

TURNIP (*BRASSICA RAPA RAPA*) RESPONSE TO ORGANIC NITROGEN FERTILIZER:
EAST TENNESSEE HARVEST COMPARISON

A Report of a Senior Study

by

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ABSTRACT

As a member of the cabbage and mustard species *Brassica rapa rapa*, the purple top turnip has major economic and agricultural significance across the globe. Turnips are nutritious, versatile, and are consumed by a number of different species. With the use of blood meal, an organic nitrogenous fertilizer, this study looked to examine turnip output by comparing fertilized and unfertilized organic turnips grown in two separate plots (Plot A and Plot B) on Maryville College's gardens. It was hypothesized that fertilized turnips would maximize turnip harvest output, mass, and diameter. Turnips were sown, counted, fertilized, and maintained weekly until harvesting. After harvesting, turnips were washed, weighed, and measured to provide quantitative data. The turnips from the fertilized sections in both plots showed no significant difference when compared to the reference sections on the scales of section count (Plot A $p=0.43$; Plot B $p=0.78$), mass (Plot A $p=0.63$; Plot B $p=0.45$), and diameter (Plot A $p=0.73$; Plot B $p=0.95$). Unexpected results were found when comparing Plot A to Plot B; Plot B produced turnips with larger masses ($p<0.0001$) and larger diameters ($p<0.001$). Future studies should examine the influence of fertilizing with nitrogen before sowing, compare sunlight and moisture of the two separate plots, and vary planting dates to compare turnip growth and nutrition.

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CHAPTER I

BACKGROUND AND INTRODUCTION

Brassica rapa rapa, Turnip

Brassica rapa rapa is more commonly referred to as the “white turnip” or the “purple top turnip.” The turnip is a member of the *Brassicaceae* family. This phylogenetic classification has a variety of flowering representatives and is more commonly translated as the mustards, cabbage family, or the crucifers. The turnip belongs to the order *Brassica*; this classification denotes further expansions of the cabbages, mustards, and other allied plants. The turnip plant is a morphotype of *Brassica rapa* which includes a variety of other morphotypes such as ssp. *oleifera* (turnip rape), ssp. *pekinensis* (Chinese/napa cabbage), ssp. *chinensis* (bok choy), and ssp. *rapifera* (rapini/broccoli rabe) (see **Figure 1**) (Bird, 2017). Many of these morphotypes have had major economic and agricultural significance around the globe.

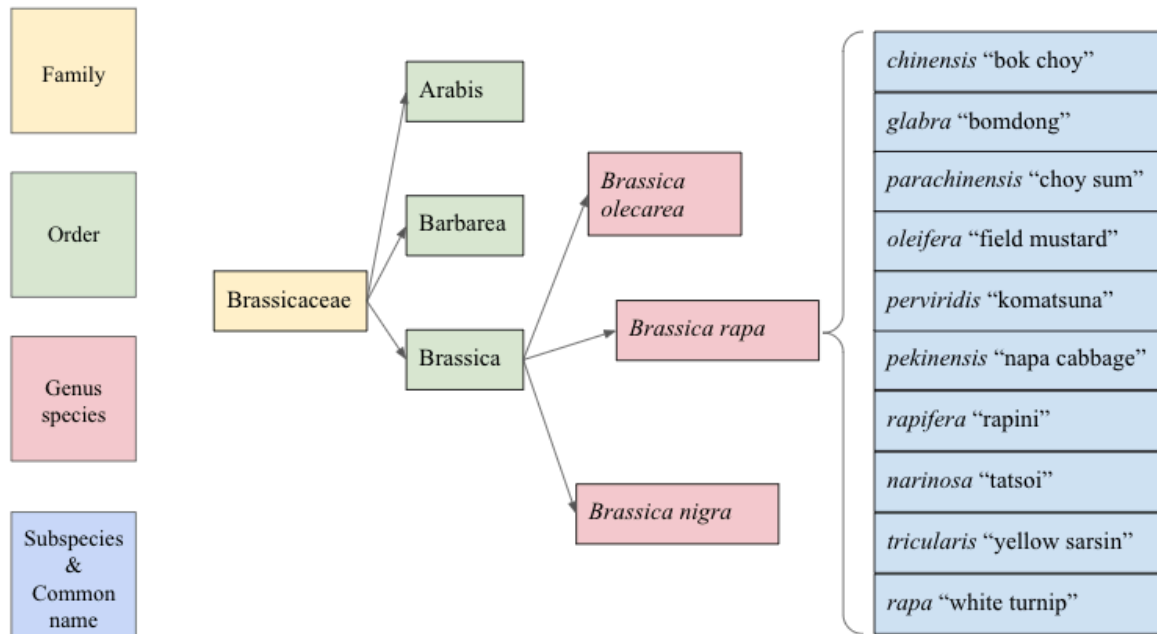


Figure 1. Phylogenetic tree of the *Brassicaceae* family. The ten subspecies of *Brassica rapa* are morphologically diverse.

Turnips differ from the other subspecies, as the vegetable has developed large fruiting bodies, tubers, that are capable of being consumed. Tubers are the enlarged structures developed by the storing of nutrients in the form of starch and disaccharides; tubers also house plant organs. Within this tuber of the turnip includes the storage organ, the hypocotyl. During maturation the hypocotyl becomes swollen from large quantities of fructose and glucose being stored (Lui, 2019).

Nutrition Value of Turnips

Turnips are believed to have originated in Eurasia over 4,000 years ago; the harvesting methods have since been developing (Hadley, 2003). Turnips are consumed in a variety of ways including but not limited to: raw, pickled, creamed, canned, boiled, and they can be combined in numerous dishes with complementary ingredients (See **Figure 1** and **Figure 2**)(FoodData Central Results, 2019).

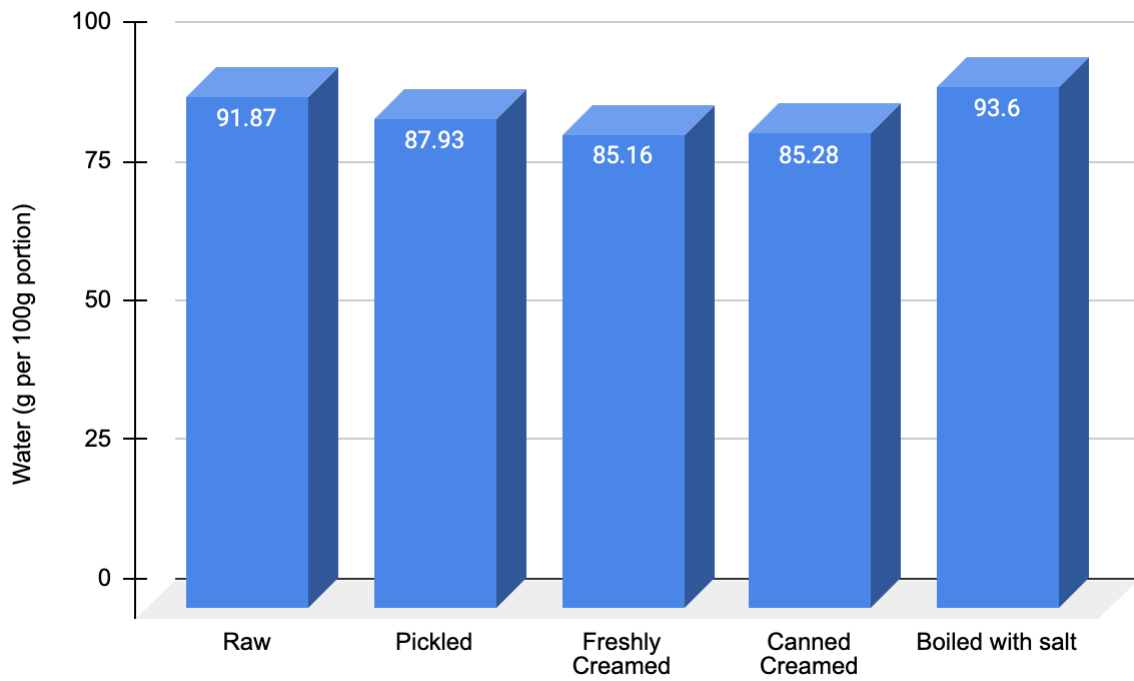


Figure 2. Water values of turnips prepared multiple ways including raw, pickled, freshly creamed, canned creamed, and boiled with salt. The water values are based on a 100 g portion of turnips.

