Marketable Yield and Quality of Yukon Gold Potatoes in Response to Organic Seed Treatments and Varied Interval Irrigation Schedules

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Abstract

Under ideal conditions, organic potato growers have thin margins for profits, so preventing disease is of utmost importance to this billion-dollar industry. Significant economic losses are caused by a soil-borne disease called common scab that creates superficial pitted-lesions on the skin of potatoes. Although yields are not typically reduced by scab, marketability is significantly diminished in tuber cultivars not being used for processing. Yukon Golds are sold as table stock so esthetics is vital for consumer confidence (II). This variety is particularly susceptible to several strains of *Streptomyces* that cause scab because of their delicate flesh. Since, potatoes can tolerate acidic soils and scab cannot, organic farmers will exploit these characteristics by maintaining the soil pH in the (4.5 to 6.0) range. However, lowering the soil pH is expensive, reduces yields, may not be effective, and is detrimental to the health of the soil which can lead to dustbowl conditions (V). While several tools can be used to impede scab in conventional potato production, few tools exist in organic tuber cultivation due to stringent guidelines for certified USDA Organic production (II). It is critical growers be given alternate methods that allow them to have timely crop rotations while preventing lesions from decimating their profits. Focusing on marketable yield and quality of Yukon Gold production, the aim of this Randomized Complete Block Design (RCBD) experiment under field conditions is threefold: **(1)** *to evaluate the effectiveness of elemental Sulphur (ES) seed treatments and* **(2)** *diatomaceous earth (DE) seed treatments when exposed to the same volume of water but delivered in increased interval micro-volumes (I1) or decreased interval macro-volumes (I2),* and **(3)** *compare the effectiveness of the two seed treatments when exposed to the two different irrigation schedules.*

Preliminary data suggests that DE and S treatments negatively impact marketable yields but more research is needed. The data also suggests that untreated tuber seeds when exposed to I1 treatments, showed significantly higher yields than all six treatments. However, I1 treatments did indicate a slight increase in salinity. I2 treatments all leached more nitrates outside the root-zone but did have lower salinity regardless of seed treatment. **(Word Count: 385)**

Introduction

More Organic Tools Needed

Even under ideal conditions, organic potato (*Solanum tuberosum*) growers have thin margins for profits, so preventing disease in potato production is of utmost importance to this billion-dollar industry. Significant economic losses are caused by a soil-borne disease called common scab that creates unsightly superficial pitted-lesions on the skin of potatoes. Although yields are not typically reduced by scab, marketability is significantly diminished in tuber cultivars not being used for processing. Yukon Gold (YG) potatoes are sold as table stock so esthetics is vital for consumer confidence (V). This variety is particularly susceptible to several strains of *Streptomyces* that cause scab because of their delicate and waxy flesh. If the tuber is infected with just 5% or more of this fungus-like disease, it will fail to make the U.S. No. 1 Grade and the market value will be greatly reduced (II). While several tools can be used to impede common scab in conventional potato production, few tools exist in organic tuber cultivation due to stringent guidelines for certified USDA Organic production. Thus, it is critical organic potato growers be given alternate methods that allow them to have timely crop rotations while preventing these lesions from decimating their profits (II & V).

Need for Crop Rotations

It is widely accepted that growing diverse crops in the same field prevents a plethora of agricultural problems such as scab from spreading. The *Streptomyces spp.* can remain unfettered for up to five years in organic matter that is decaying so crop rotations are an important cultural practice for organic growers (V). Organic growers are also mandated to use fertilizers rich in organic matter that exacerbate *Streptomyces* growth in the soil. Since potatoes can tolerate acidic soils and most species of scab cannot, organic farmers will exploit these characteristics by maintaining the soil pH in the (4.5 to 6.0) range. However, lowering the soil pH is expensive, may not be effective, reduces yields (11), and is detrimental to the health of the soil which can lead to soil compaction, erosion, and dustbowl conditions. In addition, few other crops can thrive in such inhospitable conditions (II). This limits crop rotation choices because raising the soil pH takes an extensive amount of time and money which forces growers to leave fields fallow (X). Leaving a field free of vegetative growth is not conducive to the well-being of the soil nor is it economically or environmentally sustainable (II).

