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Influence of Fertilizer Rate on Swollen Stem Formation (“Bulbing”) and Vitamin C Content in Different Kohlrabi Cultivars

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Influence of Fertilizer Rate on Swollen Stem Formation ("Bulbing") and Vitamin C Content in Different Kohlrabi Cultivars

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1. Abstract

Kohlrabi (Brassica oleracea Gongylodes Group) is a vegetable crop found in the Brassicaceae, and it is rich in antioxidants such as vitamin C. Vitamin C helps in oxidative damage repair and strengthens the immune system, so exploring vitamin C sources may contribute to improving human health. The objective of this study was to determine the effect of different fertilizer rates on kohlrabi yield, in terms of the swollen stem and the vitamin C content, and if those effects are similar in different kohlrabi cultivars. In this greenhouse study, we fertilized four potted kohlrabi cultivars with a common water-soluble greenhouse fertilizer (Peters Professional 20-10-20) at zero, one-half recommended, recommended, and double recommended rates where the recommended rate plants received 308mg of fertilizer each week in irrigation water. Results showed that plants of all cultivars that received the double rate of fertilizer had the highest yield with a fresh swollen stem weight of 448 g, while plants that received no fertilizer had the lowest yield with 21.2 g and they were visibly nutrient deficient. An increase in fertilizer rate increased the vitamin C content where the total vitamin C per swollen stem averaged 6853 mg for the double rate and 846 mg for the zero rate. The results from this study will help farmers to effectively apply fertilizers to increase kohlrabi yields and vitamin C content while doing less harm to the environment caused by excessive fertilizing. In return, this will help people to get more vitamin C sources which may improve their health.

Key words: Horticulture, greenhouse vegetable production, fertilizer recommendation rates, Kohlrabi, vitamin C content.

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2. Introduction

2.1. Background

Kohlrabi (*Brassica oleracea* Gongylodes group) is a vegetable crop that is found in the Brassicaceae family with broccoli, brussels sprouts, and cauliflower, among others. This crop is particularly important in Europe and America due to its short growing season and can be transported easily (Shams, 2012). The edible part of kohlrabi is the fleshly swollen stem, much like turnip except that the edible part of turnip is the swollen root and hypocotyl. Kohlrabi has an important nutritional value to humans as it is a source of antioxidants such as vitamin C, and nutrients including potassium (Shams, 2012). Vitamin C (ascorbic acid) is essential to human health because it strengthens the immune system, helps in body tissue repair, and iron absorption (Camarena and Wang, 2016). In 2016, over 21 million people in America were Vitamin C deficient which put their lives at considerable risk of getting diseases including cancer (nutri-facts.org, 2016). Today, people are more than ever nutrient cautious, and it is important to learn how to advance the nutritional value of kohlrabi and help respond to people's health concerns stated above.

Studies have found that the increase in yield (in terms of the swollen stem size and weight) can be improved by applying different kinds of fertilizers (Jamil, 2017). Specifically, nitrogen-containing fertilizers, either mineral or organic, have been found to improve the size and the quality of the kohlrabi swollen stem (Shams, 2012). Ahmed et al. (2003), found that the application of nitrogen, phosphorous, and potassium at the same time had higher yields than applying a single nutrient or no fertilizer. Still, there are not many studies done on how much the

increase in the fertilizer rate affects the yield and the quality of kohlrabi especially antioxidant content, e.g., Vitamin C.

2.2. Objectives

The knowledge generated by this study will help to determine the association of fertilizer rates to the quality and yield of kohlrabi which will then help to know various ways to improve human nutrition and fight against issues associated with the lack of ascorbic acid (Vitamin C) in people's diet. As an additional result, this may help to eliminate the excessive nitrogen applications that are costly and harmful to the environment while being more profitable in the operations with lower input of resources (Chuan et al, 2019). The hypothesis is that kohlrabi plants that are treated with more fertilizer levels will have more yield and contain more vitamin C than kohlrabi plants treated with less or no fertilizer.