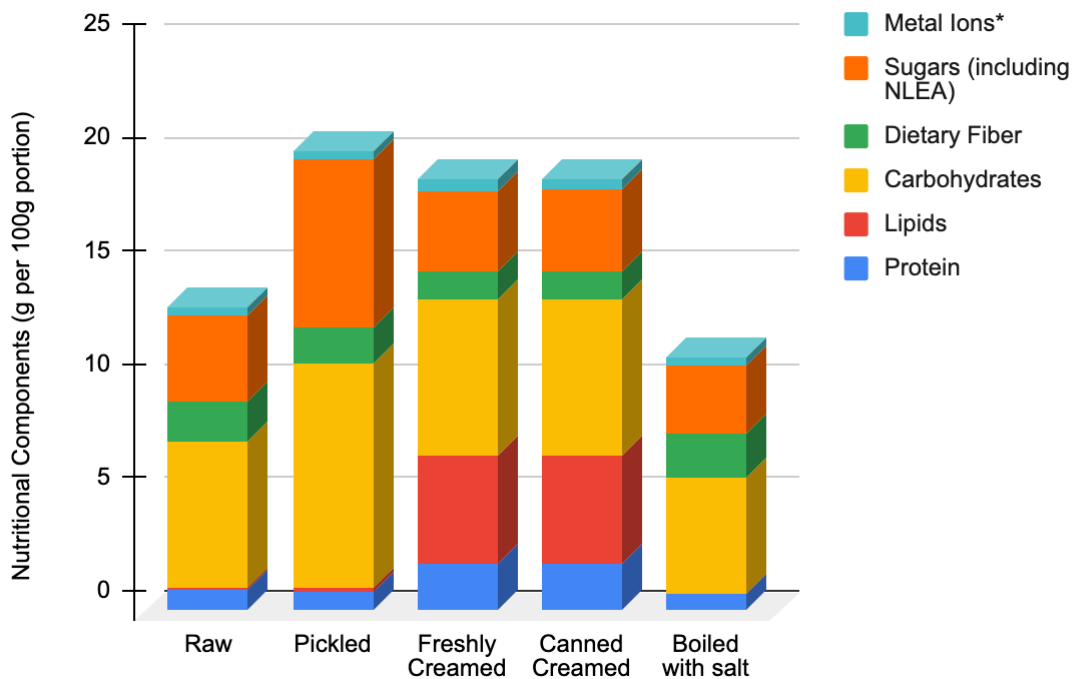


Figure 3. Nutritional values of turnips prepared multiple ways including raw, pickled, freshly creamed, canned creamed, and boiled with salt. The nutritional values are based on a 100 g portion of turnips. The metal ions row is a sum of values including Ca, Fe, Mg, P, K, Na, Zn, Cu, and Se. This table was created from data collected by the FoodData Central (FoodData Central Results, 2019).

Maximizing Turnip Output

Maximizing turnip output is economically and agriculturally important. Turnips play a significant role in feeding livestock, especially cattle. Maximizing turnip output would provide dairy farmers feed for their animals while avoiding a profit deficit for planting turnips (Clark, 1996). There is a need for studies focusing on turnips, for they have the potential to be economically profitable like other maize-based livestock feed. Another study enforced the signified a correlation between turnip yield dependence on sowing date,

precipitation, temperature tolerance, disease resistance, and water retention such of that in the photosynthetic turnip greens (Jung, 1993).

Turnips thrive in Tennessee's temperate climate. When growing turnips, soil sampling is a good indicator of success. The soils of East Tennessee provide a habitable growing medium, for they are slightly acidic and slightly basic. In Tennessee, fall planting time extends from July 15 until September 1 (Bungarner). Seeding in late summer requires special attention to multiple variables to ensure germination. Inconsistent rainfall and sunlight during the late summer and early fall indicates that maintaining soil moisture and allowing the seedlings to have full access to sunlight is vital for successful crops (Ary, 2019). Three other variables that are somewhat tedious include clearing weeds, removing insects, and monitoring for disease. These three plant antagonists, if allowed to proceed, deduct vital nutrients from the developing crop. To properly pick a turnip crop some qualities to look for include a 2-inch diameter and still tender to touch (Ary, 2019). Methods for planting turnips include planting $\frac{1}{4}$ - $\frac{1}{2}$ oz. of seeds per 100 ft. row, having 18-36 inches between rows, having 2-4 inches between plants, and have a planting depth between $\frac{1}{4}$ - $\frac{1}{2}$ inches (Bungarner).

Required Soil Nutrients and Fertilizers

Plant macronutrients have been thoroughly explained by Cornell: College of Agriculture and Life Sciences or CALS. These nutrients should always be monitored when maintaining a vegetable garden. Three required nutrients that can be supplemented in large quantities include nitrogen, phosphorus, and potassium. It is important that these nutrients can be provided in such large quantities, for high quantities are needed for optimal vegetable growth. Nitrogen is needed by all plants, but the levels of which nitrogen is available fluctuate so it is recommended that nitrogen be supplemented at a rate of 3.5 ounces per 100

square feet. A number of nitrogenous fertilizers are available on the market. Phosphorus is a second important macronutrient that is vital in early root development and plays a role in overall quality of fruits and vegetables. With the multiple phosphorus-containing fertilizers available, it is recommended for phosphorus lacking soils to be supplemented before planting to better aid in root growth. Potassium is the final macronutrient that can be added to soils in large amounts. Potassium improves water regulation, stress tolerance, and seed quality. Sources of potassium are referred to as potash, this should be supplemented before planting and after soil analyses. A number of fertilizer options are available. Organic fertilizers, most commonly manures, plant compost, and animal byproducts, provide most necessary macronutrients in an appropriate amount; organic fertilizers are also capable of creating better living environments for garden crops. Inorganic fertilizers accomplish the same goal but are synthesized in a more efficient way.

A previous study produced data supporting the efficiency of nitrogen, phosphorus, and potassium (NPK) based fertilizers (Termine, 1987). Significant data from this study embraces compost fertilizers containing NPK as a nutrient maximizing component. This study examined low nitrate levels among all treated turnips which is vital for human consumption. Another study confirms that fertilizers with high concentrations of nitrogen and phosphorus improve turnip growing mediums for leaf and root size, chlorophyll contents, and overall turnip weight (Ziaf, 2020).

CALS also described the importance of micronutrients. These necessary nutrients (excluding N, P, and K) can be deemed sufficient if the soil analysis produces pH results within an optimal range. Turnips grow best in soils with a pH ranging from 6-7.5 (MacKenzie, 2018). When a soil pH does not exhibit a pH within this range there are a

number of things that can be done to adjust the gardening plot. To increase a plots pH lime can be added, and to decrease pH acidifying fertilizers that include such things as sulfur, ammonium sulfate, or ammonium nitrate. The recommended fertilizing rate is dependent upon a number of variables, so application will vary following soil analyses which should be completed every 2-3 years.

Plant uptake of nutrients is dependent on soil minerology and the amount of rainfall in the area (Florence, 2020). Fertilizers, watering methods, and soil analyses are vital for providing crops the proper nutrients for success.

Soil Analyses

When looking to maximize harvest, it is important to consider the composition of a garden's soil. To do this soil analyses can be taken. A soil analysis quantifies soil pH, aggregates of metal ions, and it can determine what organic matter is needed to replenish the soil. Soils tested for agricultural purposes are calculated using a volume-basis method, for the bulk densities of nutrients are different. These analyses are needed to provide information and recommendations that guide soil care.

The interpretation sheet provided with the soil analyses results is used to better understand the needs of the garden. The interpretation of macronutrients is broken down into “probability of crop yield response to added nutrient across a range of soil testing values”; a “probability of yield response is high in a low index soil and none in a high index soil” (Florence, personal communication). Micronutrients are interpreted and categorized as either deficient or sufficient amounts. When the recommendations from these analyses are followed, a more suitable soil environment for the specific fruits and vegetables that are planned on being grown can be developed.

Nitrogen Fertilizers

Industrial

Industrial nitrogen fertilizers focus on two syntheses, those are the nitrogen-fixation processes that create ammonia or ammonia nitrate, NH_3 and $\text{H}_4\text{N}_2\text{O}_3$. The ammonia process occurs naturally within soils. Bacteria within soils use nitrogenase enzymes to combine N_2 and H_2O , but it does not compare to the advances of modern agricultural techniques. The three most common nitrogenous fertilizers are supplied in three forms, those are urea, nitrate, and ammonia (Bucher, 2007). Bucher also expands on the breakdown of urea, a natural excrement in urine, by describing it as a nitrogen producing reactant that interacts with the enzyme urease to form ammonia. Synthetic nitrate fertilizer is created by the combining of ammonia gas with nitric acid producing, NH_4 (Grant, 2020). Dr. Leigh Boerner expands upon ammonia productions by detailing the process. The process has been named the Haber-Bosch process, and the development of industrially produced nitrogen fertilizers has advanced agriculture and aided in population increases globally (Boerner, 2019). Industrial ammonia assists in 50% of the world's food production according to the Institute for Industrial Productivity's Industrial Efficiency Technology Database (Institute, 2012). The issue with industrially produced nitrogenous fertilizers lies with the increase demand, lack of sustainability, and overfertilization. During the manufacturing and application of industrial nitrogenous fertilizers, they emit the greenhouse gases such as nitrous oxide, methane, and carbon dioxide (Sainju, 2019). Though there are greener processes developing, ammonia production lacks sustainability efforts, for a large portion of the synthesis process requires large amounts of fossil fuel consumption. Nitrogen leaching is another issues that can result in pollution (Sainju, 2019); exceeding the crops nitrogen requirements results in the

accumulation of nitrogen that can leach, or move, into a body of water thus becoming an environment pollutant.

