaho Extension.

Murphy K., K.G. Campbell, S. Lyon, S.S. Jones. 2007. Evidence for varietal adaptation to organic farming systems. *Field Crops Research* 102:172-177.

Myers, J.R., L. McKenzie, and R.E. Voorrips. 2012. Brassicas: Breeding Cole Crops for Organic Agriculture. In: Lammerts van Bueren, E.T., and Myers, J.R. (eds.) Organic Crop Breeding. Wiley-Blackwell. 251-262.

National Potato Council. 2014. *Potato Nutritional Handbook*. Washington, DC: National Council.

National Potato Council. 2015. *Potato Statistical Yearbook*. Washington, DC: National Council.

Ponisio, L.C., L.K. M'Gonigle, K.C. Mace, J. Palomino, P. de Valpine, and C. Kremen. 2015. Diversification practices reduce organic to conventional yield gap. *Proceedings of the Royal Society B* 282: 20141396.

Rutherford, P.M., N.G. Juma. 1991. Influence of texture on habitable pore space and bacterial-protozoan populations in soil. *Biology and Fertility of Soils* 12:221-227.

Seaman, A. editor (2015). Production Guide for Organic Potatoes. Publisher: New York State Integrated Pest Management Program, Cornell University (New York State Agricultural Experiment Station, Geneva, NY). 102 pages.

Self, J.R. 2010. Soil Test Explanation. Colorado State University Extension. Fact Sheet No. 0.502.

Shelton, A.C. and W.F. Tracy. 2015. Recurrent Selection and Participatory Plant Breeding for Improvement of Two Organic Open-Pollinated Sweet Corn (Zea mays L.) Populations. *Sustainability* 7: 5140-5152.

Singh, B.N., 1955. Culturing soil protozoa and estimating their numbers in soil. In D.K. Kevan, Ed. Soil Zoology. Butterworths, London, UK, pp. 104-111.

Smith P., M. Bustamante, H. Ahammad, H. Clark, H. Dong, E.A. Elsiddig, H. Haberl, R. Harper, J. House, M. Jafari, O. Masera, C. Mbow, N.H. Ravindranath, C.W. Rice, C. Robledo Abad, A. Romanovskaya, F. Sperling, and F. Tubiello, 2014: Agriculture, Forestry and Other Land Use (AFOLU). In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Stark, J., S. Love (Eds.). 2003. Potato Production Systems: A Comprehensive Guide for Potato Production. Moscow, Idaho: University of Idaho Agricultural Communications.

Stevik, K., J. F. Hanssen, and P. D. Jenssen. 1998. A comparison between DAPI direct count (DDC) and most probable number (MPN) to quantify protozoa in infiltration systems. *Journal of Microbiological Methods* 33:13-21.

Stoltzfus, R.J. 2003. Iron deficiency: Global prevalence and consequences. *Food and Nutrition Bulletin* (24)4.

United States Potato Board. 2015. Potato Nutrition Handbook. 1-54.

USDA Census of Agriculture. 2008. *2008 Organic Survey: Table 4. Organic vegetables, potatoes, and melons harvested from certified and exempt organic farms.* [dataset]. Retrieved from http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Organics/index.php.

USDA ERS. 2012. *Organic Agriculture: Organic Market Overview*. Retrieved from http://www.ers.usda.gov/topics/natural-resources-environment/organic-agriculture/organic-market-overview.aspx.

USDA ERS. 2013a. *Table 3. Certified organic and total U.S. acreage, selected crops and livestock, 1995-2011*. [Organic Production Data Set – National Tables]. Retrieved from http://www.ers.usda.gov/data-products/organic-production.aspx.

USDA ERS. 2013b. *Table 13. Certified organic acreage of other crops. Acres of cotton, peanuts, potatoes, green manure cover crops, trees for maple syrup, fallow, and unclassified by State, 1997 and 2000-11*. [Organic Production Data Set – State-Level Tables]. Retrieved from http://www.ers.usda.gov/data-products/organic-production.aspx.

USDA National Agricultural Statistics Service. 2015. *Crop Production 2014 Summary*. Retrieved from http://www.usda.gov/nass/PUBS/TODAYRPT/cropan15.pdf.

USDA National Organic Program. 2015. 7 Agriculture C.F.R. §205.

Van Veen, J.A. and E.A. Paul. 1979. Conversion of biovolume measurements of soil organisms, grown under various moisture tensions, to biomass and their nutrient content. *Applied and Environmental Microbiology* 37: 686-692.

Zotarelli, L., C. Hutchinson, S. Byrd, D. Gerela, and D.L. Rowland. 2015. Potato Physiological Disorders – Brown Center and Hollow Heart. *University of Florida IFAS Extension.* Retrieved from https://edis.ifas.ufl.edu/hs197.

APPENDIX A: CLONE INFORMATION

Table A.1: Clone list for the 2013 and 2014 tuber mineral nutrient study.

2013	2014
CO00291-5R	CO00291-5R
CO02024-9W	CO97087-2RU
CO02033-1W	All Blue
CO4159-1R	Fortress Russet
CO95051-7W	Sangre-S10
CO97087-2RU	
CO99045-1W/Y	
VC0967-2R/Y	
VC1002-3W/Y	
All Blue	
Canela Russet	
Centennial Russet	
Colorado Rose	
Fortress Russet	
Mesa Russet	
Mountain Rose	
Norland (DR)	
Purple Majesty	
Ranger Russet	
Rio Grande Russet	
Russet Nugget	
Sangre-S10	
Yukon Gold	

APPENDIX B: 2014 TEXAS DATA

Table B.1: Tuber yield at Springlake, TX in 2014.

	Yield (cwt/acre)				
Clone	<4oz	≥4oz	≥6oz	≥10oz	Total
All Blue	75.78	46.43	0.00	0.00	122.21
CO00291-5R	136.28	73.81	5.45	0.00	210.09
CO97087-2RU	93.78	114.35	34.18	7.71	208.12
Fortress Russet	91.05	137.18	47.19	4.24	228.24
Sangre-S10	71.69	143.54	54.30	16.79	215.23

APPENDIX C: 2013 MINERAL NUTRIENT DATA

Table C.1: Tuber mineral nutrient concentrations from 2013 study, averaged across four locations.