3. Procedures

3. 1. Materials and Methods

This experiment was done in the teaching greenhouse of the University of Nebraska-Lincoln, Department of Agronomy and Horticulture. Different kohlrabi cultivars (Konan F1, Azur Star, White Vienna, Ukza (32-932)) were planted in 12-inch plastic pots using a completely Randomized Block Design. The growing medium used was the soil mix from Berger, which is composed of coarse peat, horticultural perlite, dolomitic limestone, calcitic limestone, and a non-ionic wetting agent with a pH of 5.4 to 6.2.

There were four treatments in every cultivar group and four replicates of each treatment were made throughout the greenhouse. Different levels of fertilizer (Peters Professional 20-10-20) were applied to potted kohlrabi plants in irrigation water where plants treated with the recommended rate received 308mg. We applied 50ml of water containing fertilizer and gave the same amount of water to those plants treated with zero fertilizer rate.

				Individual Nutrient Concentrations(ppm)								
Fertilizer Rates	g/gal	g/l	mg/L(ppm)	N (20%)	P(10%)	K(20%)	Mg(0.2%)	Fe(0.05%)	Mn(0.03%)	B(0.01%)	Cu(0.013%)	Zn(0.025%)
Zero	0	0	0	0	0	0	0	0	0	0	0	0
One-Half	11.66	3.08	3080.78	616.16	308.08	616.16	6.16	1.54	0.92	0.31	0.4	0.77
Recommended	23.32	6.16	6161.55	1232.31	616.16	1232.31	12.32	3.08	1.85	0.62	0.8	1.54
Double	46.65	12.32	12323.1	2464.62	1232.31	2464.62	24.65	6.16	3.7	1.23	1.6	3.08

Fig1: Fertilizer rates and individual nutrient concentrations in ppm(mg/L) used in this study
N.B: Recommended rate is what farmers usually use as 2 tablespoons per gallon (6.16g/L) and each plant in recommended received 308mg of fertilizer per week.

3.2. Data collection

Data of plant heights and plant widths using inch rulers, and swollen stem diameters using calipers were collected every week on Fridays. At the harvest time, the fresh swollen stem diameter of plants was weighed on electric weight scale and compared in different treatments and cultivars.

3.3. Vitamin C (Ascorbic Acid) Content Analysis

To determine the ascorbic acid content, we extracted the ascorbic acid from ground, wet sample into a dilute sulfuric acid solution and then injected the extract onto a BioRad Aminex HPX-87H in the same dilute sulfuric acid solution for separation and detection with a photodiode array detector. Three extractions from a sample of each replicate were tested, we then took the average

and standard deviation of the results. The results were recorded in mg of vitamin C per g of the plant material. Then that concentration was multiplied by the total weight of the swollen stem in g to get mg of total vitamin C in the whole swollen stem. These tests were run at the Food Science and Technology Lab, Lincoln-Nebraska.

3.4. Data Analysis

All the data collected were used to make tables, charts, and figures. Then we used them to make statistical analysis to interpret the results using Google Sheets and Microsoft excel.

4. Results

4.1. Plant Growth

In general, plants that were treated with more fertilizer showed more growth than others. They were big, heavy, and had thick and dark green leaves. On the other hand, plants that received no fertilizer were small and visibly nutrient deficient.

4.2. Plant Height

In all cultivars, plants that received more fertilizer grew taller and faster compared to others. The average plant height was 42.78 cm for double, 30.12 cm for recommended, 24.82 cm for one-half, and 17.81 cm for zero rate (Figure 2). At transplanting date, all plants were between two and four inches. At the end of the experiment, plants that were treated with the double amount of fertilizer were 5.08 cm taller than those treated with the recommended rate and 15.24 cm taller

than those with no fertilizer. These differences were recorded within six weeks. So, plants that received double rate grew faster than those treated with less fertilizer.