Organic

The list of organic nitrogenous fertilizers is extensive. Organic fertilizers are derived from animal excretions, plant matter, and animal byproducts. Options include alfalfa meal, animal manure, ash, bone meal, rock phosphate, unprocessed potassium sulfate, wood chips, blood meal, compost, cottonseed meal, feather meal, fish emulsion, fish meal, green manure, and soybean meal. Using organic fertilizers is a more sustainable alternative than the mass-produced industrial nitrogen fertilizers.

Animal Waste

Nitrogen fertilizer originating from animal waste is referred to as manure. Manure is most often a mixture of animal feces and plant matter (straw) from animal bedding. Manure provides multiple nutrients beyond nitrogen such as helpful bacteria and fungi. Many animals are capable of producing manure fertilizers; animal feces often used comes from horses, cattle, sheep, pigs, turkeys, rabbits, and chickens (Manure, 2004). These different animals' feces have many varying amounts of nitrogen, phosphate, potash, and other nutrients. Analyzing soil analyses and being selective when it comes to using manure fertilizer can better help maximize crop output.

Dr. Nate Storey, of Upstart University, expands upon another animal waste nitrogen source that is the use of aquaponics. Aquaponics is a method of growing plants without the use of soil. In an aquaponics system fish are given protein rich feed. The digestive system in the fish break down the proteins into ammonia and ammonium. Fish then excrete ammonia through their waste in the form of urea. Nitrifying bacteria in the system convert the

ammonia into a more absorbable and preferred product, nitrate. Disruptions in the nitrifying process can be detrimental to the fish and to the plants.

Blood Meal

Blood meal is a fertilizer that is a pure source of nitrogen. This organic fertilizer is a dry plant fertilizer that is composed of blood powder created from animal by-products. Blood meal is processed soon after slaughter by one of five drying methods; drying methods include solar and oven drying, drum drying, ring and flash drying, and spray drying (Heuzé, 2016). This process of developing blood meal removes potential plant and animal pathogens, and is a good choice non-synthetic nitrogenous source that can be used in any growing season. Most blood meals contain 95% protein, less than 1% of fat, and less than 5% ash (Heuzé, 2016). Vegetables need a large amount of nitrogen due to its photosynthetic requirements. The application of blood meal encourages leaf growth and fulfills other nitrogenous needs of the vegetable. One disadvantage to using a nitrogenous fertilizer on turnips is that if the nitrogen is not needed it can result in large leafy appendages that are disproportionate to underdeveloped turnip hypocotyls (Swift, 2014). Another disadvantage to using blood meal is so rich in nitrogen that it can be harmful when used in excess, for it will cause leaf scorch if placed too close to plant roots (Flynn). Leaf scorch as the result of the addition of too much fertilizer is referred to as fertilizer burn. It is important to note that leaf scorch can be caused by a number of other things including poor soil, weather conditions, or even limited root growth (Jones, 2008). Fertilizer burn is described as a state of hypertonicity resulting from plant tissue osmotic stress and desiccation; it presents as discoloration of leaves and eating away of roots (Rose, 2014).

Purpose of Study

The purpose of this study is to compare the harvest of blood-meal fertilized and unfertilized turnips in the Maryville College gardens. It is hypothesized that turnips grown without fertilizer will produce the minimal number of turnips, smaller mass, and nutrient smaller diameter. A goal of this study is to produce data that can assist farmers, botanists, and those of interest in their attempts to maximize turnip harvest and size. Data from this study may also be helpful for future Maryville College students, faculty, and staff as they further expand their gardening and sustainability efforts.

CHAPTER II

MATERIALS AND METHODS

Soil Sampling

Following the procedure provided by University of Tennessee Soil, Plant, and Pest Center, two sample areas were selected from different planting zones (Plot A and Plot B). The zones were labelled according to plants previously managed in the plot during the summer harvest. To collect soil samples, ten sub-samples of soil at least 6 inches deep were collected from each zone. The ten sub-samples from each zone were mixed within a bucket and left to dry indoors for three days. Once dried, the soil was packaged, labelled appropriately, and shipped to the Soil, Plant & Pest Center in Nashville, Tennessee.

The Sowing of Turnips

Two garden plots, Plot A and Plot B, were tilled and evened out with a rake. Three columns were planted in Plot A, and three columns were planted in Plot B (See **Figure 4**). The rows in Plot A include 100 seeds each; Plot B has 80 seeds sown into each column. In both Plot A and Plot B a stake marker was placed after the sowing of 20 seeds. Each seed was planted 3 inches apart from each other, covered with $\frac{1}{2}$ inch of fine soil, tamped with a rake, and then watered generously using a watering can. A total of 540 seeds were planted by hand.

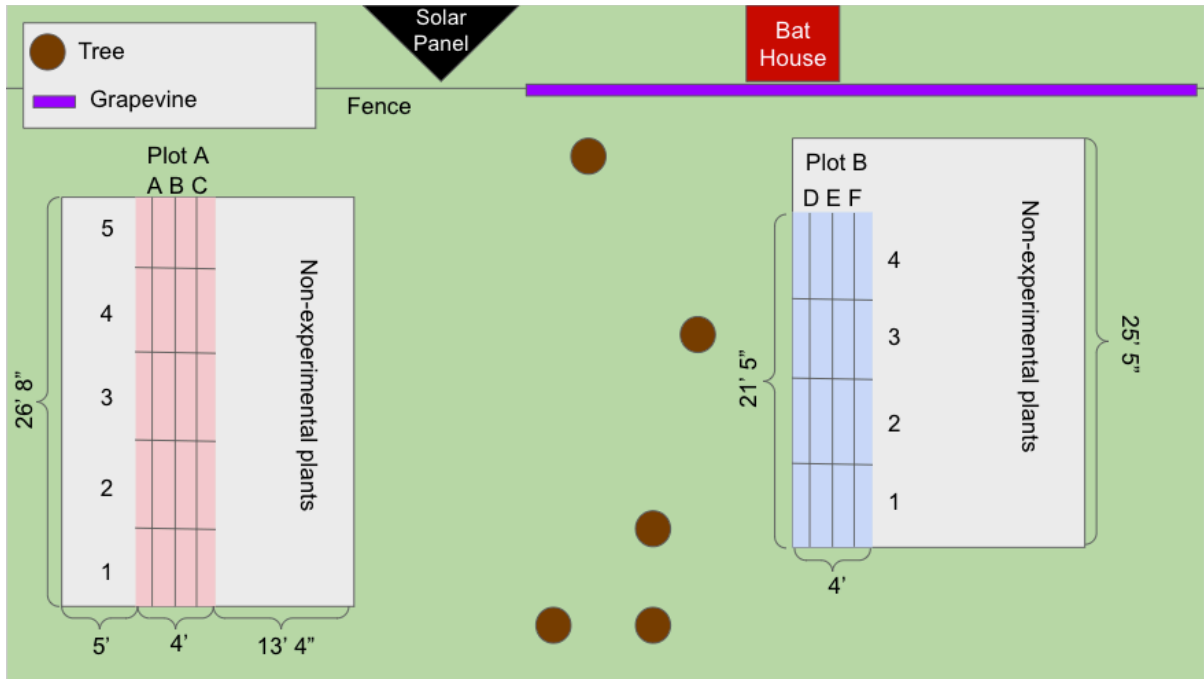


Figure 4. Map of the Maryville College gardens. There is 64” between each stake marker in Plot A and Plot B. Each column was distinguished by a letter, and each row was given a number. The odd rows contain turnips that were individually fertilized. The nonexperimental plants include tomatoes, okra, spinach, other purple-top turnips, and collard greens; the summer plants in the nonexperimental plants section perish or were manually removed during the experiment (tomatoes and okra).

Following germination, turnips were consistently quantified every week following the sowing date of September 11, 2020. Once present, weeds were cleared as needed via a scuffle hoe and by hand.

