Cultivar, Season Extension, Fertilizer Trials of Swiss Chard and Pedagogy of Assessing Cultivars Using Technology

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CULTIVAR, SEASON EXTENSION, AND FERTILIZER TRIALS OF SWISS
CHARD AND PEDAGOGY OF ASSESSING CULTIVARS USING
TECHNOLOGY

By

CHANELLE ELISABETH ANGENY, B.S. Forestry

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CULTIVAR, SEASON EXTENSION, AND FERTILIZER TRIALS OF SWISS CHARD AND PEDAGOGY OF ASSESSING CULTIVARS USING TECHNOLOGY

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ABSTRACT

Abstract. Diversity of species is a cornerstone of horticulture, and the constant stream of new plant cultivars broadens the palette of options available to the industry. Fifteen Swiss chard (Beta vulgaris var. cicla) cultivars were evaluated during the fall/winter of 2014-2015 season (season 1) and 27 cultivars during the fall/winter of 2015-2016 season (season 2) to determine the best performing cultivars for production and landscape use for east Texas and the southeast by assessing survivability and yield. There was an increase in production of 3.0 ± 0.5 g per plant per harvest under the low tunnel. The cultivar ‘Verde de Taglio’ had the best overall performance during season 1 both in covered and uncovered environments. In season 2, ‘Verde a Costa Blanca’ yielded the most uncovered. ‘Verde de Taglio’ yielded the most covered for this season. It is recommended to use the low tunnels to extend production. A trial was also conducted to determine optimum, pre-plant organic fertilizer amendment for container production of Swiss chard. Ten pre-plant organic fertilizers were compared against a control (Osmocote). There were no significant differences in dry weight, plant height, or plant width among the treatments suggesting all fertilizers were sufficient to produce Swiss chard ‘Prima Rosa’. In the 2016 spring and fall semesters, students in the Crop Science course (AGN 110) at SFASU were given an assignment where they were instructed to
use Google Sheets to assess diversity of traits of agronomic crops in a seed catalog.

Students were assessed pre-and post-assignment on their experience level with agriculture, gardening, and seed catalogs’, their comfort level with Google Sheets and Microsoft Excel and collecting and analyzing data, and their opinion on the effectiveness of using multiple people to collect data and using Google Sheets. Overall, students were able to use Google Sheets to compile data from multiple people to gain insight on which traits occurred most often in seed catalogs. Combined students, agriculture students, female students, and fall semester students showed a higher level of comfort using Google Sheets and Microsoft Excel. The results also showed that students had a better grasp of what a trait was after finishing the post-survey. Additionally, students created more robust definitions for a trait and a cultivar post-assignment. From the comments provided from the survey, it was evident that students learned more about agriculture and gardening, traits and cultivars, how to interpret seed catalogs, how to use technology, and collaboration.
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INTRODUCTION

The horticulture industry relies upon the diversity of traits in cultivars that perform well under various production systems. Evaluating these plants provides quantitative and qualitative data that can be used and interpreted by professionals and the public alike. Trialing plants ultimately helps the industry act both more efficiently and sustainably in its actions since there is a constant stream of new cultivars being introduced to the market. Trial gardens and programs are widespread throughout the United States ensuring that plants performance are evaluated in various climates and other environmental factors. The focus of this thesis research was on evaluating cultivars of Swiss chard (Beta vulgaris var. cicla) under different season extension regimes and Swiss chard growth and yield when grown with organic fertilizers.

In Chapter 1, results were reported from a trial to evaluate yield and performance of Swiss chard cultivars in east Texas when grown with and without season extension. Swiss chard is an edible ornamental on the rise in popularity, and its dual-purpose makes it attractive to consumers, especially the millennial generation. This species is the same as beets (Beta vulgaris var. crassa); however, it has been selected more for leaf production instead of root production (Kovatch, 2003). With the evaluation of new cultivars, growers can also investigate the compounding effect from management techniques such as season extension. Season extension is a useful tool for growers to lengthen the growing season by reducing harmful effects from freezing temperatures.
(Hochmuth et al., 2015). To lengthen the season of Swiss chard production, low tunnels can be used to protect plants from frost and mitigate other environmental factors. By using row covers, growers have the potential of increasing yield and therefore increasing profits. There has been limited work on evaluating Swiss chard performance in the United States, and less for the southeast region.

In Chapter 2, results were presented from a test of organic fertilizer performance were evaluated using ‘Prima Rosa’ Swiss chard. Organic farming practices are increasing in the United States (Cohn and Wheeler, 2017). Using organic fertilizers in an operation helps to maintain certified organic status, but is not required. This classification can help to raise profits by selling products for a higher value, some reports noting a 47% price increase over its conventional counterparts (Marks, 2015). Organic fertilizers can work within natural systems and cycles, and they work best for edible and ornamental crops that have a fast production time (Kuack, 2014). Similar to conventional systems, organic fertilizers can be applied either as a pre-plant fertilizer added prior to planting via incorporation into the substrate or post-plant fertilizer added through irrigation or as a top dressing. Most organic potting mixes are rich enough in fertility to support adequate plant growth for upwards of four weeks. This factor is beneficial so farmers do not have to supply labor for any additional fertility supplementation (Mattson and Beeks, no date). There are many commercially available organic fertilizers on the market, but few experiments have been conducted among them to determine the best brands for yield and nutrient extractability. Organic fertilizers consist of ground mineral rock, plant, and animal by-products including bone and blood meals, composted manures,
and ground plants like alfalfa meal (Williams, 2014). Similar to conventional systems, organic fertilizers can be applied either as a pre-plant fertilizer incorporated into the growing substrate or as post-plant fertilizer added through irrigation or as a top dressing. Most organic potting mixes are rich enough in fertility to support adequate plant growth for up to the first four weeks. This factor is beneficial, as growers do not have to apply any additional fertility supplementation (Mattson and Beeks, no date.). Trials must be conducted to know how long pre-plant fertility can carry a crop during production. Knowing this information can help growers and gardeners get the best results from their crop while producing organically.

Additionally, the concepts of traits and cultivars can be difficult for students to understand. Therefore, research reported on in Chapter 3 evaluated student use of Google Sheets to better address learning about the concept of traits in horticultural crops and to enhance collaborative learning. In agriculture education, educators are always searching for methods to integrate technology in the classroom with real world applications. The diversity of technology used in educational settings has expanded greatly in the past 20 years (Morgan et al., 2007). Instructional technology like computers, continue to enhance the educative process (Schacter, 1999), and now students also have iPads and other easily accessible handheld devices (Kyanka-Muggart, 2013). When technology is used in the classroom, it can improve mastery of content, increase a positive attitude in the students towards learning, prepare students for future careers, and potentially help with costs of instruction (Williams, 2014). Technology has the capacity to support students with varying capabilities, opening up more possible learning
opportunities (Culatta and Adams, 2014). The assignment used in this work featured an inexpensive and easy method using Google Sheets and seed catalogs to allow students from varied backgrounds to assess the diversity of traits in horticultural crops. The assignment was paired with pre- and post-surveys where students were asked about their level of experience with agriculture, gardening, and seed catalogs; their level of comfort using Google Sheets and Microsoft Excel and collecting and analyzing data; and their opinions of using multiple people and Google Sheets to collect data. The goal was to determine if the assignment would be a successful tool for agriculture educators.


CHAPTER 1

The Effects of Low Tunnels on Yield and Survival of Swiss Chard
(Beta vulgaris var. cicla) Cultivars in East Texas

(In the format appropriate for submission to HortScience)
The Effect of Low Tunnels on Yield and Survival of Swiss Chard (*Beta vulgaris* var. *cicla*) Cultivars in East Texas

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The Effect of Low Tunnels on Yield and Survival of Swiss Chard (Beta vulgaris var. cicla) Cultivars in East Texas

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Abstract. Diversity of species is a cornerstone of horticulture, and the constant stream of new plant cultivars broadens the palette of options available to the industry. To evaluate these new cultivars, trials are conducted to standardize plant performance. Cultivar trials of Swiss chard (Beta vulgaris var. cicla), an ornamental vegetable, have not previously been conducted for the southeast United States. Fifteen cultivars during the fall/winter of 2014-2015 season (season 1) and 27 cultivars during the fall/winter of 2015-2016 season (season 2) were evaluated to determine the best performing cultivars for production and landscape use by assessing survivability and yield. Plugs were installed into the field on 26 Sept. 2014 and on 7 Oct. 2015 for seasons 1 and 2. Three replications of each cultivar were randomly installed into each of six beds. Once the plant had mature leaves of at least 15.2 cm long, harvesting occurred. Leaf and petiole were cut close to the base of the plant and weighed as fresh weight (kg) for each cultivar. On 2 Nov. 2014 and on 20 Nov. 2015 for seasons 1 and 2, respectively, low tunnels were installed over three beds. The experiment was terminated after production had slowed. There were 11 harvests for season 1 and 9 harvests for season 2. There was an increase in production of 3.5 ± 0.5
grams per plant per harvest underneath the low tunnels. In season 1, cultivars underneath low tunnels had a significantly higher survivability (14.08%), and in season 2, there was no statistical difference between plants in the treatments. ‘Verde de Taglio’ had the best overall performance for season 1 both in covered and uncovered environments. In season 2, ‘Verde a Costa Blanca’ yielded the most uncovered and ‘Verde de Taglio’ yielded the most covered for this season. It is recommended to use the low tunnels to extend production and increase yield.

**Introduction**

Diversity amongst and within species is a cornerstone of horticulture, and the constant stream of new cultivars of plants broadens the palette of options available to the horticultural industry. To evaluate new cultivars, trials are conducted to standardize plant performance. Trial gardens provide quantitative and qualitative performance data on a cultivar’s performance. Trial gardens are widespread throughout the United States ensuring that many climates and environments are factored into the performance of new cultivars. Knowing this performance information can help to ensure that the industry is being sustainable and able to make wise decisions about their plant choice (All American Selections, n.d.).

With the evaluation of new cultivars, growers can also investigate the compounding effect from management techniques such as season extension. Season extension is a useful tool for growers to lengthen the growing season by reducing harmful
effects from freezing temperatures (Hochmuth et al., 2015). Passive season extension techniques include mulches (organic and black plastic), polymer-based floating row cover, low tunnels using metal hoops, or large-scale unheated greenhouses. Extending the growing season brings many benefits like higher crop yield, early or late product, and unintentional benefits such as pest and disease exclusion (Hunter et al., 2012).

Low tunnels are a method of season extension. Traditionally, they were implemented in the springtime to start the growing season earlier; however, they can also be used during the winter to provide frost protection by protecting crops from periodic freezes. Low tunnels consist of structures erected high enough to cover the tops of the crops. They are unheated and are typically 1.2 - 2.4 m tall and 1.5-3 m wide (Sideman, 2013). Low tunnels can be a cheaper alternative to unheated high tunnels. The materials used are either a thin film of plastic or polymer-based fabric (polyethylene and porous, nonwoven materials surrounding the crops) and a frame composed of metal or PVC pipe to provide support for the cover. Row covers can be flexible, semi-transparent, and can enclose multiple rows at one time (Hochmuth et al., 2015). Low tunnels can help to increase the surrounding air temperature of about 5 °C on a sunny day; however, they have minimal effects on increasing nighttime temperatures. However, some precautions should be taken with low tunnels. Since temperatures can increase under the cover of the low tunnel and cause possible damage to plants, ventilation through perforated plastic or breathable fabric allows some of the heat to escape (Maughan et al., 2014). Low tunnels can be used in the fall and in the spring for the southeastern region of the US. For the fall, mature plants are covered to extend their growing season. In the spring, low tunnels are
erected while the plants are juvenile and then removed later in the season as the temperatures begin to rise (Maughan et al., 2014).