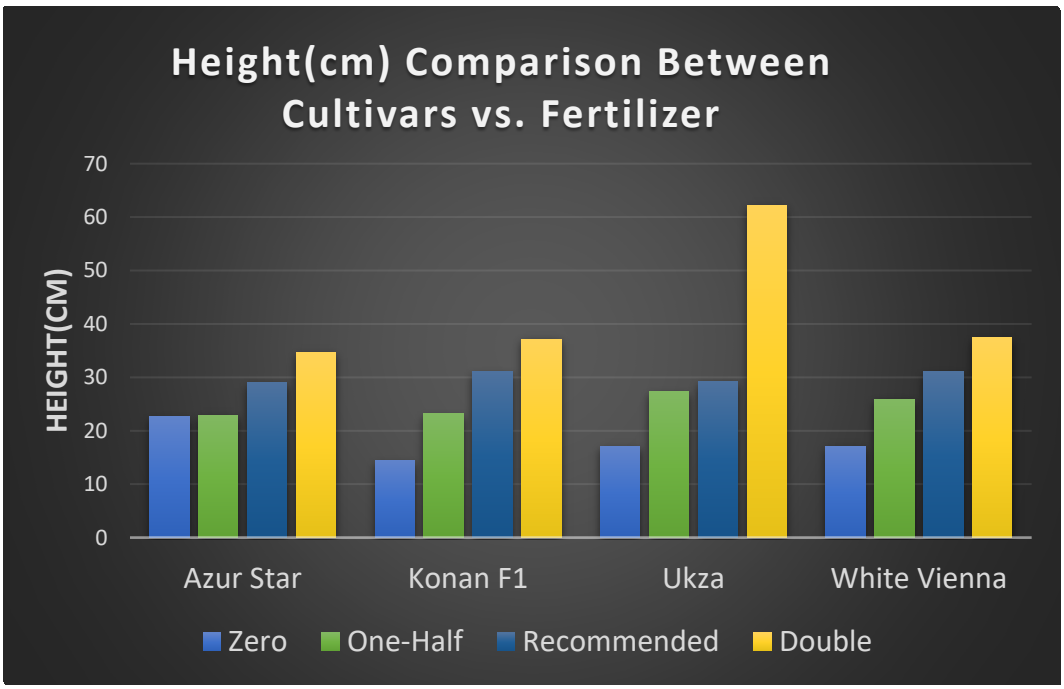

Fig 2: Plant height comparison between different kohlrabi cultivars treated with different fertilizer rates. The average plant height was 42.78 cm for double, 30.12 cm for recommended, 24.82 cm for one-half, and 17.81 cm for zero.

4.3. Plant Width

In all cultivars, plants that were treated with double amount of fertilizer were wider, where the double had 63.50 cm, recommended had 58.75 cm, one-half had 48.67 cm, and zero had 30.71 cm at the harvest stage (Figure 3).