Clone	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cu (mg/kg)	B (mg/kg)	Na (%)
All Blue	1.07	0.27	1.99	0.07	0.12	0.12	16.8	72.7	7.7	5.9	6.4	0.016
Canela Russet	1.03	0.24	1.78	0.08	0.13	0.12	17.6	69.8	7.2	5.5	6.5	0.020
Centennial Russet	1.08	0.23	2.08	0.09	0.13	0.11	15.3	78.0	7.6	4.7	6.5	0.020
CO00291-5R	0.99	0.29	2.46	0.07	0.11	0.15	20.8	57.3	7.3	5.3	7.8	0.015
CO02024-9W	1.16	0.25	2.10	0.08	0.11	0.12	18.7	54.2	8.1	6.0	7.1	0.015
CO02033-1W	1.02	0.23	1.93	0.08	0.11	0.12	16.2	56.5	6.9	5.1	6.1	0.014
CO04159-1R	0.95	0.28	2.17	0.08	0.13	0.15	20.3	54.1	9.2	6.3	7.3	0.016
CO95051-7W	1.09	0.23	2.10	0.07	0.12	0.13	15.1	65.5	9.5	5.0	9.4	0.016
CO97087-2RU	1.13	0.24	1.91	0.09	0.13	0.13	16.4	85.4	8.7	7.6	7.8	0.017
CO99045-1W/Y	0.92	0.26	2.03	0.08	0.12	0.11	12.1	62.7	6.8	6.3	6.7	0.016
Colorado Rose	0.90	0.25	1.78	0.08	0.11	0.11	14.7	55.0	7.5	5.0	5.8	0.015
Fortress Russet	0.97	0.23	2.14	0.10	0.11	0.11	13.8	68.8	7.1	5.3	9.3	0.021
Mesa Russet	1.06	0.24	2.04	0.10	0.12	0.11	15.3	74.8	8.0	4.3	6.6	0.019
Mountain Rose	0.88	0.23	1.55	0.06	0.11	0.11	15.4	47.8	7.0	4.6	5.4	0.013
Norland (DR)	1.00	0.26	1.89	0.05	0.12	0.14	16.8	69.8	8.3	5.1	5.8	0.014
Purple Majesty	0.86	0.22	1.77	0.03	0.10	0.10	13.7	43.6	5.6	3.7	5.8	0.009
Ranger Russet	1.03	0.25	1.91	0.06	0.11	0.10	14.1	62.7	7.3	4.3	6.5	0.017
Rio Grande Russet	1.17	0.24	2.04	0.08	0.14	0.12	14.8	73.9	7.8	5.4	6.3	0.018
Russet Nugget	1.05	0.27	1.88	0.08	0.11	0.11	18.6	80.4	6.0	5.4	6.5	0.018
Sangre-S10	1.01	0.25	2.01	0.07	0.11	0.12	22.3	54.8	6.0	5.1	6.2	0.025
VC0967-2R/Y	0.81	0.23	1.79	0.10	0.12	0.11	17.4	60.0	8.1	5.4	5.7	0.019
VC1002-3W/Y	0.94	0.27	2.18	0.09	0.12	0.12	15.2	58.2	7.6	5.8	7.7	0.015
Yukon Gold	1.11	0.22	2.06	0.04	0.11	0.13	13.3	59.1	6.9	3.6	6.8	0.016

Table C.2: Tuber mineral nutrient concentrations from 2014 study at Springlake, TX (n=4).

Clone	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cu (mg/kg)	B (mg/kg)	Na (%)
All Blue	1.18	0.27	2.13	0.09	0.13	0.11	18.8	97.3	6.5	10.0	15.0	0.020
CO97087-2RU	1.25	0.24	1.99	0.10	0.15	0.15	27.3	117.0	7.3	5.5	17.0	0.023
COOO291-5R	1.45	0.37	2.97	0.13	0.15	0.17	23.8	109.5	7.8	7.8	19.8	0.030
Fortress Russet	1.09	0.24	2.35	0.09	0.13	0.13	16.3	81.3	5.8	5.0	16.0	0.032
Sangre-S10	1.46	0.34	2.70	0.13	0.16	0.16	21.5	121.8	7.5	8.5	17.8	0.049

Table C.3: Tuber mineral nutrient concentrations from 2014 study at Delta, CO (n=4).

Clone	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cu (mg/kg)	B (mg/kg)	Na (%)
All Blue	0.95	0.31	2.17	0.06	0.12	0.11	12.0	12.0	7.0	6.0	14.0	0.010
CO97087-2RU	1.36	0.31	2.25	0.09	0.16	0.12	22.0	167.0	10.0	8.0	15.0	0.011
COOO291-5R	1.19	0.36	2.73	0.16	0.17	0.18	18.0	135.0	10.0	10.0	9.0	0.017
Fortress Russet	1.14	0.27	2.27	0.12	0.15	0.12	15.0	100.0	7.0	8.0	7.0	0.016
Sangre-S10	1.20	0.33	2.47	0.12	0.16	0.15	19.0	93.0	8.0	10.0	14.0	0.011

Table C.4: Tuber mineral nutrient concentrations from 2014 study averaged across all four San Luis Valley locations (n=4).