Sulfur Methodology

A common method to lower the soil pH is by incorporating substantial amounts of elemental sulphur into the soil a season prior to planting. The amount is largely governed by soil texture. For instance, when lowering the pH (7.0 to 4.5) in a loamy textured soil, 2,869 kg/ha of ES is required (X). Sulfuric acid is created when soil bacteria transform the S through biological processes. The sulfuric acid produced lowers the pH by means of chemical reactions. The conversion from S to sulfuric acid can take an entire growing season to occur depending on soil temperature and other biotic and abiotic soil factors. When the soil is moist and warm (above 12°C) this whole process can occur within a growing season. However, hydrogen sulfide is produced from sulfur under saturated (anaerobic) conditions creating a rotten egg smell. Worse, plants roots are killed by hydrogen sulfide so it is vital to ensure over irrigation does not occur. The effects of direct sulphur application on cut tuber pieces used as seed has not been evaluated extensively when exposed to varied irrigation scheduling (X).

Diatomaceous Earth Methodology

A sedimentary siliceous mineral called Diatomaceous earth (DE) is naturally occurring in abundance. Microscopic single celled algae-like plants called diatoms help to form the organic pesticide. DE is comprised naturally (86% SiO_2, 5% Na, 3% Mg and 2% Fe). The active ingredient is thought to be silicon dioxide. The ground up fossil remains of these organisms form a fine dust and are known to have insecticidal, anti-bacterial, and anti-fungal properties (VIII). DE has been utilized in a wide range of integrated pest management plans due to its innate non-hazardous characteristics and its USDA organic certification. Much is known about DE but its effectiveness as a directly coated potato seed treatment on the yield and quality of Yukon Gold Potatoes has been unexplored when exposed to varied irrigation scheduling (I).

Anaerobic Treatment

Similar to stomas, lenticels are superficial pores on potato tubers that facilitate oxygen exchange. When exposed to increased moisture, soil oxygen levels are depleted and they swell. While safe for human consumption, they reduce their marketability and increase their susceptibility to a wide host of diseases. On the contrary, decreased oxygen levels has been shown to be effective against common scab. More research is needed to determine if increased moisture levels can improve overall yield and quality of Yukon Gold potatoes while also reducing common scab occurrences (II).

More Organic Potato Research Needed

Despite considerable research on common scab and its prevention, the effectiveness of these treatments when coalesced with other treatments and cultural practices is vague. Even less is known about how these treatments will affect other disease pathologies. Although, there has been substantial documentation on prevention of common scab in conventional Yukon Gold production less is known about organic treatments and how they will affect the overall yield and quality. It is conceivable that a localized acidic environment could be created by coating cut tuber seed pieces in ES just prior to being planted. It is also conceivable to believe adverse conditions for tuber pathogens can be generated by coating cut tuber seed pieces in DE. What is largely unknown is how these seed treatments will respond to the same amount of water being delivered in micro-volumes and macro-volumes. **Broadly honing in on overall yield and quality of Yukon Gold potato production, the aim of this RCBD experiment under field conditions is threefold:**

1. *to evaluate the effectiveness of elemental sulphur seed treatments when exposed to the same volume of water but delivered in increased interval micro-volumes or decreased interval macro-volumes*
2. *to evaluate the effectiveness of DE seed treatments when exposed to the same volume of water but delivered in increased micro-volumes or decreased macro-volumes*
3. *compare the effectiveness of the two seed treatments when exposed to the two different irrigation schedules.*