Fertilizing Individual Plants

October 11, 2020, exactly a month after sow date, a portion of the turnips were fertilized. Fertilizing turnips was completed by using stock of 3.5lbs of Espoma Organic Blood Meal with an NPK ratio of 12:0:0. Using a 2mL tube and rubber garden gloves, individual turnips were distributed 2mL of blood meal in a circular shape below the drip line

of each turnip. A total of 240 turnips were fertilized; 120 turnips in each plot. Markers were used to distinguish which turnips were fertilized. The turnips within the odd rows were fertilized (see **Figure 4**). After being fertilized, all turnips, including the controls, were watered generously.

Turnip Maintenance

Following the turnip sow date (Friday, September 11, 2020), maintenance of the plots was performed each consecutive Friday with the exception of the fertilize date (Sunday, October 11, 2020). Each week, the plots were scuffled in between columns to clear undesirable plants while avoiding developing and protruding turnip greens. After scuffling, the remaining undesirable plants around the turnips were physically removed in order to inhibit nutrient competition between turnips and undesirable plants. Once the turnips began developing visible, above-ground tubers (Friday, October 23, 2020), a half-inch and circular divot was dug around each individual, allowing tuber to horizontal expansion. This action along with raking fallen leaves out of the plot were added to the weekly maintenance tasks up until the harvest date (Wednesday, December 9, 2020).

Harvesting

On Wednesday, December 9, 2020, all turnips from plots A and B were collected. In order to keep the taproot intact, the turnips were collected using a trowel. The trowel was inserted approximately an inch from each tuber and five inches deep. Using a levering motion, the turnips were ejected from the soil. The turnips were then carefully hand brushed to remove loose soil from the previously underground portion of the turnip tuber and root appendages. The turnips and turnip greens from each row were placed into plastic bags; the bags were labelled to denote which row and column the turnips were harvested from.

Data Collection

Immediately following the harvesting, the bagged turnips were taken into the laboratory for data collection. Turnips were washed under running water to clear left-over soil and were patted dry using paper towels. The turnips were massed and had their maximum diameter measured using Vernier calipers. The data collected was written into a laboratory notebook and inputted into an Excel spreadsheet.

Weather

All temperature readings and rainfall measurements have been recorded from The Weather Channel (<https://weather.com/weather/today/l/c0f8f4fb810262d57fce7465224a7af8d7453a5177b7c5361062cbf1e0214a0e>).

Statistical Analysis

Assuming normal distribution among data points, Dixon's Q test was used to identify and reject suspected outliers. Outliers were suspected but the Dixon's Q test resulted in zero outliers. Interquartile range was another method used to identify and cast out outliers, but it also resulted in no outliers.

To determine germination success, the percentage of successful turnips were calculated for each individual section. This was determined by dividing the harvested turnips from each section by the number of seeds planted in that section. Once the percentages of successful turnips were calculated, the sections were categorized into groups: Plot A fertilized, Plot A unfertilized, Plot B fertilized, and Plot B unfertilized. The sections in each category had their percentages averaged. This average represented the number of turnip seeds that survived the growing season and were harvested. The number of turnips harvested from

each category was also used to determine the average number of turnips harvested from each section.

A trimmed mean of 10% was determined in order to eliminate the influence of turnips from the extreme tails of the distribution curve of mass and diameter measurements. The largest 10% masses and diameters and the smallest 10% of masses and diameters were cast out of each section. The remaining data points were averaged in each section. These averages were used to compare masses and diameters among reference locations and fertilized treated locations.

The mass and diameter of each turnip was ranked small, medium, or large. Small turnips were classified as being under 200.0g, medium turnips ranged from 200.0g- 399.9g, and large turnips were greater than 400.0g. The small diameters of turnips were classified as being less than 40.0mm, medium diameters of turnips ranged from 40.0mm- 79.9mm, and large diameters of turnips were greater than 80mm. When ranked, the proportions were compared as parts of a whole adding up to 100%. The ranking method was used to find possible disparities between the masses and diameters of fertilized and unfertilized turnips within the sections of Plot A and Plot B.

To compare Plot A and Plot B. A t-test was performed comparing the turnip masses in Plot A and the turnip masses from Plot B. The same method was repeated for turnip diameters in respective plots.

CHAPTER III

RESULTS

Soil Sampling

Soil sampling results quantified nutrients including phosphorus, potassium, calcium, magnesium, zinc, iron, manganese, and boron (see **Table 1**); all of which can be measured in turnip nutritional values. An appropriate range for phosphorus includes 31+ (lbs/acre), for potassium is 161+ (lbs/acre) (Soil, Plant and Pest), and anything below these concentrations of potassium and phosphorus can be supplemented with fertilizer (MacKenzie, 2018). Other nutrients and their sufficient values include calcium (>500 lbs/acre), magnesium (>40 lbs/acre), zinc (<2 lbs/acre), iron (pH >7.3; could indicate iron deficiency), manganese (<16 lbs/acre).

Table 1. Soil sample results of three different Maryville College garden locations. The metal ion values are measured in units of pounds per acre (lbs/acre). See Appendix 1 for complete soil analysis reports.

	Plot A	Plot B
Phosphorus	66	131
Potassium	279	401
Calcium	3421	3213
Magnesium	544	434
Zinc	22	23.5
Iron	11	10
Manganese	133	129
Boron	1.9	2.2
Sodium	11	13
pH	7.23	7.18

Weather

The weather in Maryville, Tennessee ranged from the lowest temperature reaching 22°F and the highest temperature reaching 88°F. The total amount of rainfall in Maryville, Tennessee totaled 12.59 inches from the sowing date to harvest date. Temperature and rainfall patterns are displayed in **Figure 5**.

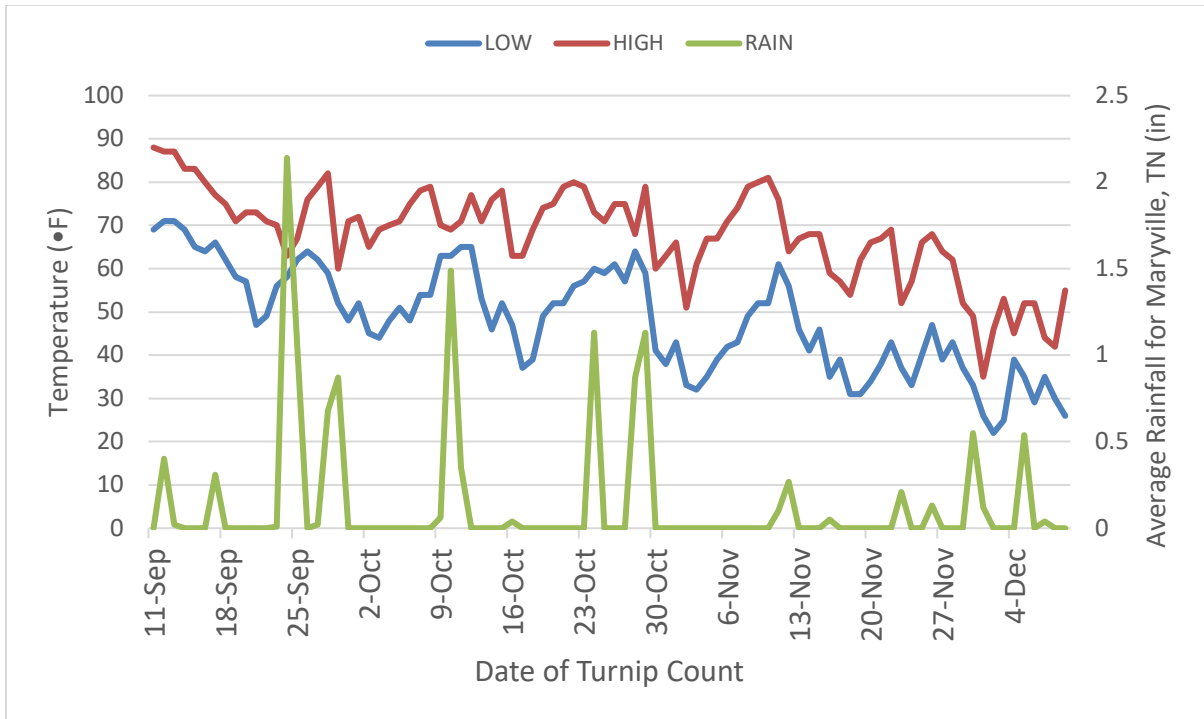


Figure 5. The average rainfall (in.), high temperature (°F), and low temperature (°F) in Maryville, Tennessee from the sowing date, September 11, 2020, to the harvesting date December 9, 2020.

Germination

No section of turnips had successful germination of all 20 seeds planted (see **Table 2**). Plot A- C3, was unintentionally skipped during the sowing process; therefore, its germination rate stayed constant at zero and its data was struck from statistical analyses.