Clone	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Zn (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cu (mg/kg)	B (mg/kg)	Na (%)
All Blue	1.06	0.20	1.71	0.09	0.11	0.11	14.6	94.7	7.1	5.7	8.5	0.022
CO97087-2RU	1.27	0.18	1.72	0.12	0.13	0.13	16.6	126.2	9.8	7.2	8.9	0.022
COOO291-5R	1.15	0.20	2.30	0.09	0.11	0.15	16.2	122.8	8.8	7.1	12.1	0.024
Fortress Russet	0.98	0.16	1.82	0.10	0.11	0.11	13.0	106.0	7.5	5.6	11.5	0.028
Sangre-S10	1.36	0.21	1.98	0.10	0.12	0.14	18.3	107.5	8.4	7.9	8.6	0.028

APPENDIX D: ANOVA TABLES

Table D.1: ANOVA table for comparison of iron concentration (mg/kg dry weight) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	12.5228	4.1743	81.52	<.0001
Clone	4	0.8404	0.2101	4.10	0.0053
Location*Clone	12	0.6955	0.0580	1.13	0.3526
Residual	60	3.0722	0.0512		

Table D.2: ANOVA table for comparison of zinc concentration (mg/kg dry weight) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	1.5574	0.5191	3.76	0.0152
Clone	4	1.4050	0.3512	2.55	0.0485
Location*Clone	12	1.5357	0.1280	0.93	0.5259
Residual	60	8.2768	0.1379		

Table D.3: ANOVA table for comparison of potassium concentration (% dry weight) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	0.1522	0.0507	13.77	<.0001
Clone	4	0.9738	0.2435	66.07	<.0001
Location*Clone	12	0.1067	0.0089	2.41	0.0127
Residual	60	0.2211	0.0037		

Table D.4: ANOVA table for comparison of total yield cwt/acre) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	5.6172	1.8724	128.79	<.0001
Clone	4	2.5599	0.6400	44.02	<.0001
Location*Clone	12	0.5168	0.0431	2.96	0.0027
Residual	60	0.8723	0.0145		

Table D.5: ANOVA table for comparison of <4oz tuber yield (cwt/acre) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	2.5457	0.8486	9.58	<.0001
Clone	4	9.5398	2.3850	26.93	<.0001
Location*Clone	12	2.3293	0.1941	2.19	0.0235
Residual	60	5.3142	0.0886		

Table D.6: ANOVA table for comparison of ≥4oz tuber yield (cwt/acre) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	17.8406	5.9469	110.59	<.0001
Clone	4	11.7560	2.9390	54.65	<.0001
Location*Clone	12	1.7689	0.1474	2.74	0.0050
Residual	60	3.2265	0.0538		

Table D.7: ANOVA table for comparison of ≥6oz tuber yield (cwt/acre) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	42.2443	14.0814	43.89	<.0001
Clone	4	43.9486	10.9871	34.25	<.0001
Location*Clone	12	6.5355	0.5446	1.70	0.0900
Residual	60	19.2498	0.3208		

Table D.8: ANOVA table for comparison of ≥10oz tuber yield (cwt/acre) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	31.1377	10.3792	75.98	<.0001
Clone	4	37.1291	9.2823	67.95	<.0001
Location*Clone	12	12.7319	1.0610	7.77	<.0001
Residual	60	8.1960	0.1366		

Table D.9: ANOVA table for comparison of specific gravity of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	0.0005	0.0002	37.14	<.0001
Clone	4	0.0025	0.0006	143.42	<.0001
Location*Clone	12	0.0002	0.0000	3.92	0.0002
Residual	60	0.0003	0.0000		

Table D.10: ANOVA table for comparison of soil respiration (ppm CO2/24 hrs) of three potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	0.8182	0.2727	12.52	<.0001
Clone	2	0.1325	0.0662	3.04	0.0665
Location*Clone	6	0.0189	0.0032	0.14	0.9884
Residual	24	0.5226	0.0218		

Table D.11: ANOVA table for comparison of organic carbon (ppm) of three potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	32523.0000	10841.0000	67.36	<.0001
Clone	2	299.6058	149.8029	0.93	0.4080
Location*Clone	6	1300.9384	216.8231	1.35	0.2756
Residual	24	3862.6155	160.9423		

Table D.12: ANOVA table for comparison of organic nitrogen (ppm) of three potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	564.0612	188.0204	10.11	0.0002
Clone	2	17.2205	8.6102	0.46	0.6350
Location*Clone	6	175.4521	29.2420	1.57	0.1985
Residual	24	446.4763	18.6032		

Table D.13: ANOVA table for comparison of soil bacteria (µg/g soil) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	293324.0000	97775.0000	4.15	0.0119
Clone	4	222751.0000	55688.0000	2.36	0.0695
Location*Clone	12	748773.0000	62398.0000	2.65	0.0105
Residual	40	943356.0000	23584.0000		

Table D.14: ANOVA table for comparison of soil fungi (µg/g soil) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	6.2525	2.0842	26.20	<.0001
Clone	4	0.8651	0.2163	2.72	0.0430
Location*Clone	12	2.2890	0.1908	2.40	0.0191
Residual	40	3.1817	0.0795		

Table D.15: ANOVA table for comparison of soil flagellates (#/g soil) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	4.1180	1.3727	1.57	0.2120
Clone	4	7.2597	1.8149	2.07	0.1023
Location*Clone	12	10.3390	0.8616	0.98	0.4796
Residual	40	35.0045	0.8751		

Table D.16: ANOVA table for comparison of soil amoebae (#/g soil) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	25.4486	8.4829	11.43	<.0001
Clone	4	4.0922	1.0231	1.38	0.2585
Location*Clone	12	3.4008	0.2834	0.38	0.9624
Residual	40	29.6795	0.7420		

Table D.17: ANOVA table for comparison of soil ciliates (#/g soil) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	117.2914	39.0971	31.57	<.0001
Clone	4	23.1003	5.7751	4.66	0.0035
Location*Clone	12	22.8531	1.9044	1.54	0.1511
Residual	40	49.5425	1.2386		

Table D.18: ANOVA table for comparison of soil nematodes (#/g soil) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	22.1025	7.3675	7.11	0.0006
Clone	4	1.2795	0.3199	0.31	0.8704
Location*Clone	12	5.8830	0.4903	0.47	0.9186
Residual	40	41.4397	1.0360		

Table D.19: ANOVA table for comparison of beneficial nematodes (%) of five potato genotypes grown in 2014.