The University of Utah, 2014, conducted field trials on asparagus growth under low tunnels. They concluded that while higher yields were noted, there was not a significant increase in total asparagus productivity. Peppers that were started early under low tunnels established early and grew rapidly ensuing a higher yield later in the season (Maughan et al., 2014).

In the southeast there is a need for more research on the use of low tunnels to grow cool season crops. Swiss chard (*Beta vulgaris var. cicla*) is a delicious, nutritious, and attractive leafy, biennial vegetable that is gaining traction with the public, especially in urban, progressive cities such as Portland, OR (Badger, 2014). This species is the same as beets (*Beta vulgaris var. crassa*); however, it has been selected more for leaf production instead of root production (Kovatch, 2003). The leaves are harvested and consist of thick stalks and wide blades that are both edible. The stalk can be a variety of colors including white, yellow, pink, green, and red (Jett, 2008). As a cool season crop, Swiss chard tolerates light frost. Bolting occurs when it is exposed to long day conditions (14+ hrs) followed by a cold period (Masabni, 2011). Mulching or floating row cover can be used to extend the season (Jett, 2008). Swiss chard can be planted throughout the year depending on when it can mature. Not only is Swiss chard nutritious and edible, it is also an attractive ornamental (Kovatch, 2003). In Arizona, Swiss chard, grown as a crop, brought in a yearly value of $158,000 between 1995 and 1999 (Dimson and Agnew, 2001). Research from Florida demonstrates Swiss chard at farmers markets
can gross $2.00–$3.00 per bundle (0.52–0.68 kg) and brings in an average of $66 per weekend for 27 bunches for a thirty-one-week-long market season (Shuler et al., 2003). It has value both in commercial growing and for small-scale farmers.

Plants like Swiss chard that can serve multiple purposes like being edible and ornamental add more value to a plant product. Drotleff (2014) reported that consumers, especially young people, want plants to be functional in varying ways.

There has been limited work to evaluate Swiss chard cultivars. In a study of 12 Swiss chard cultivars, Pokluda and Kuben (2002) found that ‘Lucullus’, ‘Genfer Selma’, ‘Swiss chard’, and ‘Bright Lights’ cultivars produced the best quality. ‘Gator’, ‘Zurcher Gelber’, and ‘Charlotte’ produced enough for commercial grower needs. As far as nutrient content within the plant, vitamin C was highest in ‘Bright Lights’, ‘Genfer Selma’, and ‘Lucullus’. Potassium and nitrogen were found to be highest in ‘Listovy Zeley’ and ‘Zurcher Gelber’.

Jett (2008), in West Virginia, evaluated 16 cultivars. Almost exactly 60 days after seeding, Swiss chard plants were harvested once-over and weighed. ‘Argentata’, ‘Five Color Australian’, and ‘Lucullus’ had the highest yield with 0.21, 0.19, and 0.07 kg, respectively.

There is a need to trial Swiss chard performance and survivability over time in the southeast United States. The primary purpose of this study was to determine the survivability and yield of 27 different cultivars of Swiss chard (Beta vulgaris var. cicla) using low tunnels in east Texas. Results will help nurseries; vegetable growers, landscapers, and home gardeners decide which cultivars are best to grow in the southeast
United States. Specific objectives of this study were: 1) to determine which cultivars of Swiss chard perform the best for east Texas, 2) to determine which cultivars of Swiss chard have the best survivability over winter using a low tunnel system in east Texas, and 3) to determine which cultivars of Swiss chard produce the most yield throughout the growing season in east Texas.

**Materials and Methods**

Swiss chard trials were conducted over two seasons starting in the fall of 2014 and 2015. On 14 Aug. 2014 and 31 Aug. 2015, 15 and 27 cultivars of Swiss chard, respectively (Table 1.1) were sown one seed per cell into 72-cell trays (6 cm × 3.8 cm × 3.8 cm) in germination media. During both sowings, the greenhouse was set at an air temperature of 22.2 °C. Before planting, six beds were tilled and amended with 5 cm of compost produced on campus. Transplants were installed into the field on 26 Sept. 2014 and 7 Oct. 2015 for seasons 1 and 2. Three replications of each cultivar were planted in each of the six beds for a total of 15 and 27 cultivars per bed for seasons 1 and 2, respectively. Plugs were planted 30.4 cm apart within the row across the bed, and cultivar plugs were spaced 30.4 cm apart down the bed. To each planting hole, 15 g of slow release fertilizer (18N-2.6P-10K) was added. Harvesting started on 17 Oct. 2014 and 11 Nov. 2015 for seasons 1 and 2, respectively. Harvesting consisted of cutting the leaf petiole close to the base of the plant with a knife for leaves that were 15.2 cm and longer. Leaves were then weighed for fresh weight. When frost threatened, low tunnels
(Agribon and 1.3 cm electrical conduit pipe) were installed randomly over three beds on 2 Nov. 2014 and 20 Nov. 2015 for seasons 1 and 2, respectively. Tunnels remained on the plants for the rest of the trial period and were only removed during times of harvest.

Sequential harvesting was conducted once per week until growth significantly slowed. Afterward, harvests were conducted every other week until most of the plants in the trial had no leaves to harvest. At this point, the project was terminated on 26 Mar. 2015 and 26 Jan. 2016 for seasons 1 and 2, respectively.

In order to generate yield curves, the harvest results were used to develop a repeated measures evaluation using a cubic model across time. In turn, the Bonferroni comparison was used and helped to reduce overall experimental wide errors.

Results and Discussion

Effects of Low Tunnels. This model was used to predict the harvests at each time period and was then summed to produce the desired yield curves. The basic structure of the model for the harvest results is as given below:

\[ W_{ijk} = \beta_0 + \beta_C I_{Ci} + \beta_1 T_j + \beta_2 T_j^2 + \beta_3 T_j^3 + \epsilon_{ijk}, \]

Where:

- \( W_{ijk} \) = Weight/Plant (kg) observed under Condition i, at Time j, for replicate k,
- \( \beta_0 \) = a constant term reflecting the predicted Weight/Plant when \( I_{Ci} = 0 \) and \( T_j = 0 \),
- \( \beta_C \) = an adjustment to the predicted Weight/Plant when \( I_{Ci} = 1 \),
\[ I_{ci} = \begin{cases} 0, & \text{when } i = 1 \text{ (Covered)} \\ 1, & \text{when } i = 2 \text{ (Uncovered)} \end{cases} \]

\( \beta_1 \) = coefficient for the linear time component effect on Weight/Plant,

\( T_j \) = Time Value (Days) for Time Period \( j, j = 1, \ldots, 11 \) for Season 1, & \( j = 1, \ldots, 9 \) for Season 2,

\( \beta_2 \) = coefficient for the quadratic time component effect on Weight/Plant,

\( \beta_3 \) = coefficient for the cubic time component effect on Weight/Plant, and

\( \epsilon_{ijk} \) = error term under Condition \( i \), at Time \( j \), for replicate \( k = 1,2,3 \).

The time value was centered using the median Julian date for each respective season, effectively making \( T_6 = 0 \) and \( T_5 = 0 \) for seasons 1 and 2, respectively.

The effects of using the low tunnels resulted in an average gain of 3.5 g (± 0.5 g 95% CI) higher yield per harvest per covered plant vs. uncovered plants. There was a significant difference in yield between the different cultivars of Swiss chard for both seasons; however, these differences were not consistent among the same cultivars across both seasons. Thus, the use of low tunnels was a beneficial practice for a higher yield in colder temperatures. There was a 58% outcome of cultivars having a significantly higher yield in season 1 than they did in season 2 (Figure 1.1).

**Cultivar Performance.** There were 12 reoccurring cultivars between seasons 1 and 2 (Table 1.1). For the 12 reoccurring cultivars from season 1 and season 2, 90% (CI of 95% Bonferroni) of the cultivars showed no difference in yield between the seasons (Figure 1.1.). The two cultivars that did show significant differences were ‘Lyon’ and ‘Magenta Sunset’. ‘Magenta Sunset’ had a yield difference of 0.114 kg while ‘Lyon’ had a yield difference of 0.036 kg between covered and uncovered conditions.
‘Verde de Taglio’ was the highest yielding cultivar (observed) in the first season with 0.346 kg from covered plants and 0.334 kg from uncovered conditions (Table 1.2). This cultivar is green, which may have allowed it to have a higher yield. The green leaf coloration in the cultivars that did well could be attributed to a higher chlorophyll concentration, which can result in higher photosynthetic rates (Ferguson et al., 1972). A positive correlation has been shown between net photosynthesis and yield on plants (Zelitch, 1982). ‘Prima Rosa’ was the second highest yielding cultivar (observed) with a yield of 0.312 kg covered and 0.242 kg uncovered. ‘Vulcan’ was the poorest performing cultivar (observed) for season 1 yielding 0.167 kg in covered conditions and 0.109 kg in uncovered conditions (Table 1.2).

The highest yielding cultivar (observed) for the uncovered conditions in season 2 was ‘Verde de Taglio’ with 0.249 kg, and the highest yielding cultivar (observed) for the covered conditions was ‘Verde a Costa Blanca’ with 0.258 kg (observed) (Table 1.3).

The following is results for highest yielding cultivar by color for uncovered conditions. For season 1 and 2, the highest yield yellow/orange cultivar was ‘Bright Yellow’ (0.131 kg) and (0.152 kg), respectively. The highest yielding red stemmed cultivar for season 1 was ‘Bali’ (0.128 kg) and ‘Rhubarb’ (0.128 kg). ‘Peppermint Stick’ (0.176 kg) was the highest yielding red stemmed cultivar for season 2. The all red (leaf and petiole) cultivar ‘Prima Rosa’ yielded 0.242 kg in season 1 and 0.145 kg for season 2. The highest yielding mixed color cultivar was ‘Rainbow’ (0.153 kg) for season 1 and ‘Northern Lights Mix’ (0.190 kg) for season 2.
Survivability. Survivability varied between the two seasons. In season 1 the covered Swiss chard had a higher survival rate (91%) than the uncovered plants (83%). For season 2 there was a 99% survival rate for the cultivars, and no significant difference was observed for survivability between covered and uncovered plants. To illustrate the differences between seasons, in season one 12 of the 18 plants of ‘Peppermint Stick’ survived, and 13 of the 18 plants of ‘Rhubarb’ survived, for season 1. However, all of the plants for these two cultivars survived in season 2.