Materials and Methods

Background

This field experiment was carried out at California State University, Fresno, CA Horticulture Unit (36.816087, -119.735434) during February 2018 to May 2018. The soil was determined to be a Hanford sandy loam (coarse-loamy, mixed, superactive, nonacid, thermic Typic Xerorthents) (NRCS 2018). The textural class was confirmed using particle size analysis. 17°C is the mean temperature and the annual precipitation is approximatively 305 mm. Rainfall, air temperature, reference evapotranspiration (ET_O), growing degree days (GDD) and solar radiation (W/m^2) were measured at the California Irrigation Management Information System (CIMIS) Fresno State Station. Soil-water tension (cb) was measured using an electrical resistance sensing device (Watermark Monitor Model 900M) at depths of 15, 30, and 45 cm. The experiment was conducted in spring 2018 and is being replicated Summer/Fall 2018.

Bed Preparation

Raised beds with a height and width of approximately 20 cm were formed with two tractor-drawn 35 cm furrower plows and flattened with a 22-kg metal pipe. The 18 plots (0.11 ha) were 1.12 m apart, 38 m long, and oriented north to south. The plots previously had peppers grown on them in the Fall of 2017 with reported *Phytophthora* blight infestations spread by hand hoeing equipment. Hand weeding and hand hoeing were the primary tools used to exterminate weeds throughout the study. Back pack flame weeding was done prior to planting and germination. No pesticides were indicated or used. Initial soil testing (Dellavalle Laboratory, Inc.) indicated nutrient levels were adequate and no starter fertilizers or amendments were added at planting. UAN-32 was applied via fertigation (56 kg/ha) on April 20. Each bed was irrigated with one pressure compensated surface-drip irrigation tape. The drip tape had (1.5 LPH) emitters spaced 30 cm apart.

Seed Treatments

February 2, (181 kg) certified organic Yukon Gold seeds were put in a greenhouse with a mean temperature (24°C). February 9, tubers were cut in half and placed on trays eyes up. Tubers receiving DE seed treatments were saturated with water and put into a 19 L plastic bucket filled half way (9 kg) with DE (Garden Safe DE). Tubers were thoroughly coated with DE dust until tuber skin was not visible and immediately planted in pre-irrigated beds. Likewise, the same was done for tubers receiving powdered ES (9 kg, Earthworks) seed treatments. All 2,250 seed pieces (181 kg) were planted at a depth of 15 cm with 30 cm spacing by hand using bulb planters.

Irrigation Treatments

Each seed treatment received two different irrigation schedules. The total volume of water needed for the week was calculated using weekly ET_O (CIMIS) data from prior week. K_C (Crop Coefficients) for 3 distinct developmental stages (emergence, blossom, and tuberization) was used (Food and Agriculture Organization 2018). A root zone (1ft.^{2}) was used for dimensions throughout growth stages. The following equation was used to calculate total water needed per plant for the week:

- ET_0 *(ft.) * root zone (ft*^{2}*) ** K_C ** 7.48 (conversion factor) =Water Requirements (G/plant).*

Total water requirements were divided by 6 days (I1) or 3 days (I2).

Experimental Design

February 16-18, 2018, Yukon Gold (*Solanum tuberosum*) seed pieces were planted. All potatoes were harvested on May 22 by hand after a tractor drawn undercut blade was used to unearth tubers. All plants were desiccated by delivering last irrigation set on May 2. The 18 rows were randomized into 6 treatment areas and replicated 3 times in this RCBD experiment. Treatment S1 received ES and I1. Treatment S2 received ES and I2. Treatment D1 received DE and I1. Treatment D2 received DE and I2. Treatment C1 received no seed treatment and I1. Treatment C2 received no seed treatment and I2.

Yield and Quality

Plant samples (15 per row) were collected at harvest and used as a composite. 45 plants comprised a plot composite. 18 composite samples were individually graded using USDA standards (USDA). Culls based on deformities, insect damage, and scab were recorded. Total harvested weight minus the weight of culls served as the marketable yield. Three marketable tubers per row were used for brix analysis. Soil pH and EC were conducted with a portable meter (Hannah HI9813-5) on 1:1 (soil:water) saturated paste at depths (15, 30, and 45 cm). Nitrates were measured at depths (15,30, and 45 cm) via photon absorbance on (AQ2 Discrete Analyzer) and analyzed on software (QCProTM Data Quality). ANOVA procedures in SAS were used for data analysis. At a 0.05 level of significance using Fisher's Least Significant Difference (LSD) test, means were separated.