Source	DF	Type III SS	MS	F-value	Pr<F
Location	3	0.9225	0.3075	21.99	<.0001
Clone	4	0.0372	0.0093	0.66	0.6204
Location*Clone	12	0.1613	0.0134	0.96	0.4997
Residual	40	0.5592	0.0140		

APPENDIX E: LEAST SQUARES MEANS ESTIMATES TABLES

Table E.1: Least squares means table for potato tuber mineral nutrients grown in conventional versus organic locations in 2014 (n=40).

Mineral	Estimate	Standard Error	DF	t value	Pr>|t|
Iron	0.1235	0.0506	60	2.44	0.0177
Zinc	0.1869	0.0831	60	2.25	0.0281
Potassium	0.0075	0.0136	60	0.56	0.5803

Table E.2: Least squares means table for yield of potatoes grown in conventional versus organic locations in 2014 (n=40).

Category	Estimate	Standard Error	DF	t value	Pr>|t|
Total Yield	0.4820	0.0270	60	17.88	<.0001
<4oz	0.0130	0.0666	60	0.19	0.8463
≥4oz	0.7619	0.0519	60	14.69	<.0001
≥6oz	1.1287	0.1267	60	8.91	<.0001
≥10oz	0.9308	0.0826	60	11.26	<.0001

Table E.3: Least squares means table for specific gravity of potato tubers grown in conventional versus organic locations in 2014 (n=40).

Quality	Estimate	Standard Error	DF	t value	Pr>|t|
Specific Gravity	-0.0045	0.0005	60	-9.52	<.0001

Table E.4: Least squares means table for soil health of soils from potato fields in conventional versus organic locations in 2014 (n=18).

Soil Health	Estimate	Standard Error	DF	t value	Pr>|t|
Organic Carbon	-42.7561	4.2288	24	-10.11	<.0001
Organic Nitrogen	-7.3622	1.4377	24	-5.12	<.0001
Respiration	-0.2540	0.0492	24	-5.16	<.0001

Table E.5: Least squares means table for soil food web of soils from potato fields in conventional versus organic locations in 2014 (n=30).

Category	Estimate	Standard Error	DF	t value	Pr>|t|
Bacteria	38.7233	-39.6517	40	0.98	0.3346
Fungi	-0.6050	0.0728	40	-8.31	<.0001
Flagellates	-0.4172	0.2415	40	-1.73	0.0918
Amoebae	-1.2204	0.2224	40	-5.49	<.0001
Ciliates	-2.5124	0.2874	40	-8.74	<.0001
Nematodes	-0.2491	0.2628	40	-0.95	0.3488
Nematode ratio	0.0313	0.0305	40	1.02	0.312

APPENDIX F: SUMMARY STATISTICS

Table F.1: Summary statistics for total yield in cwt/acre grown in 2014 (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	470	32	430	500
	CONV-2	423	36	378	463
	ORG-1	255	28	227	287
	ORG-2	259	22	230	276
CO00291-5R	CONV-1	354	13	339	370
	CONV-2	263	23	231	283
	ORG-1	201	9	189	209
	ORG-2	273	24	254	307
CO97087-2RU	CONV-1	392	49	318	419
	CONV-2	258	9	249	269
	ORG-1	165	34	117	197
	ORG-2	198	27	172	235
Fortress Russet	CONV-1	563	34	534	612
	CONV-2	445	46	412	512
	ORG-1	257	57	182	317
	ORG-2	354	38	317	389
Sangre-S10	CONV-1	472	71	404	557
	CONV-2	425	41	381	481
	ORG-1	246	30	205	277
	ORG-2	299	43	237	332

Table F.2: Summary statistics for yield of tubers <4oz in cwt/acre grown in 2014 (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	181	24	149	201
	CONV-2	271	37	216	296
	ORG-1	172	19	148	190
	ORG-2	159	63	68	211
CO00291-5R	CONV-1	102	30	76	132
	CONV-2	143	18	123	163
	ORG-1	148	16	133	164
	ORG-2	160	10	148	169
CO97087-2RU	CONV-1	71	33	44	119
	CONV-2	151	25	125	173
	ORG-1	89	20	60	103
	ORG-2	67	42	42	129
Fortress Russet	CONV-1	62	17	45	81
	CONV-2	87	14	73	105
	ORG-1	86	39	43	137
	ORG-2	92	15	73	108
Sangre-S10	CONV-1	61	11	49	72
	CONV-2	98	32	50	121
	ORG-1	118	28	97	157
	ORG-2	70	27	38	104

Table F.3: Summary statistics for yield of tubers ≥4oz in cwt/acre grown in 2014 (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	288	8	281	299
	CONV-2	151	55	98	220
	ORG-1	83	18	59	102
	ORG-2	100	72	58	208
CO00291-5R	CONV-1	252	21	227	274
	CONV-2	120	23	97	151
	ORG-1	53	13	40	70
	ORG-2	113	21	94	138
CO97087-2RU	CONV-1	321	41	274	356
	CONV-2	107	25	76	128
	ORG-1	75	16	57	96
	ORG-2	130	18	106	146
Fortress Russet	CONV-1	501	49	453	567
	CONV-2	358	55	316	435
	ORG-1	171	24	139	197
	ORG-2	262	27	229	291
Sangre-S10	CONV-1	410	83	332	507
	CONV-2	327	46	270	369
	ORG-1	127	38	95	181
	ORG-2	230	49	167	286

Table F.4: Summary statistics for yield of tubers ≥6oz in cwt/acre grown in 2014 (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	152	22	130	177
	CONV-2	49	42	21	110
	ORG-1	28	18	12	46
	ORG-2	57	88	7	188
CO00291-5R	CONV-1	112	30	88	152
	CONV-2	39	22	22	66
	ORG-1	8	7	0	15
	ORG-2	29	13	14	45
CO97087-2RU	CONV-1	212	34	178	256
	CONV-2	37	14	16	46
	ORG-1	24	4	19	29
	ORG-2	63	25	28	86
Fortress Russet	CONV-1	401	47	348	460
	CONV-2	268	51	208	327
	ORG-1	84	19	66	109
	ORG-2	160	28	130	188
Sangre-S10	CONV-1	337	96	247	454
	CONV-2	213	66	136	269
	ORG-1	65	31	38	109
	ORG-2	146	47	87	198