While there is high variability between the results from the first season and the second season, not only for yield but also for survivability and low tunnel effects, the research demonstrates that certain cultivars do perform better. Based on both seasons of data, the recommended cultivars for east Texas are, ‘Verde de Taglio’, ‘Prima Rosa’, ‘Perpetual’, and ‘Verde a Costa Blanca’. Implementing low tunnels as a means of season extension are also recommended since an average of approximately 3.5 g per harvest per plant can be gained implementing this practice. While some plants had greater survivability (‘Lyon’ and ‘Magenta Sunset’) some had lower survivability that occurred during season 1, the lack of significant difference in survivability of plants by using low tunnels in the second season suggests plant survival may vary season to season. In conclusion, this work on Swiss chard supports the use of this edible and ornamental species in landscaping and production.
Literature Cited


**Table 1.1.** Swiss chard (*Beta vulgaris* var. *cicla*) cultivars with correlating treatment number evaluated for 2014 and 2015 field trials.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Number</th>
<th>Color</th>
<th>Season 14-15</th>
<th>Color</th>
<th>Season 15-16</th>
<th>Color</th>
<th>Season 15-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bali</td>
<td>1</td>
<td>Red</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bright Yellow</td>
<td>2</td>
<td>Yellow</td>
<td>Bright Yellow</td>
<td>2</td>
<td>Bright Lights</td>
<td>2</td>
<td>Mixed</td>
</tr>
<tr>
<td>Eldorado</td>
<td>3</td>
<td>Yellow</td>
<td>Eldorado</td>
<td>3</td>
<td>Electric Neon</td>
<td>3</td>
<td>Mixed</td>
</tr>
<tr>
<td>Flamingo Pink</td>
<td>4</td>
<td>Pink</td>
<td>Flamingo Pink</td>
<td>4</td>
<td>Fordhook Giant</td>
<td>4</td>
<td>Green</td>
</tr>
<tr>
<td>Lyon</td>
<td>5</td>
<td>White</td>
<td>Lyon</td>
<td>5</td>
<td>Garden Rainbow</td>
<td>5</td>
<td>Mixed</td>
</tr>
<tr>
<td>Magenta Sunset</td>
<td>6</td>
<td>Pink</td>
<td>Magenta Sunset</td>
<td>6</td>
<td>Golden</td>
<td>6</td>
<td>Yellow</td>
</tr>
<tr>
<td>Neon Lights</td>
<td>7</td>
<td>Mixed</td>
<td></td>
<td></td>
<td>Italian Silver Rib</td>
<td>7</td>
<td>Mixed</td>
</tr>
<tr>
<td>Oriole Orange</td>
<td>8</td>
<td>Orange</td>
<td>Oriole Orange</td>
<td>8</td>
<td>Large White Ribbed</td>
<td>8</td>
<td>White</td>
</tr>
<tr>
<td>Peppermint Stick</td>
<td>9</td>
<td>Red</td>
<td>Peppermint Stick</td>
<td>9</td>
<td>Neon Glow</td>
<td>9</td>
<td>Mixed</td>
</tr>
<tr>
<td>Prima Rosa</td>
<td>10</td>
<td>Red</td>
<td>Prima Rosa</td>
<td>10</td>
<td>Northern Lights Mix</td>
<td>10</td>
<td>Mixed</td>
</tr>
<tr>
<td>Rainbow</td>
<td>11</td>
<td>Mixed</td>
<td>Rainbow</td>
<td>11</td>
<td>Perpetual</td>
<td>11</td>
<td>Green</td>
</tr>
<tr>
<td>Red and White Mix</td>
<td>12</td>
<td>Mixed</td>
<td></td>
<td></td>
<td>Scarlet Charlotte</td>
<td>12</td>
<td>Red</td>
</tr>
<tr>
<td>Rhubarb</td>
<td>13</td>
<td>Red</td>
<td>Rhubarb</td>
<td>13</td>
<td>Sel Baresse</td>
<td>13</td>
<td>Green</td>
</tr>
<tr>
<td>Verde de Taglio</td>
<td>14</td>
<td>Green</td>
<td>Verde de Taglio</td>
<td>14</td>
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<tr>
<td>Vulcan</td>
<td>15</td>
<td>Red</td>
<td>Vulcan</td>
<td>15</td>
<td>Verde a Costa Blanca</td>
<td>15</td>
<td>Green</td>
</tr>
</tbody>
</table>
Table 1.2. Season 1 total yield per plant of Swiss chard (*Beta vulgaris* var. *cicla*) in both covered and uncovered conditions with model predicted population performance. Covered plants have a confidence interval of ±0.028 kg and uncovered has a confidence interval of ±0.019 kg.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Total Yield per Plant (kg) Covered</th>
<th>Total Yield per Plant (kg) Uncovered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed During Experiment</td>
<td>Long Term Average (Beyond Experiment)</td>
</tr>
<tr>
<td>1 Bali</td>
<td>0.193</td>
<td>0.177</td>
</tr>
<tr>
<td>2 Bright Yellow</td>
<td>0.173</td>
<td>0.155</td>
</tr>
<tr>
<td>3 Eldorado</td>
<td>0.175</td>
<td>0.143</td>
</tr>
<tr>
<td>4 Flamingo Pink</td>
<td>0.168</td>
<td>0.135</td>
</tr>
<tr>
<td>5 Lyon</td>
<td>0.210</td>
<td>0.208</td>
</tr>
<tr>
<td>6 Magenta Sunset</td>
<td>0.237</td>
<td>0.166</td>
</tr>
<tr>
<td>7 Neon Lights</td>
<td>0.176</td>
<td>0.153</td>
</tr>
<tr>
<td>8 Oriole Orange</td>
<td>0.200</td>
<td>0.161</td>
</tr>
<tr>
<td>9 Peppermint Stick</td>
<td>0.183</td>
<td>0.136</td>
</tr>
<tr>
<td>10 Prima Rosa</td>
<td>0.312</td>
<td>0.286</td>
</tr>
<tr>
<td>11 Rainbow</td>
<td>0.169</td>
<td>0.150</td>
</tr>
<tr>
<td>12 Red and White Mix</td>
<td>0.222</td>
<td>0.169</td>
</tr>
<tr>
<td>13 Rhubarb</td>
<td>0.126</td>
<td>0.138</td>
</tr>
<tr>
<td>14 Verde de Taglio</td>
<td>0.346</td>
<td>0.330</td>
</tr>
<tr>
<td>15 Vulcan</td>
<td>0.167</td>
<td>0.115</td>
</tr>
</tbody>
</table>
Table 1.3. Season 2 total yield per plant of Swiss chard (*Beta vulgaris* var. *cicla*) in both covered and uncovered conditions with model predicted population performance. Covered plants have a confidence interval of ±0.022 kg and uncovered has a confidence interval of ±0.020 kg.

<table>
<thead>
<tr>
<th>Season 2</th>
<th>Total Yield per Plant (kg)</th>
<th>Total Yield per Plant (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Covered</td>
<td>Long Term Average</td>
</tr>
<tr>
<td></td>
<td>Observed</td>
<td>(Beyond Experiment)</td>
</tr>
<tr>
<td>2</td>
<td>Bright Yellow</td>
<td>0.202</td>
</tr>
<tr>
<td>3</td>
<td>Eldorado</td>
<td>0.157</td>
</tr>
<tr>
<td>4</td>
<td>Flamingo Pink</td>
<td>0.196</td>
</tr>
<tr>
<td>5</td>
<td>Lyon</td>
<td>0.210</td>
</tr>
<tr>
<td>6</td>
<td>Magenta Sunset</td>
<td>0.151</td>
</tr>
<tr>
<td>8</td>
<td>Oriole Orange</td>
<td>0.147</td>
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<tr>
<td>9</td>
<td>Peppermint Stick</td>
<td>0.212</td>
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<tr>
<td>10</td>
<td>Prima Rosa</td>
<td>0.202</td>
</tr>
<tr>
<td>11</td>
<td>Rainbow</td>
<td>0.165</td>
</tr>
<tr>
<td>13</td>
<td>Rhubarb</td>
<td>0.183</td>
</tr>
<tr>
<td>14</td>
<td>Verde de Taglio</td>
<td>0.224</td>
</tr>
<tr>
<td>15</td>
<td>Vulcan</td>
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</tr>
<tr>
<td>16</td>
<td>Bionda di Lyon</td>
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<tr>
<td>17</td>
<td>Bright Lights</td>
<td>0.199</td>
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<tr>
<td>18</td>
<td>Electric Neon</td>
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<tr>
<td>19</td>
<td>Fordhook Giant</td>
<td>0.200</td>
</tr>
<tr>
<td>20</td>
<td>Garden Rainbow</td>
<td>0.200</td>
</tr>
<tr>
<td>21</td>
<td>Golden</td>
<td>0.188</td>
</tr>
<tr>
<td>22</td>
<td>Italian Silver Rib</td>
<td>0.168</td>
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<tr>
<td>23</td>
<td>Large White Ribbed</td>
<td>0.139</td>
</tr>
<tr>
<td>24</td>
<td>Neon Glow</td>
<td>0.189</td>
</tr>
<tr>
<td>25</td>
<td>Northern Lights Mix</td>
<td>0.173</td>
</tr>
<tr>
<td>26</td>
<td>Oriole</td>
<td>0.142</td>
</tr>
<tr>
<td>27</td>
<td>Perpetual</td>
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</tr>
<tr>
<td>28</td>
<td>Scarlet Charlotte</td>
<td>0.187</td>
</tr>
<tr>
<td>29</td>
<td>Sel Baresi</td>
<td>0.167</td>
</tr>
<tr>
<td>30</td>
<td>Verde a Costa Blanca</td>
<td>0.258</td>
</tr>
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</table>
Figure 1.1. Bonferroni confidence intervals for differences in covered vs. uncovered production of Swiss chard (Beta vulgaris var. cicla) across 2014-2015 and 2015-2016 production seasons (season 1 and 2). Intervals > 0, season 1 cover is more beneficial, intervals < 0 season 2 cover is more beneficial.
Figure 1.2. Season 1 Bonferroni comparison intervals of Swiss chard (*Beta vulgaris* var. *cicla*) cultivars’ total yield from covered conditions across 2014 and 2015 production seasons (season 1). Significant differences are shown when color intervals do not overlap.
Figure 1.3. Season 1 Bonferroni comparison intervals of Swiss chard (*Beta vulgaris* var. *cicla*) cultivars’ total yield from uncovered conditions across 2014 and 2015 production seasons (season 1). Significant differences are shown when color intervals do not overlap.
Figure 1.4. Season 2 Bonferroni comparison intervals of Swiss chard (Beta vulgaris var. cicla) cultivars’ total yield from covered conditions across 2015 and 2016 production seasons (season 2). Significant differences are shown when color intervals do not overlap.
Figure 1.5. Season 2 Bonferroni comparison intervals of Swiss chard (*Beta vulgaris* var. *cicla*) cultivars’ total yield from uncovered conditions across 2015 and 2016 production seasons (season 2). Significant differences are shown when color intervals do not overlap.
CHAPTER 2

Effect of Pre-plant Organic Fertilizers on Yield and Nutrient Extractability for Swiss chard (*Beta vulgaris* var. *cicla*)

(In the format appropriate for submission to HortScience)
Effect of Pre-plant Organic Fertilizers on Yield and Nutrient Extractability for
Swiss chard (*Beta vulgaris* var. *cicla*)

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Effect of Pre-plant Organic Fertilizers on Yield and Nutrient Extractability for Swiss chard (*Beta vulgaris* var. *cicla*)

Additional index words: macronutrients, micronutrients, pH, EC, nitrogen, potassium phosphorous, sugar beet, PourThru

Abstract. The demand for organic produce has shown an increasing trend over the last decade, and organic farming is one of the fastest growing segments in the U.S. agriculture (Cohn and Wheeler, 2017). A trial at Stephen F. Austin State University was conducted to determine optimum, pre-plant organic fertilizer amendment for container production of Swiss chard (*Beta vulgaris* var. *cicla*). Plugs were planted on 21 Oct. 2016 into 10.2 cm diameter pots (8.9 cm × 8.9 cm × 12.7 cm) containing Berger OM6 certified organic growing substrate. Prior to planting, 11 batches of substrate were amended with 10 organic fertilizers and one control fertilizer at a concentration of 24.92 kg N/m³. Soluble salt levels (EC) and pH levels were evaluated once a week using the PourThru method (Whipker et al., 2001). The experiment was terminated on 8 Dec. 2016 after six weeks of growth. Plants were excised from growing substrate to measure dry weight, and the whole plants (petiole and leaf) were sampled to evaluate the tissue concentration for macronutrients and micronutrients. Electrical conductivity and pH showed a general decline over time. There were small differences in EC among the treatments. Based on this trial, all fertilizers trialed were sufficient to produce Swiss chard ‘Prima Rosa’.
Introduction

The demand for organic produce has shown an increasing trend over the last decade, and organic farming is one of the fastest growing segments in U.S. agriculture (Cohn and Wheeler, 2017). Many consumers prefer organically grown plants due to various reasons including concern for their overall health and the environment (Dimitri and Greene, 2002). To grow certified organic plants effectively, growers must use a certified organic counterpart for every component in conventional systems including growing substrates, pest control products, and fertilizers.