Table 2. Weekly turnip count from germination until harvesting. Plot A had three rows (A, B, and C), and Plot B had three rows (D, E, and F). The rows in Plot A had five sections each (1-5), and the rows in Plot B had four sections each (1-4). Each odd number denotes a section of turnips that were fertilized; each even number denotes a section of turnips that were unfertilized and reference locations. Each Friday following sow date, the turnips of each section were counted and imputed into this table.

ROW/ SECTION	9/18	9/25	10/2	10/9	10/16	10/23	10/30	11/6	11/13	12/9
A1	14	14	13	11	11	11	11	10	10	10
A2	13	15	15	15	14	13	12	11	11	10
A3	9	9	8	7	7	7	7	7	7	7
A4	12	9	9	9	8	8	8	8	8	8
A5	8	8	7	7	7	6	6	6	6	6
B1	15	12	11	11	11	11	11	11	11	11
B2	15	14	13	13	11	12	12	12	12	11
B3	17	16	15	15	15	15	15	15	15	15
B4	13	10	10	10	10	9	9	9	9	9
B5	15	14	14	14	13	13	13	13	13	13
C1	10	10	9	9	9	9	9	9	9	9
C2	14	10	10	10	10	10	10	10	10	10
C3	0	0	0	0	0	0	0	0	0	0
C4	12	9	9	9	9	9	9	8	7	7
C5	12	11	11	11	11	10	11	11	11	11
D1	11	10	7	7	6	6	6	6	6	4
D2	15	18	16	16	16	16	17	17	17	16
D3	10	10	9	8	7	5	5	5	5	4
D4	13	13	10	10	10	9	9	9	9	9
E1	18	16	16	17	17	17	17	17	17	16
E2	14	16	13	12	11	10	10	10	10	10
E3	16	16	16	15	14	15	15	15	15	12
E4	16	14	14	13	12	8	8	8	8	8
F1	18	15	15	15	14	12	12	13	13	13
F2	15	15	15	13	12	11	11	11	11	10
F3	15	13	10	9	8	8	8	8	8	8
F4	15	15	11	11	10	8	8	8	8	8

Turnip Count

The number of turnips from fertilized and unfertilized sections in Plot A and Plot B were averaged based on plot and treatment. On average, unfertilized sections in Plot A had 9.17 turnips and fertilized sections in Plot A had 10.25 turnips (p-value: 0.43; SD unfertilized: 1.47; SD fertilized: 2.96). Unfertilized sections from Plot B averaged 10.17 turnips, and fertilized sections from Plot B averaged 9.5 turnips (p-value: 0.78; SD unfertilized: 2.99; SD fertilized 4.97).

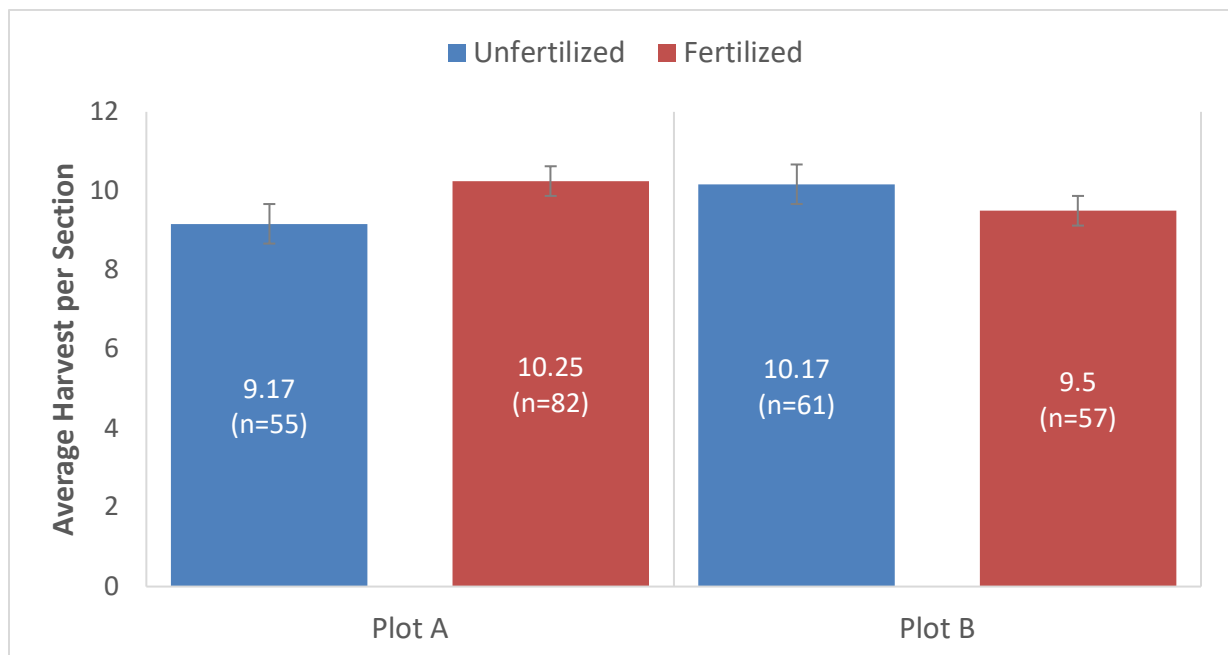


Figure 6. Average number of turnips (+1SE) harvested from fertilized and unfertilized sections of Plot A and Plot B.

Turnip Mass

The average mass of turnips from unfertilized sections in Plot A was 97.93g, and the average mass of turnips from fertilized sections in Plot A was 113.68g (p-value: 0.63; SD unfertilized 67.65; SD fertilized: 50.34). Average masses of turnips in unfertilized sections of Plot B was 248.73g, and the average masses of turnips in fertilized sections of Plot B was

290.91g (p-value: 0.45; SD unfertilized: 66.1; SD fertilized: 113.78). The mass averages are displayed in **Figure 7**. On average, fertilized sections in Plot A produced turnips 15.75g larger than unfertilized turnips in Plot A. Fertilized turnips in Plot B were 42.18g larger on average than unfertilized turnips in Plot B. Plot B, on average, produced fertilized and unfertilized turnips that were over 150g larger in mass when compared to turnips in Plot A. The average masses of turnips from Plot A and Plot B are compared in **Figure 11**.

Ranked mass, as seen in **Figure 8**, aggregates turnip masses into small, medium, and large categories. In Plot A, the mass of small turnips ranked the highest proportion with 78.05% in fertilized sections and 81.81% in unfertilized sections. The mass of medium turnips was the second largest proportion in Plot A with 17.07% in fertilized sections and 14.55% in unfertilized sections. In Plot A, the lowest proportion of masses was the large ranking turnips. 4.88% of turnips in fertilized sections of Plot A and 3.64% of turnips in unfertilized sections of Plot A were ranked as large masses. In total, of the turnip masses in Plot A 79.93% ranked small, 15.81% ranked medium, and 4.26% ranked large. Plot B had a lower percentage of disparity between masses with 43.86% of turnips in fertilized sections and 47.54% of turnips in unfertilized sections ranking small. Medium ranked turnips in Plot B had the second largest proportion with 31.58% in fertilized sections and 37.70% in unfertilized sections. 24.56% of turnips grown in fertilized sections of Plot B and 14.76% of turnips grown in unfertilized sections of Plot B had masses ranked in the large proportion. In total, of the turnip masses in Plot B 45.70% ranked small, 34.64% ranked medium, and 19.66% ranked large.

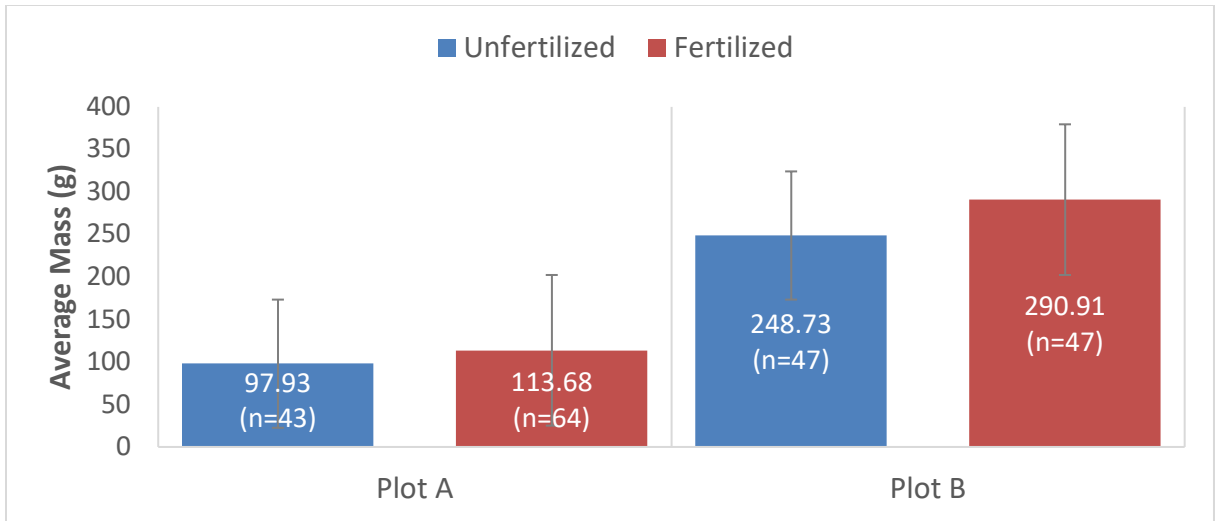


Figure 7. Average mass of turnips (+1SE) harvested from fertilized and unfertilized sections of Plot A and Plot B after a 10% trimmed mean of each section.