Table F.5: Summary statistics for yield of tubers ≥10oz in cwt/acre grown in 2014 (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	27	13	14	44
	CONV-2	2	5	0	9
	ORG-1	6	8	0	16
	ORG-2	0	0	0	0
CO00291-5R	CONV-1	9	3	7	13
	CONV-2	2	4	0	7
	ORG-1	0	0	0	0
	ORG-2	2	4	0	8
CO97087-2RU	CONV-1	83	35	43	127
	CONV-2	0	0	0	0
	ORG-1	0	0	0	0
	ORG-2	13	4	7	17
Fortress Russet	CONV-1	222	58	171	303
	CONV-2	93	27	68	126
	ORG-1	13	17	0	35
	ORG-2	31	6	24	37
Sangre-S10	CONV-1	165	57	119	249
	CONV-2	89	48	31	145
	ORG-1	11	21	0	42
	ORG-2	47	17	31	71

Table F.6: Summary statistics for specific gravity of tubers grown in 2014 (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	1.078	0.002	1.075	1.080
	CONV-2	1.079	0.001	1.078	1.080
	ORG-1	1.084	0.005	1.078	1.090
	ORG-2	1.082	0.003	1.080	1.086
CO00291-5R	CONV-1	1.075	0.002	1.073	1.078
	CONV-2	1.078	0.002	1.076	1.080
	ORG-1	1.078	0.002	1.076	1.081
	ORG-2	1.080	0.001	1.078	1.082
CO97087-2RU	CONV-1	1.087	0.001	1.085	1.088
	CONV-2	1.084	0.003	1.080	1.087
	ORG-1	1.090	0.001	1.089	1.092
	ORG-2	1.097	0.001	1.095	1.098
Fortress Russet	CONV-1	1.085	0.001	1.084	1.086
	CONV-2	1.086	0.002	1.083	1.088
	ORG-1	1.088	0.004	1.082	1.091
	ORG-2	1.095	0.001	1.094	1.096
Sangre-S10	CONV-1	1.070	0.001	1.069	1.071
	CONV-2	1.074	0.001	1.072	1.075
	ORG-1	1.075	0.002	1.072	1.078
	ORG-2	1.076	0.002	1.074	1.077

Table F.7: Summary statistics for percent of total yield of tubers grown in 2014 with hollow heart (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	0.7	0.8	0.0	1.5
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	0.0	0.0	0.0	0.0
CO00291-5R	CONV-1	0.0	0.0	0.0	0.0
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	0.0	0.0	0.0	0.0
CO97087-2RU	CONV-1	0.7	1.3	0.0	2.7
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	3.2	3.9	0.0	7.7
Fortress Russet	CONV-1	1.2	2.3	0.0	4.7
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.7	1.4	0.0	2.9
	ORG-2	6.8	3.9	1.9	10.7
Sangre-S10	CONV-1	1.8	3.6	0.0	7.1
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	2.9	2.3	0.0	5.6

Table F.8: Summary statistics for percent of total yield of tubers grown in 2014 with brown center (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	0.0	0.0	0.0	0.0
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	0.0	0.0	0.0	0.0
CO00291-5R	CONV-1	0.0	0.0	0.0	0.0
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	0.0	0.0	0.0	0.0
CO97087-2RU	CONV-1	0.0	0.0	0.0	0.0
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	0.0	0.0	0.0	0.0
Fortress Russet	CONV-1	0.6	1.1	0.0	2.2
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	0.0	0.0	0.0	0.0
Sangre-S10	CONV-1	0.0	0.0	0.0	0.0
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	0.0	0.0	0.0	0.0

Table F.9: Summary statistics for percent of total yield of tubers grown in 2014 with growth cracks (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	0.0	0.0	0.0	0.0
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.7	1.4	0.0	2.9
	ORG-2	0.9	1.3	0.0	2.7
CO00291-5R	CONV-1	0.5	0.6	0.0	1.2
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.1	0.3	0.0	0.5
	ORG-2	0.1	0.2	0.0	0.4
CO97087-2RU	CONV-1	0.2	0.5	0.0	1.0
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	0.6	1.1	0.0	2.2
Fortress Russet	CONV-1	0.4	0.8	0.0	1.5
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	3.6	2.6	0.0	5.6
Sangre-S10	CONV-1	2.4	1.2	1.5	4.1
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.3	0.5	0.0	1.0
	ORG-2	3.5	2.2	1.2	6.1

Table F.10: Summary statistics for percent of total yield of tubers grown in 2014 with knobs (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	0.4	0.8	0.0	1.6
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.7	1.4	0.0	2.9
	ORG-2	0.0	0.0	0.0	0.0
CO00291-5R	CONV-1	0.0	0.0	0.0	0.0
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	0.0	0.0	0.0	0.0
CO97087-2RU	CONV-1	0.0	0.0	0.0	0.0
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	1.1	2.2	0.0	4.5
Fortress Russet	CONV-1	0.2	0.4	0.0	0.8
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.2	0.4	0.0	0.7
	ORG-2	1.0	2.0	0.0	4.0
Sangre-S10	CONV-1	0.0	0.0	0.0	0.0
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	0.0	0.0	0.0	0.0

Table F.11: Summary statistics for percent of total yield of tubers grown in 2014 with misshapes (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	0.5	0.7	0.0	1.4
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.3	0.6	0.0	1.3
	ORG-2	0.0	0.0	0.0	0.0
CO00291-5R	CONV-1	0.0	0.0	0.0	0.0
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	0.0	0.0	0.0	0.0
CO97087-2RU	CONV-1	0.4	0.7	0.0	1.5
	CONV-2	0.0	0.0	0.0	0.0
	ORG-1	0.0	0.0	0.0	0.0
	ORG-2	0.4	0.8	0.0	1.7
Fortress Russet	CONV-1	1.6	2.6	0.0	5.5
	CONV-2	4.9	9.7	0.0	19.4
	ORG-1	0.3	0.6	0.0	1.1
	ORG-2	0.6	0.7	0.0	1.3
Sangre-S10	CONV-1	0.0	0.0	0.0	0.0
	CONV-2	0.4	0.7	0.0	1.5
	ORG-1	0.9	1.4	0.0	2.9
	ORG-2	1.5	1.8	0.0	3.5