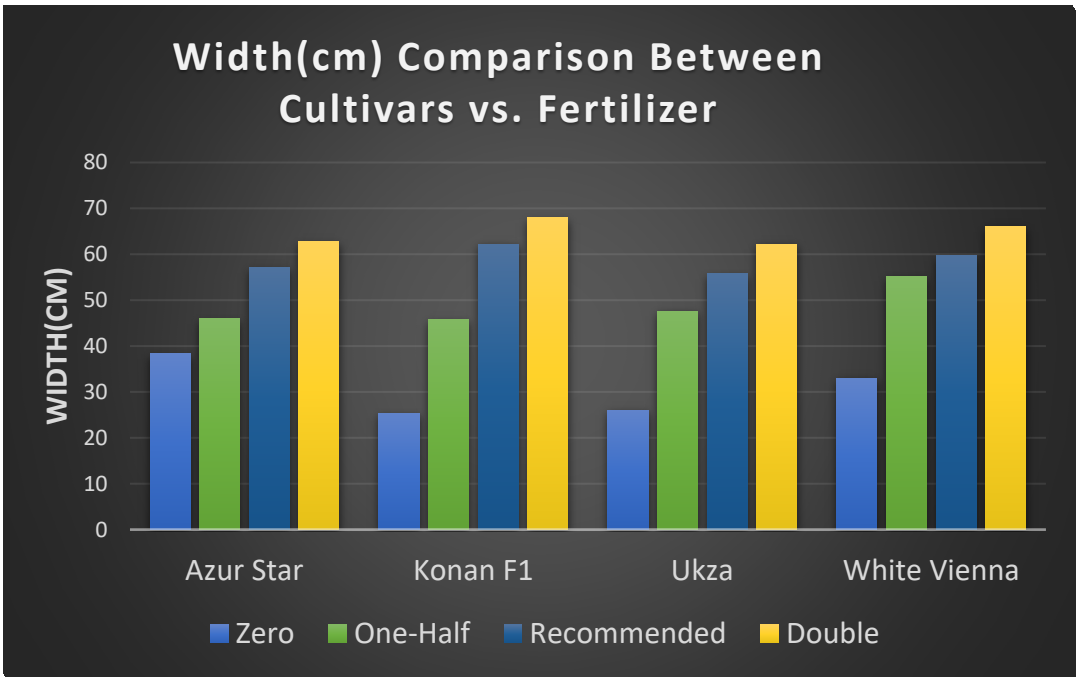

Fig 3: Plant width comparison between kohlrabi cultivars treated with different fertilizer rates. The average width for double was 63.50 cm, 58.75 cm for recommended, 48.67 cm for one-half, and 30.71 cm for zero.

4.4. Swollen Stem Diameter and Fresh Weight

In all cultivars, plants that were treated with double rate had biggest and heaviest swollen stems. The average diameter for plants treated with double rate was 8.94 cm, 7.85 cm for recommended, 6.35 cm for one-half, and 2.84 cm for zero rate. The average swollen stem fresh weight for double was 448 g, 320 g for recommended rate, 176 g for one-half rate, and 21.2 g for the zero rate. (See figures 4, 5, and 6).