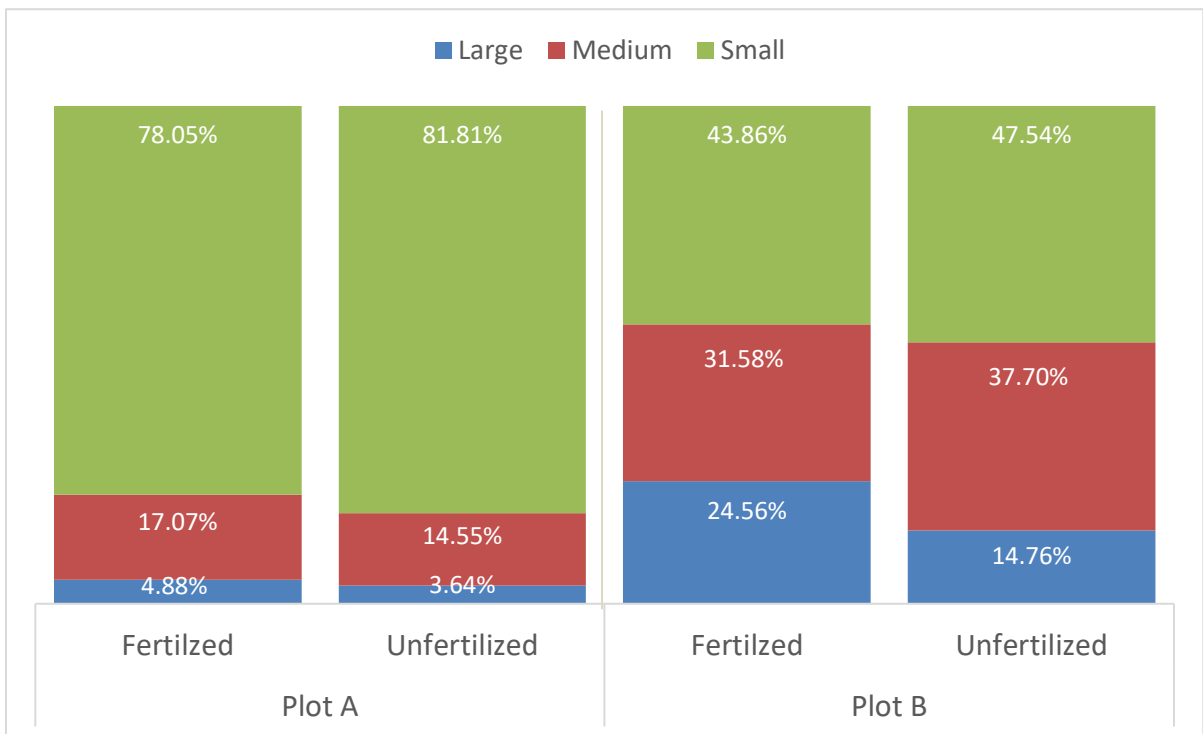


Figure 8. Ranked masses of turnips harvested from fertilized and unfertilized sections of Plot A and Plot B (small <200.0g; medium 200.0g- 399.9g; large >400.0g). Proportions of each section is divided among small, medium, and large ranking masses.

Turnip Diameter

The average diameter for turnips in unfertilized sections of Plot A was 41.89mm, and the average diameter for turnips in fertilized sections of Plot A were 43.94mm (p-value: 0.73; SD unfertilized: 13.06; SD fertilized: 9.27). The average diameter of unfertilized turnips in Plot B was 60.24mm, and the average diameter of fertilized turnips in Plot B was 60.64mm (p-value: 0.95; SD unfertilized: 6.53; SD fertilized: 12.97). On average, the diameter of turnips in Plot B were 17mm greater than turnips in Plot A. The diameter averages are displayed in **Figure 9**. The average diameters of turnips from Plot A and Plot B are compared in **Figure 11**.

Figure 10 categorizes the turnips diameter into small, medium, and large turnips. Ranked diameters of the fertilized sections in Plot A include 51.22% of turnips ranking small, 45.13% of turnips ranking medium, and 3.65% of turnips ranking large. Ranked diameters of the unfertilized sections in Plot A include 26.31% of turnips ranking small, 50.88% of turnips ranking medium, and 22.81% of turnips ranking large. In total, of the turnip diameters in Plot A 38.77% ranked small, 48.01% ranked medium, and 13.23% ranked large. Ranked diameters of the fertilized sections in Plot B include 50.91% of turnips ranking small, 40.00% of turnips ranking medium, and 9.09% of turnips ranking large. Ranked diameters of the unfertilized sections in Plot B include 22.95% of turnips ranking small, 59.02% of turnips ranking medium, and 18.03% of turnips ranking large. In total, of the turnip diameters in Plot B 36.93% ranked small, 49.51% ranked medium, and 13.56% ranked large.

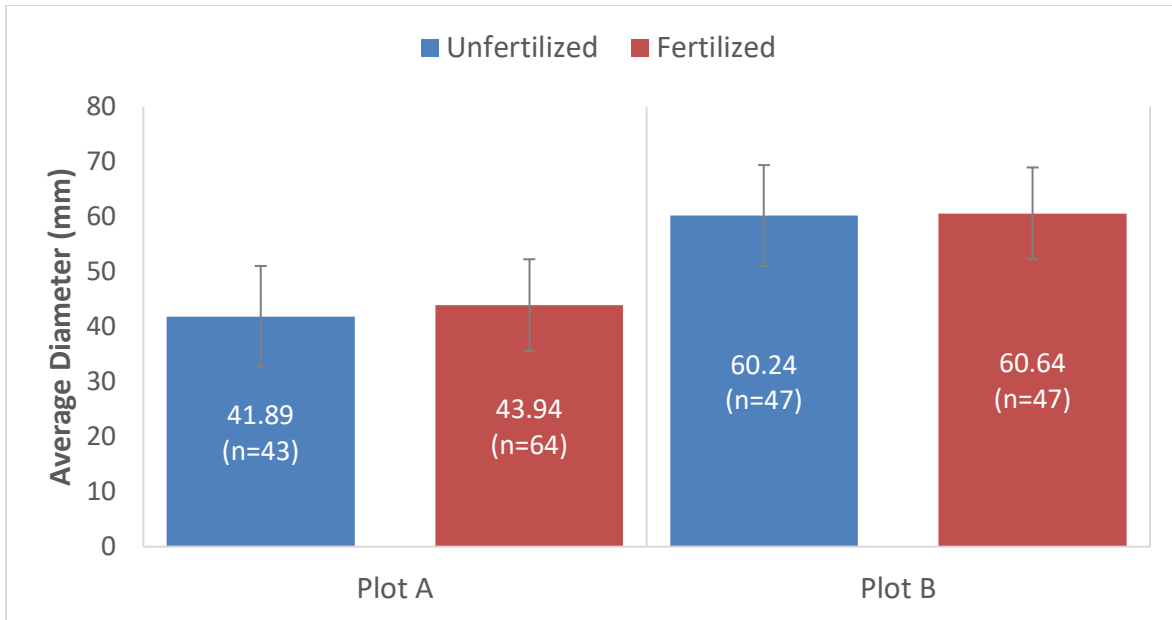


Figure 9. Average diameter of turnips harvested from fertilized and unfertilized sections of Plot A and Plot B after a 10% trimmed mean of each section.