Table F.12: Summary statistics for potato tuber iron concentration (ug/kg dry weight) (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	159.3	38.1	114.0	196.0
	CONV-2	62.8	13.4	48.0	78.0
	ORG-1	79.5	18.3	53.0	94.0
	ORG-2	77.3	18.3	52.0	93.0
CO00291-5R	CONV-1	203.8	29.2	169.0	233.0
	CONV-2	71.5	12.7	57.0	87.0
	ORG-1	142.5	60.5	83.0	224.0
	ORG-2	73.3	13.8	54.0	85.0
CO97087-2RU	CONV-1	203.3	29.1	168.0	230.0
	CONV-2	77.5	13.2	68.0	97.0
	ORG-1	137.5	31.8	109.0	167.0
	ORG-2	86.5	12.4	73.0	98.0
Fortress Russet	CONV-1	172.3	33.0	151.0	221.0
	CONV-2	53.0	7.6	45.0	60.0
	ORG-1	123.5	46.1	89.0	191.0
	ORG-2	75.3	14.9	53.0	84.0
Sangre-S10	CONV-1	162.5	29.3	140.0	205.0
	CONV-2	61.8	13.7	42.0	73.0
	ORG-1	132.5	32.0	103.0	176.0
	ORG-2	73.3	10.6	58.0	82.0

Table F.13: Summary statistics for potato tuber zinc concentration (ug/kg dry weight) (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	11.0	0.8	10.0	12.0
	CONV-2	15.3	1.0	14.0	16.0
	ORG-1	12.3	1.0	11.0	13.0
	ORG-2	19.8	18.3	9.0	47.0
CO00291-5R	CONV-1	15.8	1.9	13.0	17.0
	CONV-2	15.3	3.1	11.0	18.0
	ORG-1	16.3	4.7	12.0	23.0
	ORG-2	17.5	8.5	12.0	30.0
CO97087-2RU	CONV-1	16.5	7.7	12.0	28.0
	CONV-2	25.5	15.1	16.0	48.0
	ORG-1	13.0	0.8	12.0	14.0
	ORG-2	11.5	1.9	9.0	13.0
Fortress Russet	CONV-1	10.3	0.5	10.0	11.0
	CONV-2	18.3	15.3	9.0	41.0
	ORG-1	10.8	3.6	8.0	16.0
	ORG-2	12.8	8.8	8.0	26.0
Sangre-S10	CONV-1	18.5	9.8	12.0	33.0
	CONV-2	28.0	13.1	17.0	43.0
	ORG-1	15.0	0.8	14.0	16.0
	ORG-2	11.8	1.0	11.0	13.0

Table F.14: Summary statistics for potato tuber potassium concentration (% dry weight) (n=4).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	1.64	0.15	1.48	1.83
	CONV-2	1.83	0.06	1.76	1.90
	ORG-1	1.71	0.06	1.65	1.76
	ORG-2	1.67	0.01	1.65	1.68
CO00291-5R	CONV-1	2.30	0.13	2.20	2.48
	CONV-2	2.23	0.32	1.79	2.54
	ORG-1	2.28	0.04	2.24	2.33
	ORG-2	2.38	0.15	2.26	2.60
CO97087-2RU	CONV-1	1.58	0.02	1.55	1.60
	CONV-2	1.97	0.10	1.85	2.08
	ORG-1	1.64	0.08	1.57	1.74
	ORG-2	1.69	0.12	1.55	1.84
Fortress Russet	CONV-1	1.68	0.12	1.54	1.83
	CONV-2	1.92	0.22	1.73	2.23
	ORG-1	1.79	0.02	1.76	1.81
	ORG-2	1.89	0.09	1.77	1.98
Sangre-S10	CONV-1	1.83	0.06	1.74	1.89
	CONV-2	2.18	0.05	2.11	2.22
	ORG-1	1.91	0.08	1.80	2.00
	ORG-2	2.02	0.06	1.98	2.11

Table F.15: Summary statistics for soil respiration (ppm CO2/24 hrs) (n=3).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	16.5	2.0	14.7	18.7
	CONV-2	16.9	1.4	15.6	18.3
	ORG-1	25.0	3.8	22.2	29.3
	ORG-2	20.0	4.3	17.2	24.9
CO00291-5R	CONV-1	16.2	2.0	14.5	18.4
	CONV-2	15.8	1.4	14.7	17.3
	ORG-1	21.8	5.0	18.9	27.6
	ORG-2	18.0	2.2	15.7	20.1
Fortress Russet	CONV-1	17.9	2.8	14.9	20.3
	CONV-2	18.1	1.5	16.5	19.4
	ORG-1	27.1	3.2	23.4	29.5
	ORG-2	20.7	4.5	17.6	25.9

Table F.16: Summary statistics for organic carbon (ppm) (n=3).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	114	8	105	121
	CONV-2	77	5	74	82
	ORG-1	168	16	155	186
	ORG-2	127	7	119	134
CO00291-5R	CONV-1	115	17	105	134
	CONV-2	77	5	74	83
	ORG-1	148	3	145	150
	ORG-2	119	10	108	128
Fortress Russet	CONV-1	130	23	115	156
	CONV-2	70	1	69	72
	ORG-1	164	19	142	179
	ORG-2	114	15	97	127

Table F.17: Summary statistics for organic nitrogen (ppm) (n=3).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	26.3	4.6	22.6	31.5
	CONV-2	19.8	2.6	17.2	22.3
	ORG-1	32.9	1.2	32.1	34.3
	ORG-2	33.3	2.3	30.8	35.1
CO00291-5R	CONV-1	26.0	1.5	24.3	27.0
	CONV-2	19.9	3.6	16.9	23.9
	ORG-1	32.2	1.5	30.9	33.8
	ORG-2	31.1	2.1	28.8	32.9
Fortress Russet	CONV-1	26.3	0.3	26.1	26.6
	CONV-2	28.4	12.5	20.7	42.8
	ORG-1	33.4	2.6	30.4	35.1
	ORG-2	27.9	1.9	26.5	30.1