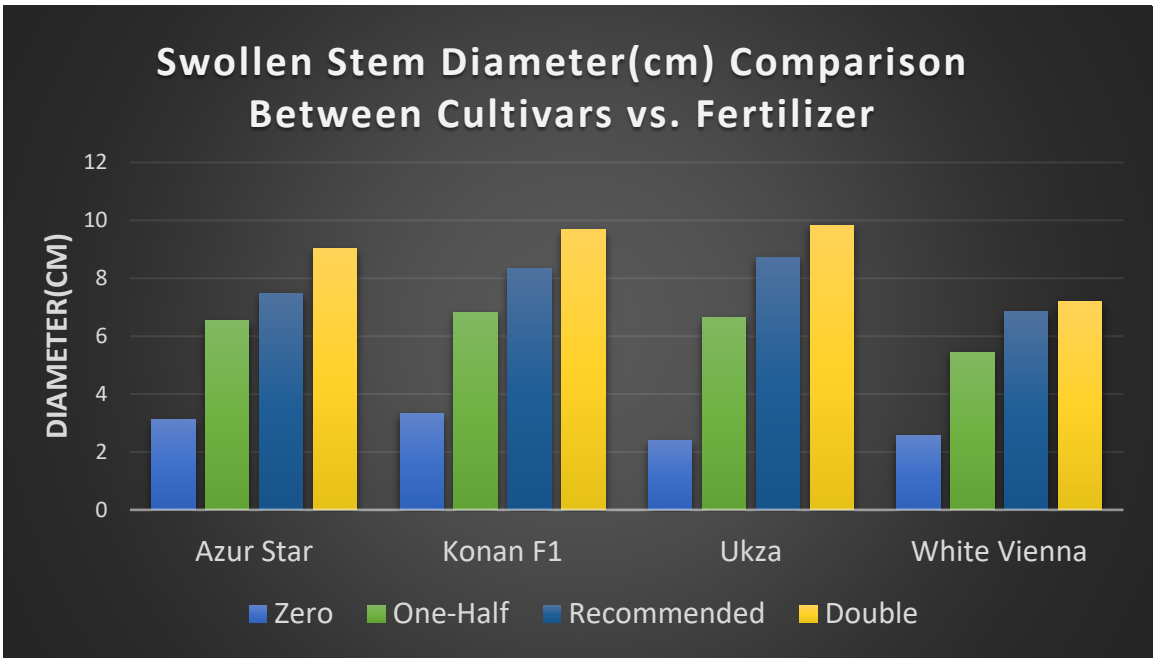

Fig 4: Diameter comparison between kohlrabi cultivars treated with different fertilizer rates. The average diameter for plants treated with double rate was 8.94 cm, 7.85 cm for recommended, 6.35 cm for one-half, and 2.84 cm for zero.

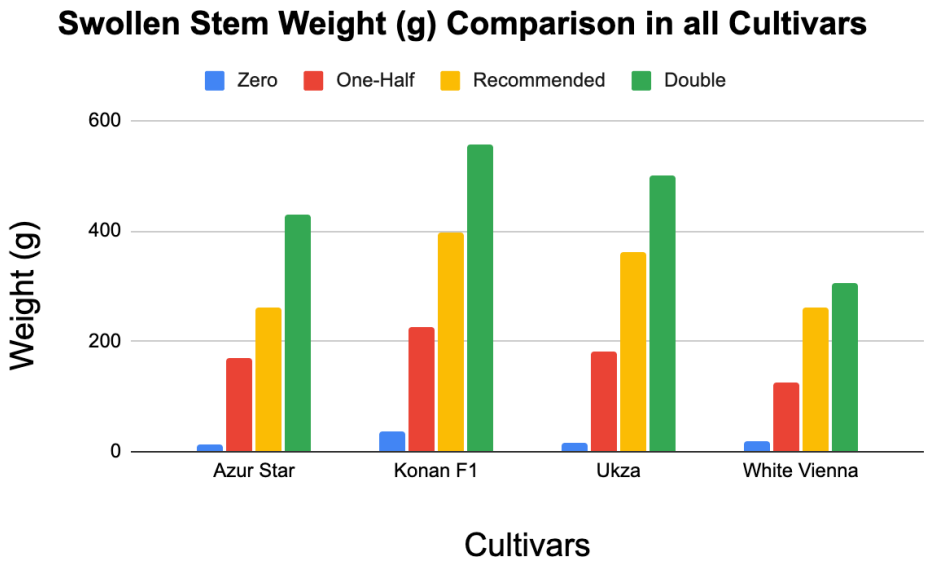

Fig 5: Swollen stem weight in all kohlrabi cultivars treated with different fertilizer rates. The weights are means of four swollen stems per treatment per cultivar. The average swollen stem fresh weight for double was 448 g, 320 g for recommended rate, 176 g for one-half rate, and 21.2 g for the zero.

Fig 6: Pictures of swollen stems of kohlrabi cultivars (Azur Star at the top, with Konan F1, and Uzar, and White Vienna at the bottom) treated with different fertilizer rates in a decreasing order from double rate on the left in all cultivars.

4.5. Vitamin C Content

The vitamin C concentration (mg of vitamin C/g fresh swollen stem) decreased as the size of the swollen stem increased and the effect was the same in all cultivars (Figure 7). Vitamin C content (total g of vitamin C in the whole swollen stem) was found to be mostly high in plants treated with more fertilizer.

Total vitamin C per swollen stem in all cultivars averaged about 6853 mg for the double rate, 6086 mg for recommended rate, 3272 mg (about the weight of a penny) for one-half rate, and 846 mg for zero rate (Figure 8).