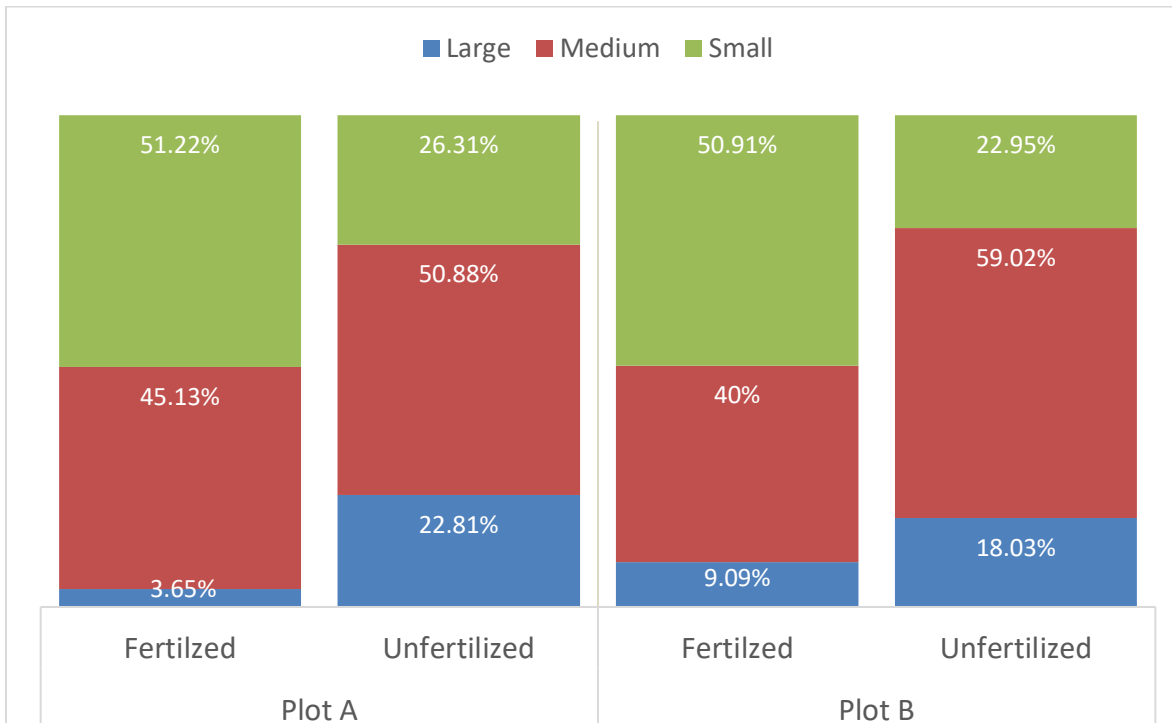


Figure 10. Ranked diameters of turnips harvested from fertilized and unfertilized sections of Plot A and Plot B (small <40.0mm; medium 40.0mm- 79.9mm; large >80mm). Proportions of each section is divided among small, medium, and large ranking diameters.

Comparing Plot A and Plot B

After the 10% trimmed mean statistical analyses, the turnips in Plot A and the turnips in Plot B had t-test performed on their respective mass and diameter measurements, the results are shown in **Figure 12**. The average mass of turnips in Plot B was 240.63g which is significantly larger than turnips averaging 105.34g in Plot A (p-value <0.0001; SD Plot A: 94.56; SD Plot B: 156.93). On average turnips in Plot B were 135.29g larger than turnips in Plot A. The average diameters of turnips in Plot B, 57.82mm, was significantly higher than diameters of turnips in Plot A, 42.83mm (p-value <0.0001; SD Plot A 18.63; SD Plot B 20.83). On average the turnips in Plot B were 14.99mm larger than turnips in Plot A.

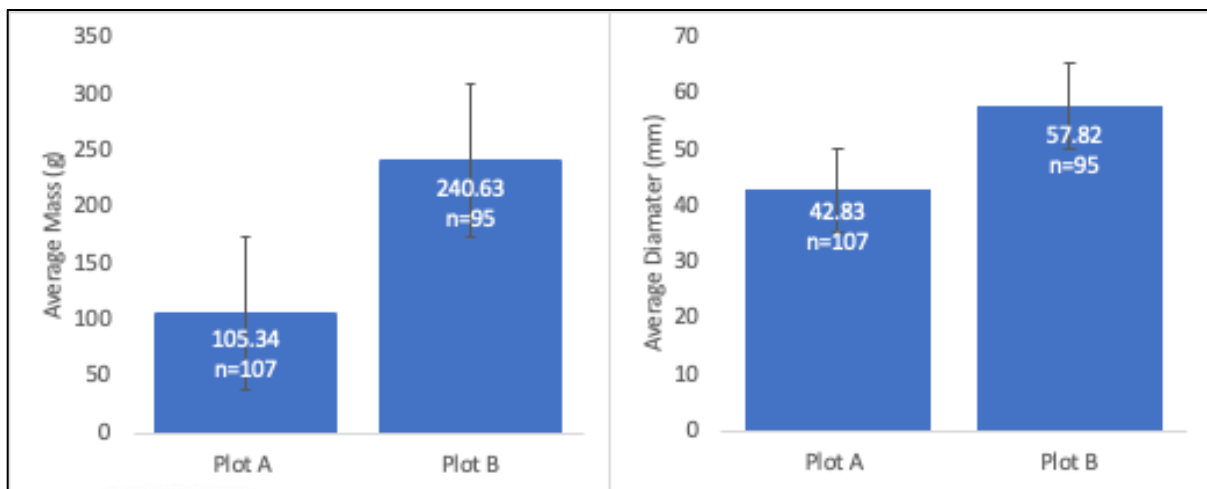


Figure 11. Average mass and diameters (+ 1 SE) of turnips after a 10% trimmed mean in Plot A (n=107) and Plot B (n=95).

CHAPTER IV

DISCUSSION

Interpreting Results

It was hypothesized that unfertilized turnips would have lower harvest rates, smaller turnip mass, and a smaller turnip diameter. Though the mass and diameter averages of the turnips in the unfertilized sections are lower than the averages of the fertilized turnips, there is not a significant difference between the harvest rate, turnip mass, or turnip diameter of fertilized and unfertilized section of turnips. Overall, while not statistically significant, the results suggest that fertilized turnips may trend toward higher harvest rates, larger masses, and larger diameters.

When comparing averages of the sections, the fertilized sections of Plot A produced the greater harvest rate. It has been shown that supplementing plants with nitrogen produces a higher yield of crops (Sainju, 2019); this was seen in Plot A. Fertilized sections of Plot B had a lower harvest rate than the unfertilized sections of the same plot, but had a higher harvest rate than the unfertilized sections of Plot A. Another comparison of section averages suggests that fertilized turnips in Plot A and Plot B have greater masses and diameters when compared to the reference turnips in their respective plots.

Though there is some suggestion that the organic blood meal nitrogenous fertilizer maximized turnip mass, diameter, and harvest success, there is no significant data that shows

that supplementing nitrogen in this study improved the turnips overall. The organic nitrogen fertilizer may not have worked as well as originally hypothesized due to the the application date occurring after germination. Nitrogen supplementation is a known method to increase crop yield. Therefore, if fertilized sections of Plot A and B were supplemented with blood meal before the sowing of turnip seeds, then results may have varied. It is possible that providing blood meal to the soil before the planting of the turnip seeds would have provided turnips with a sufficient amount of nitrogen to successfully germinate, for blood meal is an excellent product for replenishing nitrogen to soil (Jnawali, 2015).

Unexpected Results

The turnips in Plot A had an average mass and diameter that was significantly smaller than turnips in Plot B. This result was unexpected, for the soil profiles were similar and not tremendously different; however, there were some subtle differences that could have contributed to the enhanced growth in Plot B. First, turnips are better developed when grown in soils that are slightly acidic (Undersander, 2021), and when comparing the plots, Plot A (7.23) had a more basic soil than Plot B (7.18). Both Plot A and Plot B met the appropriate, optimal nutrient ranges for phosphorus and potassium, which are most often supplemented when in a lower range. Second, Plot B had higher concentrations of both phosphorus and potassium. The calcium nutritional measurement exceeded sufficient values in both plots; other minor nutrients such as magnesium, zinc, iron, boron, and sodium met sufficient soil expectations.

When ranked on a scale between small and large, the masses of turnips in Plot A had a more unequal distribution when compared to turnips in Plot B. Plot A had the largest amount

of turnips ranking small with 79.93% of the harvest; this contrasts to Plot B where only 45.70% of the turnips harvested ranked small,

Due to the Plot B turnips being larger overall, it is believed that those turnips retained more water. To confirm this, future studies are needed to examine soil moisture content with a soil moisture meter. This would allow for data collected from consistent measurements to be used to understand garden water content and the water status of the turnips; it would also be beneficial for each turnip to be analyzed under a microscope so that measurements of the vascular plant organs within the hypocotyl-tubers can be compared.

Another possibility is that the sunlight may have had an effect on the different plots. During the experiment, qualitative results showed that the turnips in Plot B had turnip greens that were seemingly larger. It was also noted that shade from the surrounding trees often shielded sunlight away from Plot B but not Plot A. To confirm this, it is recommended that a future study utilize photosensors to analyze the hours of sunlight in each plot, and future studies should measure the turnip greens in each plot according to surface area, color, and mass. Measuring the size of the turnip greens could provide insight into chloroplast quantity and light absorption capabilities.