Organic fertilizers consist of ground mineral rock, plant and animal by-products including bone and blood meals, composted manures, and ground plants like alfalfa meal (Williams, 2014). Organic fertilizers have been shown to be good for the environment because more of their ingredients derive from renewable resources as opposed to synthetic fertilizers (Flanary, 2016). Growers who switch to organic fertilizers often have to adjust their production systems for successful crop production (Kuack, 2014). Organic fertilizers can work within natural systems and cycles, and they work best for edible and ornamental crops that have a fast production time (Kuack, 2014). Similar to conventional systems, organic fertilizers can be applied either as a pre-plant fertilizer added prior to planting via incorporation into the substrate or post-plant fertilizer added through irrigation or as a top dressing. Most organic potting mixes are rich enough in fertility to support adequate plant growth for upwards of four weeks. This factor is beneficial so farmers do not have to supply labor for any additional fertility supplementation (Mattson
and Beeks, no date). However, for production past four weeks, growers often have to use supplemental nutrition to ensure a successful crop. Kuack (2014) reports that vegetable growers who produce crops with a short production time can have the best success with pre-plant amendments of granular fertilizers since they potentially could have higher concentrations of nitrogen, phosphorus, and potassium. Growers who produce for longer periods need to supplement this pre-plant fertilizer with top-dressing or a liquid feed.

Use of organic fertilizers does have its challenges, and they should only be used if organic plants are in high demand as the costs can be much higher (Kuack, 2014). Additionally, substrate electrical conductivity (EC) and pH should be regularly monitored since high salt concentrations can damage plugs (Williams, 2014). Use of organic fertilizers in crop production can result in high salt levels, especially when using manure-based composts as excess quantities can hinder and even become toxic to plants (Mattson and Beeks, no date). High soluble salts can cause many detrimental side effects including drought stress, burned roots, wilted stems, and necrotic leaves (Gruttadaurio et al., 2016). Monitoring EC levels in the substrate when applying organic fertilizers is crucial to ensure toxicity is not an issue with production. Additionally, nutrient uptake in plants can depend heavily on the pH of the growing substrate (Barnes et al., 2014). A nutrient must be soluble and remain soluble to be able to be absorbed by the plant. When transplants are grown in potting media, the pH can change rapidly. This is due to a shift in pH varying conditions including a reduced buffering capacity in potting substrate as opposed to soil (Shaw et al., n.d.). This makes monitoring pH crucial. There are many commercially available organic fertilizers on the market, but few trials have been
conducted among them to determine the best types for yield and nutrient extractability. This information would help organic growers get the best results from their organically grown crop.

Swiss chard (Beta vulgaris var. cicla) is an ornamental vegetable that is grown for production purposes, landscaping, and pot crops (Sher, 2008). Fertilizer optimizes Swiss chard yield and provides profitable returns. Typical fertilizer analysis recommended for Swiss chard is 10N-4.3P-8.3K for seedlings at a rate of 1.3 or 1.4 kg 30.4 m$^2$ and 15N-12.9P-12.45K or 10N-22.36P-14.11K for transplants (Kovatch, 2003). Nitrogen plays a key role in Swiss chard growth and development. Escher et al. (2012) analyzed how Swiss chard performed and yielded under nitrogen fertilization regimens of 0, 40, 80, 120 and 160 kg·ha$^{-1}$ at plant spacings of 0.3 and 0.5 m. The crop was completely harvested after 90 days of transplanting into the soil. Spacing at 0.5 m produced the highest total fresh weight whereas the spacing at 0.3 m produced the highest total marketable yield coupled with the 160 kg·ha$^{-1}$ application rate. However, the greater distance in spacing was beneficial for total marketable weight because in the smaller spacing the plants were more susceptible to disease making them less desirable for market. The nitrogen application showed a linear increase in total yield; however, an overallotment of nitrogen significantly increased the susceptibility of plants to disease reducing the quality and marketable production of the plant (Escher et al., 2012). Kolota and Czerniak (2010) showed that on average nitrogen in moderate doses accumulated almost 4.8 times more nitrates in the petioles than the blades of the leaf. They also found that an increase in nitrogen fertilizer from 50 kg N ha$^{-1}$ to 100 kg N ha$^{-1}$ increased yield
from 30.90 t/ha\(^{-1}\) to 40.51 t/ha\(^{-1}\) in Swiss chard (Kolota and Czerniak, 2010). Nitrogen applications can be reapplied to soil every four to six weeks with of 20N-10P-10K if desired (Kovatch, 2003). Calcium and boron should be applied as a foliar fertilizer during the growing season or calcium nitrate as a top dressing application to the Swiss chard (Starke Ayres, 2014). If micronutrients are needed, broad-spectrum foliar application is recommended (Starke Ayres, 2014). Swiss chard has value both in commercial growing and for smaller scale vegetable farmers (Shuler et al., 2003), so determining organic fertilizers that can maximize yield would be beneficial to a growing operation.

The objectives of this study were to determine which organic fertilizer produces the most Swiss chard yield and growth with a one-time pre-plant substrate amendment and to determine if nutrient concentration from harvested plant material.

**Materials and Methods**

‘Prima Rosa’ seeds were sown on 24 Sept. 2016 into 72 cell flats (6 cm × 3.8 cm × 3.8 cm) in germination substrate Sunshine Redi-earth Plug and Seedling (Agawam, MA). Plugs were fertigated once a week with Alaska (OMRI Listed) fish fertilizer (5N-0.44P-0.83K) at the labeled rate of 5 ml/4 L. Prior to planting, the trays were leached with clear water for approximately 1 minute to remove as much fertilizer concentration as possible from the plugs. Plugs were transplanted on 21 Oct. 2016 into 10.2 cm diameter pots (8.9 cm × 8.9 cm × 12.7 cm) containing Berger OM6 certified organic growing
substrate. Substrate was amended with 10 certified organic fertilizers and Osmocote (18N-2.6P-10K) as a control (Table 2.1) at a concentration of 24.92 kg N m⁻³. Plants were grown in the greenhouse at 31.6°N latitude with a day/night temperature of 22.2°C. Once a week EC and pH levels were evaluated using the PourThru method (Whipker et al., 2001). Plants were watered 30 minutes before data collection and allowed to drain. Then, saucers were placed underneath the pots, and 0.05 L of deionized water were applied to the substrate. The leachate was collected and evaluated using a HANNA 9813-6 combination EC and pH meter (HANNA Instruments, Smithfield, RI). Additionally, the height and width of the plants were measured during weeks two, four, and six. Swiss chard was grown for a total of six weeks.

The experiment was terminated on 8 Dec. 2016. Each plant was excised (both leaf and petiole) from the growing substrate to evaluate tissue nutrient concentration. All samples were dried at 60°C to constant weight. After drying, above ground plant tissue was ground in a Cyclone Sample Mill (UDY Corporation, Ft. Collins, CO) to pass a ≤ 1 mm sieve. Tissue analysis for N was performed with a C-H-N analyzer (Model 628 series, LECO, Saint Joseph, MI) by weighing 0.15-0.18 g of dried, ground tissue and placing it into the analyzer. Other nutrient concentrations were determined using the nitric digest preparation and analyzed with an inductively coupled plasma optical emission spectroscopy (ICP-OES; Model iCAP 7000 ThermoScientific, ThermoFisher, Waltham, MA). Data were subjected to PROC GLM (SAS Inst., Cary, NC).
Significantly different means ($P \leq 0.05$) were separated by Tukey’s Studentized Range Test mean separation.

Data for week five was removed for both pH and EC readings due to all the treatments having a higher pH and EC value for that week. A calibration error may have resulted in this error.

Results and Discussion

Growing Substrate pH, EC, Plant Dry Weights and Tissue Nutrient Concentration.

Both pH and EC showed a general decline over time (Figures 2.1 and 2.2). The highest pH was observed with Verdanta N-vita during the first week at 6.51. The lowest pH was observed with Verdanta Ecovita during the fourth week at 5.44 (Table 2.2). All treatments during the duration of the experiment fall within the optimum pH growing range of 5.4 - 6.8 for nutrient uptake (Nau, 2011).

The highest EC was observed in Espoma for week one at 4.0 ms cm$^{-1}$ and the lowest observed in week six for Osmocote at 0.14 ms cm$^{-1}$. Osmocote consistently had the lowest observed EC over the six-week experiment. MicroStart 7-1-1 and Sustane had the lowest observed EC four out of the six weeks for the organic fertilizer treatments (Table 2.3). A plants’ EC threshold can be highly variable. No plant damage was observed due to high EC levels.

Both pH and EC readings declined over the six-week experiment (Figures 1.2 and 2.2). The drop in EC is to be expected as the salts in the fertilizer were either leached out
of the pots or absorbed by the plants. The drop in pH may have been due to the physiological fertilizer effect (Barnes et al., 2014). There was no significant difference in dry weight ($P = 0.10$) among the treatments. Dry weights ranged from 3.05 g to 4.28 g.

**Nitrogen.** There were significant differences ($P < 0.0001$) between extractable nitrogen among the treatments. Microstart 9-0-0, San Jacinto MicroLife, and Verdanta Ecovita had the highest amounts of extractable nitrogen at 5.67% and 5.66%, respectively (Table 2.4). These are within the sufficient range for nitrogen which is between 1 and 6% of the dry weight (Bryson et al., 2014).

**Phosphorus.** There were significant differences between the extractable phosphorous ($P < 0.0001$) among the treatments. MicroStart 60 3-2-3 (1.98%), Espoma (1.99%), chicken litter (1.96%), Verdanta Ecovita (1.62%), and Carl Pool Natural Balance (1.41%) all had the highest amounts of extractable phosphorous (Table 2.4). These exceeded the sufficiency range for phosphorus (0.2-0.5% of dry weight) (Bryson et al., 2014). All of the treatments exceeded the phosphorus sufficiency range.