There were differences in how vitamin C content of cultivars responded to the increase of fertilizer rate. When the rate increased from the recommended rate to the double rate, ‘Azur Star’

exhibited an increase of 3818 mg, ‘Konan F1’ increased 1764 mg, while ‘Ukza’ increased only 6.58 mg, and ‘White Vienna’ had 2181.78 mg less vitamin C than at the recommended rate (Fig 7 and 8).

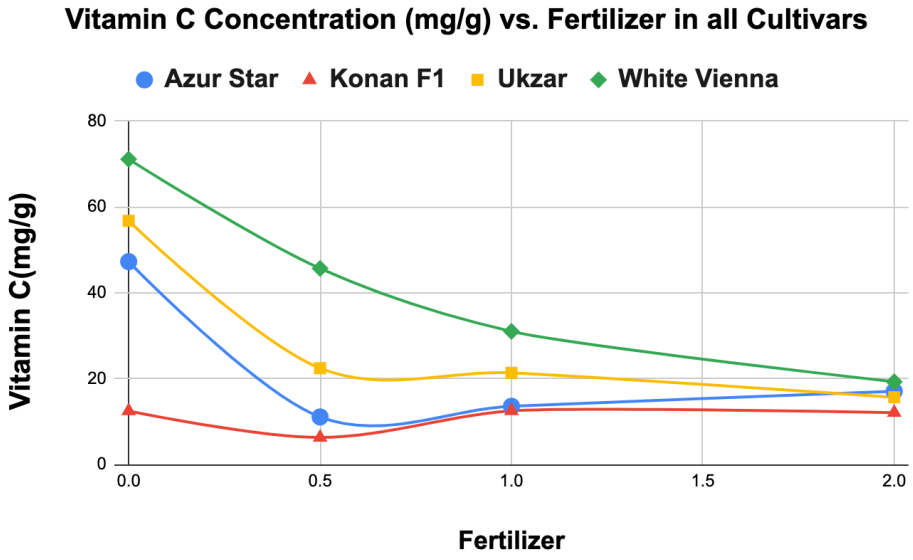

Fig 7: The graph for vitamin C concentration (mg of vitamin C/g fresh swollen stem) vs. fertilizer rates in all cultivars.

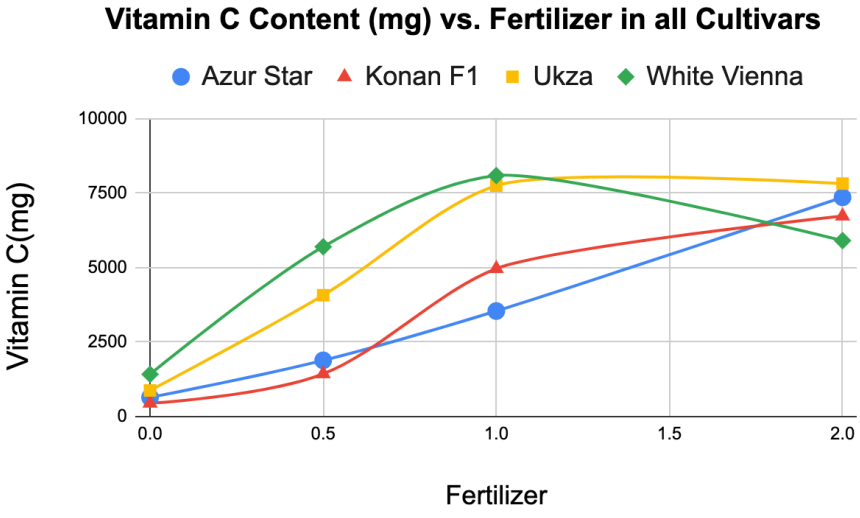

Fig 8: Total vitamin C content (total g of vitamin C in the whole swollen stem) vs. fertilizer rates in all cultivars.