Table F.18: Summary statistics for soil bacteria biomass (µg/g soil) (n=3).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	686	70	611	750
	CONV-2	464	392	22	768
	ORG-1	637	77	557	711
	ORG-2	797	124	671	918
CO00291-5R	CONV-1	684	174	574	884
	CONV-2	621	195	497	846
	ORG-1	907	86	811	978
	ORG-2	712	69	635	768
CO97087-2RU	CONV-1	827	93	733	918
	CONV-2	867	208	639	1047
	ORG-1	986	160	802	1081
	ORG-2	547	83	468	634
Fortress Russet	CONV-1	1060	206	829	1222
	CONV-2	721	169	611	916
	ORG-1	831	43	785	870
	ORG-2	597	80	538	688
Sangre-S10	CONV-1	713	114	585	803
	CONV-2	713	18	699	733
	ORG-1	887	176	716	1067
	ORG-2	844	66	777	909

Table F.19: Summary statistics for soil fungi biomass (µg/g soil) (n=3).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	125	7	117	129
	CONV-2	246	27	229	278
	ORG-1	134	19	112	147
	ORG-2	251	53	194	298
CO00291-5R	CONV-1	87	18	75	108
	CONV-2	138	10	131	150
	ORG-1	212	9	204	222
	ORG-2	233	40	201	278
CO97087-2RU	CONV-1	139	31	108	169
	CONV-2	133	18	120	154
	ORG-1	282	47	231	324
	ORG-2	355	215	169	591
Fortress Russet	CONV-1	107	24	83	132
	CONV-2	105	32	68	126
	ORG-1	218	70	157	295
	ORG-2	278	32	248	311
Sangre-S10	CONV-1	147	31	122	182
	CONV-2	189	130	77	331
	ORG-1	290	23	275	317
	ORG-2	292	84	234	388

Table F.20: Summary statistics for soil flagellates (#/g soil) (n=3).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	12493	15959	1557	30806
	CONV-2	4331	2507	1540	6393
	ORG-1	8647	5462	4848	14906
	ORG-2	13147	15626	3115	31152
CO00291-5R	CONV-1	7437	1746	6393	9452
	CONV-2	1502	845	638	2327
	ORG-1	3078	2751	1474	6254
	ORG-2	3494	2586	516	5175
CO97087-2RU	CONV-1	4927	1713	3081	6465
	CONV-2	12846	15575	3047	30806
	ORG-1	6319	2274	5006	8944
	ORG-2	17755	12451	6538	31152
Fortress Russet	CONV-1	2434	2366	646	5117
	CONV-2	4229	2458	1557	6393
	ORG-1	6209	39	6187	6254
	ORG-2	19848	24306	5175	47904
Sangre-S10	CONV-1	5098	32	5061	5117
	CONV-2	3222	1773	1523	5061
	ORG-1	4931	2234	2352	6254
	ORG-2	12324	16462	646	31152

Table F.21: Summary statistics for soil amoebae (#/g soil) (n=3).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	40665	10050	31152	51177
	CONV-2	89525	56260	50615	154033
	ORG-1	312061	173985	149064	495268
	ORG-2	166147	140475	31152	311526
CO00291-5R	CONV-1	49237	17197	31152	65381
	CONV-2	52424	18735	30806	63928
	ORG-1	340263	268630	30136	500652
	ORG-2	210799	174464	9346	311526
CO97087-2RU	CONV-1	44812	11527	31506	51752
	CONV-2	52541	19119	30468	63928
	ORG-1	366001	111948	301368	495268
	ORG-2	208275	89423	155764	311526
Fortress Russet	CONV-1	44578	11931	30806	51752
	CONV-2	47484	16388	31152	63928
	ORG-1	299207	1871	298127	301368
	ORG-2	240399	245986	47904	517528
Sangre-S10	CONV-1	44199	11602	30806	51177
	CONV-2	43259	25167	15234	63928
	ORG-1	131234	148174	30468	301368
	ORG-2	88267	70238	15576	155764

Table F.22: Summary statistics for soil ciliates (#/g soil) (n=3).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	36	9	31	47
	CONV-2	37	25	15	64
	ORG-1	97	46	61	149
	ORG-2	317	161	156	478
CO00291-5R	CONV-1	23	22	6	48
	CONV-2	19	28	0	51
	ORG-1	46	1	45	46
	ORG-2	79	67	31	156
CO97087-2RU	CONV-1	49	17	31	64
	CONV-2	109	171	6	307
	ORG-1	151	130	63	301
	ORG-2	2114	2651	522	5175
Fortress Russet	CONV-1	17	13	6	51
	CONV-2	19	28	0	2405
	ORG-1	78	62	38	149
	ORG-2	1013	1216	156	31
Sangre-S10	CONV-1	9	5	6	15
	CONV-2	0	0	0	0
	ORG-1	137	143	47	301
	ORG-2	1219	1655	65	3115

Table F.23: Summary statistics for soil nematodes (#/g soil) (n=3).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	0.6	0.2	0.4	0.7
	CONV-2	2.4	1.0	1.4	3.3
	ORG-1	3.0	1.0	1.8	3.8
	ORG-2	2.0	0.2	1.8	2.2
CO00291-5R	CONV-1	1.2	0.8	0.2	1.7
	CONV-2	6.6	5.3	3.1	12.7
	ORG-1	2.6	0.8	1.9	3.5
	ORG-2	1.4	1.0	0.7	2.5
CO97087-2RU	CONV-1	0.7	0.6	0.3	1.4
	CONV-2	4.6	3.9	0.7	8.6
	ORG-1	3.7	3.1	0.2	5.8
	ORG-2	2.0	1.2	1.3	3.4
Fortress Russet	CONV-1	1.0	0.4	0.6	1.5
	CONV-2	4.6	6.0	1.0	11.5
	ORG-1	2.0	0.8	1.5	3.0
	ORG-2	0.8	0.5	0.4	1.4
Sangre-S10	CONV-1	0.8	0.8	0.1	1.7
	CONV-2	11.7	14.0	0.4	27.4
	ORG-1	3.4	2.5	0.6	5.0
	ORG-2	3.1	0.4	2.6	3.4

Table F.24: Summary statistics for proportion of good soil nematode species (n=3).