**Potassium.** There were significant differences between extractable potassium ($P < 0.0001$) among the treatments. MicroStart60 (6.00%), San Jacinto MicroLife (4.79%), Sustane (4.87%), Carl Pool Natural Balance (4.69%), Espoma (5.52%), chicken litter (5.20%), and Verdanta Ecovita (5.15%) had the highest amounts of extractable potassium (Table 2.4). All of the treatments listed above exceed the sufficiency level (1.5-4% of...
dry weight) (Bryson et al., 2014). Microstart 7-1-1, MicroStart 9-0-0, and Verdanta N-vita are all within the sufficiency ranges for potassium.

**Arsenic.** There were no significant differences between the treatments for extractable arsenic ($P \leq 0.18$). MicroStart 9-0-0 (0.53 mg·kg$^{-1}$) had the highest positive concentration of extractable arsenic but was not significantly different from the other treatments (Table 2.5). Arsenic was a surprising result from the analysis. Arsenic, and other trace amounts of heavy metals, can be found, however, in a number of sources of organic fertilizer (manure, rock phosphates, fish emulsions, guano, etc.). Origin of the main source of the fertilizer could play a key component of the output level of arsenic (Kuepper, 2003). No national health-based standards have been produced for levels of arsenic in vegetables and fruits in the United States. However, standards have been developed in China that limit concentrations of arsenic to no more than 0.2 mg·kg$^{-1}$ in rice, beans, and vegetables (McBride et al., 2015). MicroStart 7-1-1 (0.36 mg·kg$^{-1}$), Microstart 9-0-0 (0.53 mg·kg$^{-1}$) Carl Pool Natural Balance (0.35 mg·kg$^{-1}$), Verdanta N-Vita (0.28 mg·kg$^{-1}$), and Verdanta Ecovita (0.21 mg·kg$^{-1}$) had the highest amount of extractable arsenic, exceeding the Chinese standards. Arsenic was non-detectable in MicroStart60 and San Jacinto MicroLife. This observation should be considered when choosing an organic fertilizer. Sufficiency ranges were not provided for arsenic because it is not an essential element to plant growth.
**Boron.** Boron was also significantly different (P < 0.0001). MicroStart 60 (53.04 mg·kg⁻¹), MicroStart 7-1-1 (50.15 mg·kg⁻¹), Sustane (37.00 mg·kg⁻¹), and chicken litter (42.88 mg·kg⁻¹) were not significantly different from each other but had the highest amounts of boron (Table 2.5). All of these treatments exceed the sufficiency limit for boron (20 mg·kg⁻¹ on a dry weight basis) (Bryson et al., 2014). Verdanta Ecovita is the only treatment that fell within the sufficiency range of boron (18.51 mg·kg⁻¹).

**Zinc.** Zinc had significant differences as well (P < 0.0001). MicroStart60 (287.09 mg·kg⁻¹), Espoma (228.85 mg·kg⁻¹), and chicken litter (245.95 mg·kg⁻¹) had the highest amounts of extractable zinc (Tables 2.5). All of the treatments exceeded the sufficiency range for zinc (15-50 mg·kg⁻¹) (Bryson et al., 2014).

**Other Nutrients.** For macronutrients, there were no significant differences among treatments for calcium (P = 0.22), and sulfur (P = 0.31). For micronutrients there were no significant differences among the treatments for extractable copper (P = 0.14), iron (P = 0.30), manganese (P = 0.18) and molybdenum (P = 0.87). Magnesium showed a significant difference (P = 0.03) however, there were no significant differences among the treatments. All of the treatments fall within the sufficiency range (0.5-1.5%) for calcium. All treatments exceed the sufficiency range (0.15-0.5%) for sulfur. Only one treatment, MicroStart 9-0-0 (25.67 mg·kg⁻¹), exceeded the sufficiency range (2-20 mg·kg⁻¹) for copper, all other treatments were within range. Only one treatment, chicken litter, fell within the sufficiency range (50-75 mg·kg⁻¹) for iron. All other treatments exceeded
the sufficiency range for iron. All treatments exceeded the sufficiency range for manganese (10-50 mg·kg⁻¹). All treatments that had detectable molybdenum exceed the sufficiency level (0.2 mg·kg⁻¹) (Tables 2.4 and 2.5). No toxicity was observed in any of the treatments. These nutrients all fall within or exceed the sufficiency levels for plant analysis (Bryson et al., 2014).

**Conclusion**

All ten fertilizers trialed are viable options for use in Swiss chard pot crop production. Extractable nutrient levels were high, yet no toxicity symptoms were observed on the plants in this trial. The elevated levels of arsenic in some of the treatments may need to be considered when choosing which to implement in an organic operation. There was no obvious plant damage observed due to elevated EC readings; however, they should be also taken into consideration when choosing an organic fertilizer.
Literature Cited


Table 2.1. Percent nitrogen, phosphorous, and potassium in organic fertilizers used as pre-plant substrate amendments in a trial of *Beta vulgaris* var. *cicla* ‘Prima Rosa’.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osmocote(^z)</td>
<td>18.00</td>
<td>2.60</td>
<td>10.00</td>
</tr>
<tr>
<td>MicroStart 60 3 2 3</td>
<td>3.00</td>
<td>2.20</td>
<td>2.49</td>
</tr>
<tr>
<td>MicroStart 7-1-1</td>
<td>7.00</td>
<td>0.43</td>
<td>0.83</td>
</tr>
<tr>
<td>MicroStart 9-0-0</td>
<td>9.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>San Jacinto MicroLife</td>
<td>6.00</td>
<td>1.80</td>
<td>3.32</td>
</tr>
<tr>
<td>Sustane</td>
<td>8.00</td>
<td>2.20</td>
<td>3.32</td>
</tr>
<tr>
<td>Carl Pool Natural Balance</td>
<td>5.00</td>
<td>2.15</td>
<td>4.15</td>
</tr>
<tr>
<td>Verdanta N-vita</td>
<td>9.00</td>
<td>1.72</td>
<td>2.50</td>
</tr>
<tr>
<td>Verdanta Ecovita</td>
<td>7.00</td>
<td>2.15</td>
<td>8.30</td>
</tr>
<tr>
<td>Espoma</td>
<td>3.00</td>
<td>1.72</td>
<td>3.32</td>
</tr>
<tr>
<td>Chicken Litter</td>
<td>3.00</td>
<td>0.40</td>
<td>0.80</td>
</tr>
</tbody>
</table>

\(^z\) Control chemical fertilizer treatment

Table 2.2. Average pH of growing substrate per treatment, per week for *Beta vulgaris* var. *cicla* ‘Prima Rosa’.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>28-Oct-16</th>
<th>11-Nov-16</th>
<th>17-Nov-16</th>
<th>27-Nov-16</th>
<th>8-Dec-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osmocote(^z)</td>
<td>6.28 a(^z)</td>
<td>6.35 a(^z)</td>
<td>6.21 ab(^z)</td>
<td>5.87 ab(^z)</td>
<td>5.89 abcd (^z)</td>
</tr>
<tr>
<td>MicroStart 60</td>
<td>6.20 c</td>
<td>5.96 bc</td>
<td>5.91 bc</td>
<td>5.78 ab</td>
<td>5.80 bcd</td>
</tr>
<tr>
<td>MicroStart 7-1-1</td>
<td>6.28 bc</td>
<td>6.15 abc</td>
<td>5.93 abc</td>
<td>5.60 b</td>
<td>5.60 d</td>
</tr>
<tr>
<td>MicroStart 9-0-0</td>
<td>6.43 ab</td>
<td>6.20 ab</td>
<td>6.05 abc</td>
<td>5.75 ab</td>
<td>5.71 cd</td>
</tr>
<tr>
<td>San Jacinto MicroLife</td>
<td>6.39 ab</td>
<td>6.23 ab</td>
<td>6.09 abc</td>
<td>5.58 b</td>
<td>5.51 d</td>
</tr>
<tr>
<td>Sustane</td>
<td>6.37 ab</td>
<td>6.29 a</td>
<td>6.16 abc</td>
<td>5.87 ab</td>
<td>6.30 ab</td>
</tr>
<tr>
<td>Carl Pool Natural Balance</td>
<td>6.33 bc</td>
<td>6.21 ab</td>
<td>6.11 abc</td>
<td>5.79 ab</td>
<td>6.18 abc</td>
</tr>
<tr>
<td>Verdanta N-vita</td>
<td>6.51 ab</td>
<td>6.33 a</td>
<td>6.11 abc</td>
<td>5.66 ab</td>
<td>5.73 cd</td>
</tr>
<tr>
<td>Verdanta Ecovita</td>
<td>6.32 bc</td>
<td>6.29 a</td>
<td>6.12 abc</td>
<td>5.44 b</td>
<td>5.49 d</td>
</tr>
<tr>
<td>Espoma</td>
<td>5.98 d</td>
<td>5.90 c</td>
<td>5.84 c</td>
<td>5.61 b</td>
<td>5.75 bcd</td>
</tr>
<tr>
<td>Chicken Litter</td>
<td>6.41 ab</td>
<td>6.14 abc</td>
<td>6.24 a</td>
<td>6.08 a</td>
<td>6.44 a</td>
</tr>
</tbody>
</table>

\(^z\) Mean separation (columns) by Tukey’s multiple range test at P ≤ 0.05
\(^z\) Control chemical fertilizer treatment
Table 2.3. Average EC of growing substrate per treatment per week for Beta vulgaris var. cicla ‘Prima Rosa’.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>28-Oct-16</th>
<th>11-Nov-16</th>
<th>17-Nov-16</th>
<th>27-Nov-16</th>
<th>8-Dec-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.47 f'z</td>
<td>0.34 f'z</td>
<td>0.26 d'z</td>
<td>0.18 c'z</td>
<td>0.14 c'z</td>
</tr>
<tr>
<td>Chemical fertilizer treatment</td>
<td>1.90 b</td>
<td>1.47 cd</td>
<td>0.81 cd</td>
<td>0.35 bc</td>
<td>0.25 bc</td>
</tr>
<tr>
<td>MicroStart 7-1-1</td>
<td>0.74 ef</td>
<td>0.80 def</td>
<td>0.61 cd</td>
<td>0.29 c</td>
<td>0.15 c</td>
</tr>
<tr>
<td>MicroStart 9-0-0</td>
<td>0.94 def</td>
<td>1.18 cde</td>
<td>0.74 cd</td>
<td>0.42 bc</td>
<td>0.26 bc</td>
</tr>
<tr>
<td>San Jacinto MicroLife</td>
<td>1.43 bcd</td>
<td>1.61 c</td>
<td>1.12 bc</td>
<td>0.72 ab</td>
<td>0.42 abc</td>
</tr>
<tr>
<td>Sustane</td>
<td>0.81 ef</td>
<td>0.60 ef</td>
<td>0.31 d</td>
<td>0.19 c</td>
<td>0.15 c</td>
</tr>
<tr>
<td>Carl Pool Natural Balance</td>
<td>1.21 cde</td>
<td>1.19 cde</td>
<td>0.77 cd</td>
<td>0.23 c</td>
<td>0.27 bc</td>
</tr>
<tr>
<td>Verdanta N-vita</td>
<td>0.97 def</td>
<td>0.93 cdef</td>
<td>0.85 cd</td>
<td>0.43 bc</td>
<td>0.35 abc</td>
</tr>
<tr>
<td>Verdanta Ecovita</td>
<td>1.52 bc</td>
<td>2.40 b</td>
<td>1.85 a</td>
<td>0.98 a</td>
<td>0.84 a</td>
</tr>
<tr>
<td>Espoma</td>
<td>4.00 a</td>
<td>3.80 a</td>
<td>1.66 ab</td>
<td>1.00 a</td>
<td>0.66 ab</td>
</tr>
<tr>
<td>Chicken Litter</td>
<td>1.55 bc</td>
<td>1.01 cdef</td>
<td>0.48 d</td>
<td>0.17 c</td>
<td>0.22 bc</td>
</tr>
</tbody>
</table>

\( ^2 \) Mean separation (columns) by Tukey’s multiple range test at P ≤ 0.05
\( ^{y} \) Control chemical fertilizer treatment

Table 2.4. Dry weight and foliar tissue concentrations of macro-elements of Beta vulgaris var. cicla ‘Prima Rosa’. Tissue samples taken after six weeks of growth.