Results and Discussion

Increased Micro Irrigation Versus Decreased Macro Irrigation (Untreated)

Preliminary data suggests that delivering the same volume of water over the course of the week in increased micro irrigations is positively correlated to increased marketable weights and germination rates when tuber seeds are untreated (figure 1). The brix (% sucrose) was identical in both C1 and C2 treatments indicating no effect (figure 2). The C2 treatment had germination rates 9% less than the C1 treatment which suggests increased micro irrigations are more beneficial than macro irrigation scheduling (figure 3). When the data is extrapolated to a 1 ha field, the C1 treatment produced 3,070 kg of potatoes more than the C2 treatment. The C1 treatment also leached significantly less nitrates out of the root zone. The C1 treatment had a nitrate-N level (25 ppm) at 15 cm and (5 ppm) at 30 cm and (10 ppm) at 45 cm after harvest. The C2 treatment had a nitrate-N level (5 ppm) at 15 cm, (16 ppm) at 30 cm, and (18ppm) at 45 cm after harvest. C2 treatment did see some negligible benefits in leaching salts because the EC at 15 cm dropped (2.5 dS/m to 1.6 dS/m). The pH dropped slightly (6.7 pH to 6.5 pH) but it did so uniformly on all treatments which is likely due to fertigation of UAN-32 and not seed or irrigation treatments.

Although both treatments received unexpected rains (144 mm) they did not the exceed the total ET_O (497.4 mm) and K_C requirements which necessitated enough irrigation events to show a statistical response. C1 received 48 irrigation events and C2 received 16 irrigation events. It is unclear if the uniform precipitation events had any other significant effect on yields and quality. The experiment will be replicated for statistical purposes in Summer/Fall 2018. This will also serve to clear up the ambiguity as to the effect of the precipitation events.

Increased Micro Irrigation Versus Decreased Macro Irrigation Sulphur Treated

It is unclear if the two different irrigation schedules had any effect on either yield or brix as both were nearly identical. The heavy rains that exceeded weekly ET_O and K_C requirements after planting may have created hydrogen sulfide. This may explain why there was no significant pH changes in the S1 and S2 plots. Perhaps if moisture does not exceed crop requirements, the sulphur may not convert to hydrogen sulfide. More Research is needed on how sulphur interacts with water in reduced amounts under field conditions. S2 like C2 saw statistically identical benefits in lowering salinity within the tuber root-zone.

Increased Micro Irrigation Versus Decreased Macro Irrigation DE Treatment

The two irrigation treatments did not affect marketable yields of the DE treatments. The brix was the highest in the D2 treatment but not enough to affect consumer appeal. If this increase in brix is replicated again I would suspect the cause is from being water stressed and possibly salt stressed. DE has Na (5%) so it's logical to infer that under water stress, photosynthates translocate from source to tuber like observed in tomatoes as they are both in the nightshade family (III). More research is needed on how DE affects salinity and how salinity influences brix and specific gravity (SG) in potatoes.

Comparisons of Treatments

The C1 treatment had the highest marketable yield amongst all 6 treatments. The C2, S1, and S2 treatments all had nearly identical marketable yields. When data was extrapolated, they all produced approximately 8,085 kg/ha. C1 produced 11,077 kg/ha. D1 and D2 had significantly less yields than all treatments. DE treatments had nearly half the marketable yield of C1 tubers.