Comparative Studies

A previous study growing turnips with nitrogenous fertilizers saw an increase in turnip yield as the amount of fertilizer was increased (Sadia, 2013). This study also examined turnip root length and diameter where they found that nitrogenous fertilizer had a significant increase on these variables. However, this study only examined organic blood meal as a nitrogenous source and did not examine the same variables. Future studies examining the

effectiveness of organic blood meal as a nitrogenous fertilizer should consider adapting methods of measuring turnips root lengths.

A study in Pakistan examined turnip growth influenced by various levels of nitrogenous and phosphatic fertilizers. They found that the highest turnip mass was found in turnips fertilized with the largest amount of nitrogen and phosphorus (Khetran, 2016).

Though this experiment used a different nitrogenous fertilizer, their results on turnip mass are congruent with our hypothesis.

Limitations

This study has a number of potential limitations. First, turnips were sown in the middle of September. In the state of Tennessee, for a fall turnip harvest it is recommended that turnips be planted between the end of July to the beginning of September (Bumgarner). With this information, it is possible that the results could have varied if the turnips had been sown during an earlier time. Though it has been shown in other studies that turnip greens can maintain their nutritional values following repeated frosts, the turnip itself experiences its most vigorous root growth between temperatures of 40-60°F (Undersander, 2021). Our results show that the temperatures in Maryville, Tennessee plummeted below 40°F on a number of occasions until the turnip harvest date; this suggests that root growth during times of low temperature could have been altered or even halted. When sowing time is considered, fertilizing time should also be considered. Future studies should look into fertilizing turnips during the prime sowing dates. If the turnips had been sown and fertilized during the suggested months, then there could have been different results.

During the sowing of turnip seeds. Section C3, which would have been considered a fertilized section, was skipped unintentionally. Therefore, the planned population size of that

section (n=20) was excluded and no data was produced from this section, for there were never seeds planted there.

Future research should examine the nutrition facts of each turnip as this would be beneficial to understanding macromolecule levels in the soil and their effects on turnips during growth and development.

Final Remarks

The present study showed no effects of an organic nitrogenous fertilizer on the growth of turnips in two Plots of the Maryville College gardens. Future studies should examine the influence of various nitrogen concentrations, varying sunlight effects, and varying planting dates on turnip growth and nutrition.

APPENDIX 1: SOIL ANALYSIS RESULTS

Crawford House Garden Soil Results Sept. 2020

Lab Number: 593987

Sample Name: TOMATO

Farm Name:

Soil Results

pH		Phosphorus	Potassium	Calcium	Magnesium	Zinc	Iron	Manganese	Boron	Sodium
Soil pH	Buffer Value	P	K	Ca	Mg	Zn	Fe	Mn	B	Na
Pounds per acre - Mehlich 1										
7.23		66	279	3421	544	22	11	133	1.9	11

Lab Number: 593986

Sample Name: OKRA

Farm Name:

Soil Results

pH		Phosphorus	Potassium	Calcium	Magnesium	Zinc	Iron	Manganese	Boron	Sodium
Soil pH	Buffer Value	P	K	Ca	Mg	Zn	Fe	Mn	B	Na
Pounds per acre - Mehlich 1										
7.34		61	432	3464	550	20.1	9	158	2.1	12

Lab Number: 593988

Sample Name: PEPPER

Farm Name:

Soil Results

pH		Phosphorus	Potassium	Calcium	Magnesium	Zinc	Iron	Manganese	Boron	Sodium
Soil pH	Buffer Value	P	K	Ca	Mg	Zn	Fe	Mn	B	Na
Pounds per acre - Mehlich 1										
7.18		131	401	3213	434	23.5	10	129	2.2	13



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 615.832.5850 | SoilLab@Tennessee.edu
soilab.tennessee.edu

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utextension.tennessee.edu

DREW CRAIN
 502 E. LAMAR ALEXANDER PKWY
 MARYVILLE TN 37804

09/15/2020
 Customer County: Blount
 Sample County: Blount

Lab Number: 593987

Sample Name: TOMATO

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pH		Phosphorus	Potassium	Calcium	Magnesium	Zinc	Iron	Manganese	Boron	Sodium
Soil pH	Buffer Value	P	K	Ca	Mg	Zn	Fe	Mn	B	Na
		Pounds per acre - Mehlich 1								
7.23		66	279	3421	544	22	11	133	1.9	11

Crop/plant Interpretation ranges on last sheet

<i>Additional tests, if they were requested</i>											
Sulfur	Nitrogen			Carbon	C/N Ratio	Organic Matter	Soluble Salts	Particle Size Analysis - Hydrometer Method			
LBS/ACRE	NH4-N ppm	NO3-N ppm	Total N %	%	%	%	dS/m	% Sand	% Silt	% Clay	Soil Texture

Recommendations

Crop	Fertilizer				Lime	
	Nitrogen (as N)	Phosphate (as P ₂ O ₅)	Potash (as K ₂ O)	Rate	As 65% RNV	
Okra	15-30	30	30	pounds per acre	0	tons per acre
Vine Crops: Cantaloupe, cucumber, squash, watermelon	30-40	0	0	pounds per acre	0	tons per acre
Beans, Snap or Lima	45	30	0	pounds per acre	0	tons per acre
Tomatoes	60	60	60	pounds per acre	0	tons per acre

Please read any text below or on next sheet for additional suggestions and resources

Sample Number: TOMATO --- Crop: Okra

Apply an additional 30 pounds of nitrogen per acre after the first picking.

Sample Number: TOMATO --- Crop: Vine Crops: Cantaloupe, cucumber, squash, watermelon

Apply an additional 15-30 pounds of nitrogen per acre when runners are 12 inches long or early bloom.

If cantaloupes, cucumbers, or squash are being grown on plastic with fertigation, apply all of the recommended phosphate and 1/2 of the recommended nitrogen and potash prior to laying the plastic. Distribute the remaining nitrogen and potash in weekly intervals over the remainder of the growing season (4 to 6 weeks).

Sample Number: TOMATO --- Crop: Beans, Snap or Lima

Use only 15 pounds of nitrogen per acre when a Blue Lake variety of snap beans is used.

Apply 2 pounds of zinc per acre when zinc tests deficient. If zinc is not tested, apply two pounds of zinc per acre when soil pH is above 6.0 or anytime lime is applied.

Sample Number: TOMATO --- Crop: Tomatoes

Apply an additional 30 pounds of nitrogen per acre as a sidedressing when first fruits are 1 inch in diameter and continue at four week intervals during picking.

If tomatoes are being grown on plastic with fertigation, apply all of the recommended phosphate and 1/2 of the recommended nitrogen and potash prior to installing the plastic. Apply the remaining nitrogen and potash in weekly intervals over the remainder of the growing season. (8 to 12 weeks)

Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development.

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UT Extension provides equal opportunities in programs and employment.

Interpretation Page

Soil pH interpretations

Lime Recommended when soil pH is less than:

5.6	Sweet Potatoes, brambles
6.1	Corn, wheat, soybeans, red/white clovers, Lawns, most vegetables
6.6	Alfalfa, Apples, Pears, Peaches

Buffer pH helps tell us how much resistant the soil has to being limed. The buffer starts at pH 7.9, the lower the buffer value is from 7.9 the more lime that is required.

Nutrient Interpretations

	Phosphorus (P)	Potassium (K) Lbs. / acre	Potassium Cotton	Yield response to fertilizer
Low	0 to 17	0 to 90	0 to 140	High probability
Medium	18 to 30	90 to 160	141 to 280	Probable
High	31 to 120	161 to 320	281 to 320	None
Very High	120+	320+	320+	None

Calcium is sufficient when greater than 500 pounds per acre.

Magnesium is sufficient when greater than 40 pounds per acre.

Zinc is recommended for: Corn or Snap Beans when Zn levels are less than 2 lbs per acre

Iron: Availability is controlled by soil pH. If the pH is greater than 7.3 one may begin to see iron deficiency symptoms.

Manganese is recommended for: Soybeans when the soil pH is greater than 7 and Mn levels are less than 16 lbs per acre.

Boron is recommended for: Cotton when boron levels are less than 0.8 lbs per acre, or the soil pH is greater than 6, or when lime is used.

Tabacco when the B levels are less than 1.2 lbs per acre.

General low dose application recommended annually for Alfalfa, Cauliflower, and broccoli.

Soluble Salts

dS/m	approximate ppm	Rating
0.4	560	Low
0.8	1120	Very Slightly Saline
1.6	2240	Slightly Saline
2.4	3360	Moderately Saline
3.2	4480	Strongly Saline
3.2	4480+	Very Strongly Saline

Resources

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