<table>
<thead>
<tr>
<th>Dry Wt (g)</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osmocote</td>
<td>3.05 a'z 4.50 c'z 1.12 bc'z</td>
<td>4.36 bde'z 0.59 a'z 0.89 a'z 0.69 a'z</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MicroStart 60 3-2-3</td>
<td>4.18 a</td>
<td>3.65 de</td>
<td>1.98 a</td>
<td>6.00 a</td>
<td>0.59 a</td>
<td>0.80 a</td>
</tr>
<tr>
<td>MicroStart 7-1-1</td>
<td>3.73 a</td>
<td>4.38 dc</td>
<td>1.00 c</td>
<td>3.89 cd</td>
<td>0.72 a</td>
<td>1.11 a</td>
</tr>
<tr>
<td>MicroStart 9-0-0</td>
<td>3.66 a</td>
<td>5.67 a 0.92 c 3.54 d</td>
<td>0.65 a</td>
<td>1.00 a</td>
<td>0.62 a</td>
<td></td>
</tr>
<tr>
<td>San Jacinto MicroLife</td>
<td>4.13 a</td>
<td>5.66 a 1.01 c</td>
<td>4.79 abcd</td>
<td>0.57 a</td>
<td>1.00 a</td>
<td>0.79 a</td>
</tr>
<tr>
<td>Sustane</td>
<td>3.85 a</td>
<td>3.57 e</td>
<td>1.15 bc 4.87 abcd</td>
<td>0.52 a</td>
<td>0.78 a</td>
<td>0.68 a</td>
</tr>
<tr>
<td>Carl Pool Natural Balance</td>
<td>4.23 a 4.59 bc</td>
<td>1.41 abc</td>
<td>4.69 abcd</td>
<td>0.66 a</td>
<td>0.88 a</td>
<td>0.61 a</td>
</tr>
<tr>
<td>Verdanta N-vita</td>
<td>4.13 a 5.29 ab</td>
<td>1.16 bc 3.65 dc</td>
<td>0.59 a</td>
<td>0.97 a</td>
<td>0.72 a</td>
<td></td>
</tr>
<tr>
<td>Verdanta Ecovita</td>
<td>3.13 a 5.48 a 1.62 abc 5.15 abc</td>
<td>0.60 a</td>
<td>0.81 a</td>
<td>0.85 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Espoma</td>
<td>3.88 a</td>
<td>3.70 de 1.99 a</td>
<td>5.52 ab</td>
<td>0.52 a</td>
<td>0.78 a</td>
<td>0.87 a</td>
</tr>
<tr>
<td>Chicken Litter</td>
<td>4.28 a 2.97 e 1.96 a 5.20 abc</td>
<td>0.64 a</td>
<td>0.80 a</td>
<td>0.79 a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( ^2 \) Mean separation (columns) by Tukey’s multiple range test at P ≤ 0.05
\( ^{y} \) Control chemical fertilizer treatment
**Table 2.5.** Foliar tissue concentrations of micro-elements of *Beta vulgaris* var. cicla ‘Prima Rosa’. Tissue samples taken after six weeks of growth.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>As  (mg kg(^{-1}))</th>
<th>B   (mg kg(^{-1}))</th>
<th>Cu  (mg kg(^{-1}))</th>
<th>Fe  (mg kg(^{-1}))</th>
<th>Mn  (mg kg(^{-1}))</th>
<th>Mo  (mg kg(^{-1}))</th>
<th>Zn  (mg kg(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osmocote(^2)</td>
<td>0.07 a (^z)</td>
<td>34.00 bcde (^z)</td>
<td>9.38 a (^z)</td>
<td>109.74 a (^z)</td>
<td>362.23 a (^z)</td>
<td>- -</td>
<td>118.23 c (^z)</td>
</tr>
<tr>
<td>MicroStart 60 3-2-3</td>
<td>- -</td>
<td>53.04 a</td>
<td>14.10 a</td>
<td>77.12 a</td>
<td>342.35 a</td>
<td>- -</td>
<td>287.09 a</td>
</tr>
<tr>
<td>MicroStart 7-1-1</td>
<td>0.36 a</td>
<td>50.15 ab</td>
<td>15.21 a</td>
<td>139.29 a</td>
<td>287.70 a</td>
<td>0.89 a</td>
<td>143.19 bc</td>
</tr>
<tr>
<td>MicroStart 9-0-0</td>
<td>0.53 a</td>
<td>34.24 bcde</td>
<td>25.67 a</td>
<td>205.93 a</td>
<td>293.85 a</td>
<td>- -</td>
<td>121.03 c</td>
</tr>
<tr>
<td>San Jacinto MicroLife</td>
<td>- -</td>
<td>30.51 cde</td>
<td>8.00 a</td>
<td>139.14 a</td>
<td>373.74 a</td>
<td>- -</td>
<td>109.72 c</td>
</tr>
<tr>
<td>Sustane</td>
<td>0.14 a</td>
<td>37.00 abdc</td>
<td>10.66 a</td>
<td>80.17 a</td>
<td>295.36 a</td>
<td>- -</td>
<td>124.53 c</td>
</tr>
<tr>
<td>Carl Pool Natural Balance</td>
<td>0.35 a</td>
<td>26.44 de</td>
<td>7.89 a</td>
<td>128.66 a</td>
<td>261.52 a</td>
<td>- -</td>
<td>98.30 c</td>
</tr>
<tr>
<td>Verdanta N-vita</td>
<td>0.28 a</td>
<td>21.51 de</td>
<td>11.24 a</td>
<td>120.29 a</td>
<td>265.38 a</td>
<td>0.99 a</td>
<td>91.81 c</td>
</tr>
<tr>
<td>Verdanta Ecovita</td>
<td>0.22 a</td>
<td>18.51 e</td>
<td>8.12 a</td>
<td>135.65 a</td>
<td>360.19 a</td>
<td>1.07 a</td>
<td>95.88 c</td>
</tr>
<tr>
<td>Espoma</td>
<td>0.14 a</td>
<td>36.48 bcd</td>
<td>13.20 a</td>
<td>94.62 a</td>
<td>320.98 a</td>
<td>0.71 a</td>
<td>228.85 ab</td>
</tr>
<tr>
<td>Chicken Litter</td>
<td>0.19 a</td>
<td>42.88 abc</td>
<td>13.87 a</td>
<td>66.90 a</td>
<td>288.16 a</td>
<td>1.02 a</td>
<td>245.95 a</td>
</tr>
</tbody>
</table>

\(^2\) Mean separation (columns) by Tukey’s multiple range test at P ≤ 0.05
\(^\circ\) Control chemical fertilizer treatment
Figure 2.1. Change in substrate average pH over time with *Beta vulgaris* var. *cicla* ‘Prima Rosa’ Swiss chard over a six-week period.
Figure 2.2. Change in substrate average EC over time with *Beta vulgaris* var. * cicla* ‘Prima Rosa’ Swiss chard over a six-week period.
CHAPTER 3

Effectiveness of Using Google Sheets with University Students to Assess Diversity in Vegetable Crops

(In the format appropriate for submission to HortScience)
Effectiveness of Using Google Sheets with University Students to Assess Diversity in Vegetable Crops

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We are grateful for the seed catalogs provided by Johnny’s Selected Seeds (Winslow, ME) for this research experiment.

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Abstract. In the 2016 spring and fall semesters, students enrolled in Crop Science at Stephen F. Austin State University (SFA) were given an assignment where they were instructed to use Google Sheets to assess diversity of traits in a seed catalog. Students were assessed before and after the assignment on their experience level with agriculture, gardening, and seed catalogs, their comfort level with Google Sheets and Microsoft Excel, collecting and analyzing data, and their opinion on the effectiveness in using multiple people to collect data and using Google Sheets. In total, 102 students assessed 1056 cultivars in Google Sheets. Overall, students were able to use Google Sheets to compile data from multiple people to gain insight on which traits occur most often in seed catalogs. All students, agriculture students, female students, and fall semester students showed a higher level of comfort using Google Sheets/ Microsoft Excel after the assignment. The results also showed that students had a better grasp of what a trait was after completing the assignment. Additionally, students created more robust definitions for a trait and a cultivar post-assignment. From the comments provided on the survey, it
was evident that students learned about agriculture and gardening, traits and cultivars, how to interpret seed catalogs, how to use technology, and collaboration. This activity could be useful for agriculture educators.

**Introduction**

In agriculture education, educators are always searching for methods to integrate technology in the classroom through real world applications. The diversity of technology used in educational settings has expanded greatly in the past 20 years (Morgan et al., 2007). Instructional technology like computers continues to enhance the educative process (Schacter, 1999), and now students also have access to iPads and other handheld electronic devices (Kyanka-Muggart, 2013). When technology is used in the classroom, it can improve mastery of content, increase students’ positive attitudes towards learning, prepare students for future careers, and potentially lessen costs of instruction (Williams et al., 2014). Technology has the capacity to support students with varying ability levels, opening up more possible learning opportunities (Culatta and Adams, 2014). By engaging with educators technology, educators can bridge the gap between the way students live and the way they learn (Kyanka-Muggart, 2013).

Despite technology becoming a part of every-day life, a lack of support from school systems regarding technology use (Eristi et al., 2012) has resulted in little evidence that shows technology and online learning are improving learning outcomes for most students (Herold, 2016). Common problems with technology include limited access
or prohibitive cost. Access to technology is not always available even though technology is quickly becoming a prerequisite for higher quality education programs (Culatta and Adams, 2014). While the federal government has attempted to provide affordable high-speed internet and free online sources to even the most remote schools (Herold, 2016), costs of technology can still be problematic (Garland, 2014). Therefore, if technology is to be used in the classroom, reducing costs and increasing availability can create more possible opportunities for learning.

In 2010 the Google Apps Suite announced an addition to its software that included Google Sheets (Google, 2009). The Google Apps Suite is free and provides a small set amount of storage. The apps mimic their Microsoft Office counterparts without any cost. Google Apps Suite lets users compose, edit, and share documents, spreadsheets, and presentations. Because multiple users can access files, it facilitates easy collaboration in real time across the internet (Sawers, 2011). Few studies have been conducted to evaluate students learning outcomes after using Google Apps Suite. This is largely due to the lack of knowledge about possibilities for using this application in education (Zhou et al., 2012). Nevertheless, the Google Apps Suite is a valuable tool for collaborative communication and learning (Zhou et al., 2012).