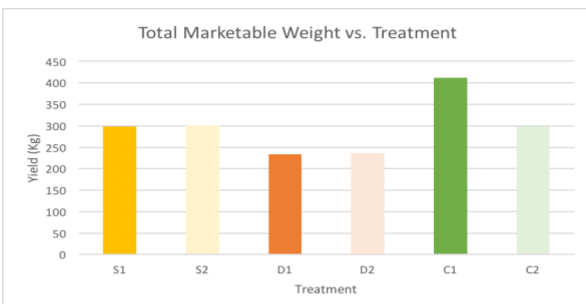
Despite different irrigation schedules germination rates did correlate to the seed treatment when isolated. C1 and C2 had germination rates of 79% and 70% respectfully. D1 and D2 treatments had the lowest germination rates of 60% and 62%. S1 and S2 had germination rates of 69% and 65% respectfully. Until the experiment can be replicated it is not possible to discuss how the irrigation schedules affected germination rates definitively due to rainfall that exceeded weekly ET_O prior to first observed germination on March 17. However, it is clear that DE treatments had a substantial negative affect on germination rates and thus yields.

While brix differences were observed, they would not be enough for consumers to detect the difference. C1 and C2 had the lowest brix at 7 while D2 had brix of 7.4. In the context of brix and human consumption a 0.4 difference is insignificant.

There was detectable correlation amongst nitrate leaching and seed treatments. This likely had to do with the seed treatment's negative effects on germination rates which led to plants not utilizing the excess nitrates in the root-zone. Overall, the decreased macro irrigation treatments showed to have the biggest impact on nitrate leaching regardless of seed treatment. Sandy loams have moderate water holding capacity due to moderate porosity. The increased micro irrigations did not saturate the soil pores completely so gravimetric forces could not drive water and thus nitrates below the root-zone.

Similar findings were encountered in regards to salinity. I1, regardless of seed treatment, had increased salinity. Very little water was pushed outside the rhizosphere so salts present in the water began to build as the water evaporated leaving behind salts.

In summary, C1 treatment produced the best results. Although I1 caused salinity to increase slightly in all trials it was not enough to reach the threshold for tubers. Potatoes are moderately sensitive to salinity with a threshold of 1.7 dS/m (7). While I1 may increase salinity slightly within one crop season the salinity may increase more overtime so monitoring is advised. More so depending on the salinity of the irrigation water. However, this is can be mitigated by reaching salt leaching requirements after harvest when nitrates are lowest. The increases in salinity are within the threshold of a wide variety of crops so crop rotation choices will not be greatly affected (7). More research is needed to definitively make a conclusion on DE and S treatments. The data does show that when precipitation exceeds plant requirements before germination, there is a statistically significant negative impact on marketable yields in DE and S treatments. Both treatments should be avoided if excess rainfall is expected. **(Word Count:3252)**



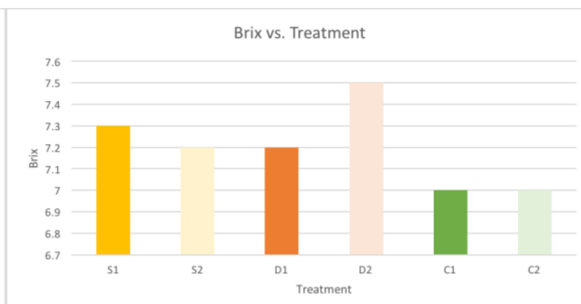


Figure 1 (top left). *Total marketable weight compared to treatment*

Figure 2 (top right). *Brix (% sucrose) compared to treatment*

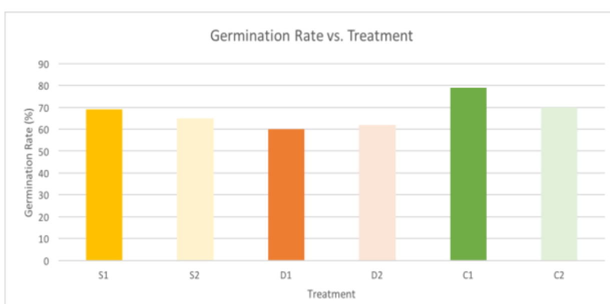


Figure 3 (above). *Germination rates compared to treatment*

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