Clone	Location	Mean	Std Dev	Minimum	Maximum
All Blue	CONV-1	0.68	0.03	0.66	0.72
	CONV-2	0.91	0.02	0.88	0.92
	ORG-1	0.64	0.11	0.54	0.75
	ORG-2	0.88	0.12	0.76	1.00
CO00291-5R	CONV-1	0.58	0.13	0.46	0.72
	CONV-2	0.83	0.04	0.79	0.87
	ORG-1	0.52	0.07	0.43	0.56
	ORG-2	0.95	0.05	0.89	1.00
CO97087-2RU	CONV-1	0.74	0.15	0.56	0.84
	CONV-2	0.92	0.01	0.91	0.93
	ORG-1	0.54	0.18	0.37	0.73
	ORG-2	0.90	0.01	0.89	0.92
Fortress Russet	CONV-1	0.70	0.06	0.64	0.74
	CONV-2	0.86	0.11	0.76	0.97
	ORG-1	0.62	0.16	0.46	0.79
	ORG-2	0.87	0.01	0.86	0.88
Sangre-S10	CONV-1	0.75	0.13	0.63	0.89
	CONV-2	0.69	0.31	0.34	0.92
	ORG-1	0.58	0.11	0.46	0.68
	ORG-2	0.87	0.03	0.84	0.89

APPENDIX G: KRUSKAL-WALLIS TESTS

Table G.1: Kruskal-Wallis test for hollow heart (df=3).

Clone	Chi-Square	Pr>Chi-Square
All Blue	6.4000	0.0937
CO00291-5R	0.0000	1.0000
CO97087-2RU	4.6044	0.2032
Fortress Russet	9.8811	0.0196
Sangre-S10	6.4816	0.0904

Table G.2: Kruskal-Wallis test for brown center (df=3).

Clone	Chi-Square	Pr>Chi-Square
All Blue	0.0000	1.0000
CO00291-5R	0.0000	1.0000
CO97087-2RU	0.0000	1.0000
Fortress Russet	3.0000	0.3916
Sangre-S10	0.0000	1.0000

Table G.3: Kruskal-Wallis test for growth cracks (df=3).

Clone	Chi-Square	Pr>Chi-Square
All Blue	3.8449	0.2787
CO00291-5R	3.1694	0.3662
CO97087-2RU	2.1500	0.5419
Fortress Russet	8.3090	0.0400
Sangre-S10	12.5000	0.0059

Table G.4: Kruskal-Wallis test for knobs (df=3).

Clone	Chi-Square	Pr>Chi-Square
All Blue	2.1500	0.5419
CO00291-5R	0.0000	1.0000
CO97087-2RU	3.0000	0.3916
Fortress Russet	1.1867	0.7562
Sangre-S10	0.0000	1.0000

Table G.5: Kruskal-Wallis test for misshapes (df=3).

Clone	Chi-Square	Pr>Chi-Square
All Blue	4.1772	0.2430
CO00291-5R	0.0000	1.0000
CO97087-2RU	2.1500	0.5419
Fortress Russet	0.6189	0.8921
Sangre-S10	3.2283	0.3578

APPENDIX H: 2014 MANAGEMENT INFORMATION

Table H.1: Routine soil test results from Colorado State University Soil, Water, and Plant Testing Lab. Soil samples were taken in 2014 before planting.

				Modified Walkley Black	AB-DTPA Extract	NaHCO3 Extract	--------AB-DTPA Extract--------			
Location	pH	Salts (mmhos/cm)	Texture	%SOM	Nitrate N (ppm)	P (ppm)	P (ppm)	K (ppm)	Zn (ppm)	Fe (ppm)
CONV-1	7.9	0.6	Sandy Clay Loam	1.0	11	19.4	10	209	3.4	6.0
CONV-2	7.8	1.4	Sandy Clay Loam	0.9	15	62.5	30	319	3.8	5.8
ORG-1	8.0	1.1	Sandy Clay Loam	1.9	33	75.6	40	360	5.3	6.2
ORG-2	7.7	1.3	Sandy Loam	1.2	24	47.3	24	552	4.1	8.5

Table H.2: Cultural management information from 2014 field season reported by farmer or farm manager.

Location	CONV-1	CONV-2	ORG-1	ORG-2
Fertilizer (lb/acre)	N (120), P_2O_5 (60), K_20 (40), S (25), Zn (2.5)	N (95), P_2O_5 (120), K_20 (10), S (37), Ca (14)	Kelp (0.16 gal/acre), AgrothriveLF* (8.6 gal/acre), AgrothriveTD* (8.6 gal/acre), Soyaplex* (8.6 gal/acre)	Feedlot manure (7 ton/acre), compost tea (3 gal/acre)
Biological Amendment			Sobec, Rutopia, Micronoc*, Therm X-70	
Herbicide (active ingredient)	Outlook (dimethenamide-P), Eptam 7E (S-ethyl dipropylthiocarbamate), Matrix SG (rimsulfuron)	Dual Magnum (S-metolachlor), Glory (Metribuzin)		
Insecticide (active ingredient)	Leverage 360 (imidacloprid and ß-cyfluthrin), Belay (clothianidin), Movento (spirotetramat)	Perm Up 3.2 EC (permethrin)		
Fungicide (active ingredient)	Quadris (azoxystrobin), Luna Tranquility (fluoryram and pyrimethanil)	Penncozeb 75DF (zinc ion, manganese ethylenebisdithiocarbamate), Super Tin 4L (triphenyltin hyrdoxide), Endura (boscalid)		
Fumigant (active ingredient)		Telone II (1,3-dichloropropene)		

*OMRI Listed