Millennials are showing that they have a greater interest in participating in gardening and growing their own food. Concepts like urban farming, school gardens, and community sustainable agriculture programs have heightened interest among young people in acting more sustainably and growing their own food (Baldwin, 2017). Incorporating seed catalogs, can help them further their interest and knowledge in what
they can utilize in their own gardens, as well as giving them an idea of sought after traits.

Seed catalogs offer students a glimpse at the diversity of crop varieties and cultivars. Students can use text features in the catalog to locate information in order to understand characteristics of plants that are sold by various seed companies. Often, seed companies are willing to distribute their catalogs for free to educational institutions for classroom use, which then allows students to see the diversity of crops and food grown in agricultural settings. These publications are a great inspiration for garden-related activities that can help support classroom learning (NYBG, 2017).

For this study, an assignment was created where college students used Google Sheets to assess the diversity of vegetable crop traits in seed catalogs. The purpose of this study was to evaluate the effectiveness of using Google Sheets to facilitate collaborative learning in an agriculture classroom curriculum.

**Materials and Methods**

In the 2016 spring and fall semesters, students in the freshman level Crop Science course at SFA were given an outside of class assignment where they were instructed to use Google Sheets to assess diversity of traits in a seed catalog. Seed catalogs were procured from Johnny’s Selected Seeds (Albion, ME) and handed out with the assignment. Students were instructed to choose a crop by signing up for it on Google Sheets and then to choose ten cultivars of that crop. Students were told to not select a crop that another person had already selected in their lab section; however, crops could
be repeated in different lab sections. Students then used an Excel spreadsheet to enter the selected crop cultivars. Microsoft Excel was used to reduce initial confusion of editing in Google Sheets. Based on experience with this assignment in previous years a preliminary list of traits for students to use as examples was developed in Excel, and students were encouraged if they observed any new traits listed to add those to the Excel list. Once the spreadsheet was set up, students read the traits that were listed for each cultivar in the seed catalog and marked the trait with a 1 if the trait was listed and a 0 if it was not listed.

A quasi-experimental pre/post-test study was designed to investigate the research question in the spring and fall semesters, the pre-survey and the assignment were given on 18 Apr. – 27 Apr. 2016 and 23 Sept. – 3 Oct. 2016, respectively. Students were instructed to complete the pre-survey prior to doing the assignment. The post survey was conducted from 4 May – 14 May 2016 and 7 Oct. – 17 Oct. 2016.

For the surveys, data collected on the students included gender, college, major, year classification, ethnicity, and hometown/zip code. Students were also asked to define a trait and a cultivar in their own words and not copy from a source. Answers for a trait were then coded based on the presence or absence of a statement about genetics and characteristics. Answers for the question about a cultivar were coded based on the presence or absence of a statement about unique crop characters and man-made efforts to perpetuate these. Additionally, students were asked to rate their level of experience, comfort, or opinion on seven specific questions during both the pre- and post-surveys (note: question numbers do not correspond with question numbers in the survey listed in the appendix).
Q1: What level of experience do you have with agriculture?
Q2: What level of experience do you have with gardening?
Q3: What level of experience do you have with using seed catalogs?
Q4: How comfortable are you with using Google Sheets and Microsoft Excel?
Q5: How comfortable are you with collecting and analyzing data?
Q6: In your opinion, how effective is using multiple people to collect a large quantity of data?
Q7: In your opinion, how effective is using Google Sheets to collect a large quantity of data?

For Q1–Q5, students answered the seven questions using a Likert scale where 1 = very uncomfortable, 2 = somewhat uncomfortable, 3 = neutral, 4 = somewhat comfortable, and 5 = comfortable. For Q6 and Q7, the Likert scale used was 1 = not effective, 2 = somewhat not effective, 3 = indifferent/neutral, 4 = somewhat effective, and 5 = very effective. In the post survey, we asked students to provide feedback if the assignment changed their perspective on Q1–Q7. Additionally, we asked students if they encountered any obstacles or had any additional feedback from the assignment. Data were analyzed using SPSS (version 23) used a paired t-test, and responses were counted significant at an alpha value of 0.05.
Results and Discussion

Combined Student Assignment Answers. In total, 102 students assessed 1056 cultivars in Google Sheets. In the 2016 spring and fall semesters, 35 out of 52 students (67.3%) and 67 out of 89 students (75.3%) completed the assignment on Google Sheets assessing 391 and 665 cultivars, respectively. The top five traits observed for the spring were 279 for color (71%), 277 for appearance (71%), 274 for flavor/taste (70%), 245 for size (63%), and 218 for shape (56%, Fig 3.1). The top five traits observed for the fall were the same: 506 for color (76%), 486 for appearance (73%), 411 for flavor/taste (62%), 388 for size (58%), and 314 for shape (47%) (Fig 3.2). The top five observed traits for both semesters were the same and in the same descending order. Since students assessed the same catalog in each semester, this result is somewhat expected. These traits are important characteristics on which breeders frequently focus (Bernardo, 2014).

Combined Student Survey Responses. In total, 55 students completed both surveys out of a total of 141 from both semesters, for a response rate of 39%. Answers by students to Q3 were interesting, but not significant. Results show that student experience levels with seed catalogs increased 0.31 from 1.89 pre-survey to 2.20 post-survey (P = 0.06). Answers by students to Q4 were significantly different (P = 0.007). Students indicated their comfort level with Google Sheets and Microsoft Excel increased by 0.44 from 3.33 pre-survey to 3.76 post-survey. None of the other questions were significantly different between the pre-survey and post-survey.
Agriculture Majors vs. Other Majors. Agriculture students’ answers to Q4 were significantly different from students in other colleges ($P = 0.011$). Students indicated that their comfort level with Google Sheets and Microsoft Excel increased by 0.46 from 3.32 pre-survey to 3.78 post-survey. Answers to Q6 were significantly different ($P = 0.010$), as well. Their opinion on how effective using multiple people to collect large quantities increased by 0.30 from 4.27 pre-survey to 4.57 post-survey. All other answers were not significant for agriculture and non-agriculture students; there was no significant difference between pre-survey and post-survey.

Male vs. Female. Male student answers to Q6 were significantly different ($P = 0.029$). Male students indicated a change of 4.26 pre-survey to 4.61 post-survey (difference of 0.35) on their opinion on using multiple people to collect a large quantity of data. Female students answers to Q4 ($P = 0.006$) and Q7 ($P = 0.051$) were significantly different than the male students. Female students indicated an increase in comfort level when using Google Sheets and Microsoft Excel by 0.57 from 3.31 pre-survey to 3.88 post-survey. Female students also indicated an increase in comfort level when collecting and analyzing data by 0.28 from 3.75 pre-survey to 4.03 post-survey. Female students indicated a change of opinion for Q7 from 4.63 pre-survey to 4.19 post-survey. The decrease in opinion of how effective is using Google Sheets to collect a large quantity of data could be attributed to other students in their class or initial confusion of using a new program. Other questions were not significantly different pre- or post-survey.
Spring vs. Fall. There were no significant differences between the pre-survey answers and the post-survey answers for the students in the spring semester. Students in the fall semester class had a significant difference in Q4 (P = 0.034). Students in the fall semester indicated an increase in comfort level when using Google Sheets and Microsoft Excel by 0.41 from 3.23 pre-survey to 3.64 post-survey.

Student Definitions of Cultivar and Traits. There were significant differences between pre-survey and post-survey answers for the character component of their definition of a trait (P = 0.002). On the pre-survey 18% of students indicated in their definition that a trait has a “unique character” and post-survey the percentage increased to 42%. Answers for the genetic component of a trait were not significantly different. There were no significant differences between pre-survey and post-survey answers for the variation of species or the selective breeding component of their definition of a cultivar.

From a visual perspective, the answers students gave were generally longer post survey. Students answer length to “What is a trait?” were 8.4 words long pre-survey and 9.6 words long post-survey. Students’ answers to “What is a cultivar” were 8.5 words long pre-survey and increased to 9.16 post-survey.

Student Feedback. Additional data was procured from requested feedback during the post-survey, and the number of students who provided comments are shown in parentheses. For Q1-Q3, students were asked to give feedback if the assignment changed
their perspective on the level of experience they had with agriculture, gardening, and seed
catalogs. In total 32 students provided responses. Common comments were lack of
awareness of different cultivars in crops (10, 31.3%), increased knowledge of agriculture
and/or gardening (9, 28.1%), increased familiarity with seed catalogs (7, 22.6%),
considering a new crop for cultivation (6, 18.8%), positive remarks on the assignment (4,
12.5%), and agriculture being vital for life (1, 3.1%). When students were asked after Q4
and Q5 how the assignment changed their perspective for the level of experience they had
with Google Sheets and Microsoft Excel and collecting and analyzing data, 10 students
provided comments. Comments included enhanced learning (2, 20%), no change (2,
20%); it was difficult (1, 10%), easy (1, 10%), and already experienced with collecting
and analyzing data (1, 10%). When students were asked in Q6 about their perspective
changing for multiple people collecting data, 12 provided feedback. Explanations
included more people collecting data was better (9, 75%), it enhances collaboration (1,
8.3%), and one (8.3%) comment was made about “core factors recorded for all cultivars”
indicating some understanding of using data to perceive patterns. For Q7, students were
asked if their perspective changed on using Google Sheets to collect data, seven students
responded. Six students responded it was easy or great, and one said it allowed location-
independent collaboration.

Students were also asked if they encountered any obstacles during the assignment,
and 38 students provided the following feedback: no obstacles (18, 47.3%), confusion or
difficulty using the seed catalog (5, 13.16%), unclear instructions (3, 7.90%), trouble
recognizing or identifying traits (3, 7.90%), difficulty but learning occurred (3, 7.90%),
fear of being wrong (2, 5.26%), confusion with Google Sheets or Microsoft Excel (2, 5.26%), technical difficulties (2, 5.26%), and no learning occurred (1, 2.63%). For the final open response feedback, 20 students responded, and comments included positive enjoyment of the activity (10, 50%), no comments (4, 20%), more directions on traits and technology use (2, 10%), increased experience with seed catalogs (1, 5%), increased experience with computer programs (1, 5%), provided instructional material was helpful (1, 5%), learning occurred (1, 5%), and enjoyed the diversity in crops (1, 5%). Additional feedback allows the student to provide any other information that was not asked in previous questions that they want to include.

In summary, students said that they had a lack of awareness of different cultivars and that this assignment increased their knowledge of agriculture. Majority of the students that gave feedback believed that using more people to collect data was helpful and that they didn’t run into many obstacles completing the assignment. This feedback, both positive and negative, helps to improve the lesson plan and make it more effective in future use.