5. Discussions

In general, the height increased as the fertilizer rate increased in all cultivars (Figure 2). Ukza height reacted more when the fertilizer was above the recommended rate where the height increased by 112.58% while other cultivars increased by about 19% from the recommended rate (Figure 2). The width was increased as the fertilizer level increased in all cultivars without exceptions (Figure 3). The same results happened to the swollen stem diameter where the increase in fertilizer level increased the diameter of the swollen stem in all cultivars. The White Vienna cultivar showed slightly smaller diameters but increased when the fertilizer was increased (Figure 4). The weight of swollen stem in all cultivars increased as the fertilizer rates were increased (Figure 5).

From all cultivars we studied, White Vienna showed less yields than other cultivars (Figures 4, 5 and 6). So, if the farmer's target is to grow for big and heavy swollen stems, we would recommend growing Azur Star, Konan F1 and Ukza because they reacted more to a slight increase in fertilizer than White Vienna. In case there is no fertilizer at all, Konan F1 would be the best choice as it had more weight almost double than other cultivars without fertilizer (Figure 5). Of course, in choosing what cultivar to use, other factors like the soil type, growing conditions and others should be considered.

The vitamin C concentration was found to be higher at zero rate, while the total vitamin C content increased as the fertilizer rate increased (Figure 7, and 8). There were differences in how vitamin C content of cultivars responded to increasing fertilizer rate. When the rate increased from the recommended rate to the double rate, 'Azur Star' gained 3818 mg, 'Konan F1' gained

1764 mg, while ‘Ukza’ gained only 6.58 mg, and ‘White Vienna’ had 2181.78 mg less vitamin C than others at the recommended rate (Figure 8). It seems like Azur Star and Konan F1 kept responding to the increase in fertilizer rates while the Ukza reached a plateau at recommended rate and White Vienna started to decrease in total vitamin C content beyond the recommended rate (Figure 8).

Since vitamin C is derived from sugars, its concentration is attributed to the amount of sugar contents in plants. Adding nitrogen is known to reduce the sugar concentration in cabbages and spinach (Yano et al., 1981). An explanation of this is that the fresh weight is mostly affected by vacuole size of the cells. Since the cells of bigger plants have more water, their weight will increase, and the sugar concentrations will decrease (Kano et al., 2007). That is why plants treated with more fertilizer had more weight and less vitamin C concentration (mg of vitamin C per g of fresh swollen stem). However, the increase in weight was faster than the decrease in vitamin C concentration and that resulted into having more total vitamin C content (mg of vitamin C in the whole swollen) in bigger swollen stems. However white Vienna showed a decrease in total vitamin C content with increase in fertilizer. Future studies should learn more about what causes this cultivar to behave like that. It would also be helpful to analyze what would happen if even more fertilizer rates were used, for example, triple or quadruple fertilizer rate.

6. Conclusions

Kohlrabi has been found to contain various kinds of metabolites that are responsible for its ability to be an antioxidant, antidiabetic, and anti-inflammatory. Those metabolites include anthocyanins and isothiocyanates for anti-inflammatory and most of them are at elevated levels in purple colored kohlrabi (Park et at., 2017). The anti-inflammatory capability is because kohlrabi has isothiocyanates and phenolics (Higdon et at., 2007 and Jung et al., 2014). These benefits plus the ability of kohlrabi to prevent cancer can be used as a natural medicine for different human conditions like diabetes and cancer (Jung et al., 2014). These properties are what makes it important to explore different ways to improve the production of kohlrabi. One way to improve the production, is to apply fertilizers. In our study we proved that adding more fertilizer on all kohlrabi cultivars would increase the yield in terms of swollen stem diameter, weight, and total vitamin C content. Those plants that received doubled rate were heavier and bigger in size which means they can satisfy many people where quantity of food is concerned. We would recommend farmers to consider their purpose before adding more fertilizers. If the quantity is the target, they can keep using the recommended rate to avoid contamination of the environment with chemical runoffs. To those who are targeting the antioxidation properties of kohlrabi, they can apply a little less than the recommended. Though this can make them use larger lands, it is a better way at reducing food waste. It is important to have enough and quality foods, but it as well important to maintain the balance between crop production and the integrity of the environment.

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