**Conclusion**

Overall, students were able to use Google Sheets to compile data from multiple people to gain insight on which traits occur most often in seed catalogs (color, appearance, flavor/taste, size, and shape). Combined students, agriculture students, female students, and fall semester students showed a higher level of comfort using
Google Sheets and Microsoft Excel after the assignment. Both agriculture students and male students exhibited an increase in agreement with their opinion of the effectiveness of using multiple people to collect a large quantity of data. Female students’ opinions increased about their comfort level using the technology and collecting and analyzing data. The results also showed that students had a better grasp of what a trait was after finishing the post-survey. Additionally, students created more robust definitions for a trait and a cultivar post-assignment. From the comments provided from the survey, it was evident that students learned more about agriculture and gardening, traits and cultivars, how to interpret seed catalogs, how to use technology, and collaboration. Additionally, positive comments reinforce the use of this activity in the agriculture classroom. Constructive criticism about confusion, unclear instructions, and difficulty using the seed catalogs can help to better prepare educators when using these types of learning assignments.
Literature Cited


Schacter, J., 1999. The impact of education technology on student achievement: What the most current research has to say. Milken Exchange on Education Technology. ED. 430.537.

Figure 3.1. Spring 2016 Crop Science (AGN 110) student counts of trait observations observed from Johnny’s Selected Seed catalog descriptions.
Figure 3.2. Fall 2016 Crop Science (AGN 110) student counts of trait observations observed from Johnny’s Selected Seed catalog descriptions.
APPENDIX

Pre – assignment survey given to students of AGN 110 (Crop Science class) for completion

Q1 USE OF GOOGLE DOCS TO ASSESS DIVERSITY IN VEGETABLE CROPS
Jared Barnes, Ph.D., is conducting a research project on the use of Google docs to evaluate diversity of traits within a seed catalog. You have been sent this survey because you are a student at Stephen F. Austin State University taking Crop Science (AGN 110).

The expectations with this research is to illustrate that evaluating cultivars in seed catalogs is a useful pedagogical activity and that Google docs is a useful technological tool for collaborative learning. We value your views and opinions on this topic and appreciate you taking the time to complete this 15 minute survey. Your student ID number will be collected for this survey to be used only as a unique identifier. It will not be shared with anyone and will not be used to identify you during research analysis.

Your Involvement
I agree to take part in this project which aims to understand how Google docs can be used to evaluate the diversity of traits present in vegetables in a seed catalog and enhance learning. I understand that agreeing to take part means that I am willing to complete the survey accurately and honestly to the best of my ability. I understand that any information I provide is confidential, and that no information that could lead to the identification of any individual will be disclosed in any reports on the project, or to any other party. I understand that this research may be included in a research article, but that no identifying information will ever be reported. I also understand that my participation is voluntary, that I can choose not to participate in part or all of the survey, and that I can withdraw at any stage of the survey without being penalized or disadvantaged in any way. I understand that once I complete and submit the survey, I am no longer able to withdraw my participation.  

We greatly appreciate your assistance. If you have any questions or concerns about this research study, please feel free to contact me by telephone at 936-468-7850 or via e-mail at barnesj@sfasu.edu. Any concerns with this research may be also be directed to the Office of Research and Sponsored Programs at 936-468-6606. -- By clicking the Next arrows, I give my approval:
Q2 What is your gender?

- Male (1)
- Female (2)

Q3 What school are you a student in a Stephen F. Austin State University?

- Arthur Temple College of Forestry and Agriculture (1)
- College of Fine Arts (2)
- College of Liberal and Applied Arts (3)
- College of Sciences and Mathematics (4)
- James I. Perkins College of Education (5)
- Nelson Rusche College of Business (6)
- Other (7) ____________________

Q4 What is your current major?

- Agribuisness (1)
- Agriculture Development (2)
- Ag Engineering Technology (4)
- Animal Science (5)
- Horticulture (6)
- Poultry Science (7)
- Other: (9) ____________________

Q5 What is your current student classification for the spring 2016 semester?

- Freshman (1)
- Sophomore (2)
- Junior (3)
- Senior (4)
- Other (5) ____________________
Q6 What is your Ethnicity?

☐ Hispanic (1)
☐ American Indian/Alaska Native (2)
☐ Asian (3)
☐ Black/African American (4)
☐ Native Hawaiian/Pacific Islander (5)
☐ White/Non-Hispanic (6)
☐ Wish not report (7)

Q7 What is the zip code of your home town?

Q8 What is your student ID#? (Your identity will not be used in the analysis of this data, only for giving you points for completion and linking your survey responses.)

Q9 In your own words, what is a trait in regards to plants in crop science? (This response is not graded for accuracy, please do not copy from the handout, your notes, or another reference source.)

Q10 In your own words, what is a cultivar? (This response is not graded for accuracy, please do not copy from the handout, your notes, or another reference source.)
Q11 Please answer the following questions.

<table>
<thead>
<tr>
<th>What level of experience do you have with agriculture? (3)</th>
<th>1 Very Uncomfortable (1)</th>
<th>2 Somewhat Uncomfortable (2)</th>
<th>3 Neutral (3)</th>
<th>4 Somewhat Comfortable (4)</th>
<th>5 Very comfortable (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>What level of experience do you have with gardening? (4)</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
</tr>
<tr>
<td>What level of experience do you have with using seed catalogs? (5)</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
<td>☒</td>
</tr>
</tbody>
</table>
Q16 Please answer the following questions.

<table>
<thead>
<tr>
<th>1 Very Uncomfortable (1)</th>
<th>2 Somewhat Uncomfortable (2)</th>
<th>3 Indifferent/Neutral (3)</th>
<th>4 Somewhat Comfortable (4)</th>
<th>5 Very Comfortable (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>How comfortable are you with using Google sheets and Microsoft Excel? (4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How comfortable are you collecting and analyzing data? (3)</td>
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</tr>
</tbody>
</table>

Q12 Have you ever used any of the following to collaborate on a class project?

<table>
<thead>
<tr>
<th></th>
<th>Yes (1)</th>
<th>No (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Sheets (1)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Google Docs (2)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Google Slides (3)</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Q13 Please answer the following question.

<table>
<thead>
<tr>
<th>In your opinion how effective is using multiple people to collect a large quantity of data? (1)</th>
<th>1 Not effective (1)</th>
<th>2 Somewhat not effective (2)</th>
<th>3 Indifferent/Neutral (3)</th>
<th>4 Somewhat effective (4)</th>
<th>5 Very effective (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>〇</td>
<td>〇</td>
<td>〇</td>
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<td>〇</td>
<td>〇</td>
</tr>
</tbody>
</table>
Q14 Please answer the following question.

<table>
<thead>
<tr>
<th>In your opinion how effective is using Google sheets to collect a large quantity of data? (1)</th>
<th>0 I've never used Google sheets before (6)</th>
<th>1 Not effective (1)</th>
<th>2 Somewhat not effective (2)</th>
<th>3 Indifferent/Neutral (3)</th>
<th>4 Somewhat effective (4)</th>
<th>5 Very effective (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
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Your Involvement I agree to take part in this project which aims to understand how Google docs can be used to evaluate the diversity of traits present in vegetables in a seed catalog and enhance learning. I understand that agreeing to take part means that I am willing to complete the survey accurately and honestly to the best of my ability. I understand that any information I provide is confidential, and that no information that could lead to the identification of any individual will be disclosed in any reports on the project, or to any other party. I understand that this research may be included in a research article, but that no identifying information will ever be reported. I also understand that my participation is voluntary, that I can choose not to participate in part or all of the survey, and that I can withdraw at any stage of the survey without being penalized or disadvantaged in any way. I understand that once I complete and submit the survey, I am no longer able to withdraw my participation. We greatly appreciate your assistance. If you have any questions or concerns about this research study, please feel free to contact me by telephone at 936-468-7850 or via e-mail at barnesj@sfasu.edu. Any concerns with this research may be also be directed to the Office of Research and Sponsored Programs at 936-468-6606. -- By clicking the Next arrows, I give my approval:
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- Male (1)
- Female (2)
- Other

Q3 What school are you a student in a Stephen F. Austin State University?
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- James I. Perkins College of Education (5)
- Nelson Rusche College of Business (6)
- Other (7) ____________________

Q4 What is your current major?
- Agribusiness (1)
- Agriculture Development (2)
- Ag Engineering Technology (4)
- Animal Science (5)
- Horticulture (6)
- Poultry Science (7)
- Other: (9) ____________________

Q5 What is your current student classification for the spring 2016 semester?
- Freshman (1)
- Sophomore (2)
- Junior (3)
- Senior (4)
- Other (5) ____________________

Q6 What is your Ethnicity?
- Hispanic (1)
- American Indian/Alaska Native (2)
- Asian (3)
☐ Black/African American (4)
☐ Native Hawaiian/Pacific Islander (5)
☐ White/Non-Hispanic (6)
☐ Wish not report (7)
Q7 What is the zip code of your home town?

Q8 What is your student ID#? (Your identity will not be used in the analysis of this data, only for giving you points for completion and linking your survey responses.)

Q9 After this assignment, in your own words, what is a trait in regards to plants in crop science? (This response is not graded for accuracy, please do not copy from the handout, your notes, or another reference source.)

Q10 After this assignment, in your own words, what is a cultivar? (This response is not graded for accuracy, please do not copy from the handout, your notes, or another reference source.)
Q11 Please answer the following question.

<table>
<thead>
<tr>
<th>Question</th>
<th>1 Very unexperienced (1)</th>
<th>2 Somewhat unexperienced (2)</th>
<th>3 Neutral (3)</th>
<th>4 Somewhat Experienced (4)</th>
<th>5 Very experienced (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>What level of experience do you have with agriculture? (3)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>What level of experience do you have with gardening? (4)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>What level of experience do you have with using seed catalogs? (5)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Q12 If the assignment changed your perspective, please explain why.
Q13 Please answer the following question.

<table>
<thead>
<tr>
<th></th>
<th>1 Very Uncomfortable (1)</th>
<th>2 Somewhat Uncomfortable (2)</th>
<th>3 Indifferent/Neutral (3)</th>
<th>4 Somewhat Comfortable (4)</th>
<th>5 Very Comfortable (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>After this assignment, how comfortable are you with using Google sheets and Microsoft Excel? (4)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>After this assignment, how comfortable are you with collecting and analyzing data? (3)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Q14 If the assignment changed your perspective, please explain why.
Q15 Please answer the following question.

<table>
<thead>
<tr>
<th></th>
<th>1 Not effective (1)</th>
<th>2 Somewhat not effective (2)</th>
<th>3 Indifferent/Neutral (3)</th>
<th>4 Somewhat effective (4)</th>
<th>5 Very effective (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>After this assignment, in your opinion how effective is using multiple people to collect a large quantity of data? (1)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Q16 If the assignment changed your perspective, please explain why.
Q17 Please answer the following question.

<table>
<thead>
<tr>
<th></th>
<th>1 Not effective (1)</th>
<th>2 Somewhat not effective (2)</th>
<th>3 Indifferent/Neutral (3)</th>
<th>4 Somewhat effective (4)</th>
<th>5 Very effective (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>After this assignment, in your opinion how effective is using Google sheets to collect a large quantity of data? (2)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
</tbody>
</table>

Q18 If the assignment changed your perspective, please explain why.

Q19 Please explain any barriers that you encountered in this assignment.

Q20 Do you have any additional feedback you would like to provide?

Q21 Thanks for taking this survey! #keepgrowing
VITA

After completing her work at Richardson High School in Richardson, Texas, in 2009, Chanelle entered Stephen F. Austin State University at Nacogdoches, Texas in the spring of 2012. She received her degree of Bachelors of Science from Stephen F. Austin State University in May of 2015. In August of 2015 she entered the graduate school of Stephen F. Austin State University, and received a Master of Science in August of 2017.

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