Nurture the Earth and Nourish its People

Michelle Laterrade
Ponchatoula, Louisiana

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Introduction

Personal Remarks

I turn on my television and there on the other side of the screen is a boy with a swollen stomach, tattered overalls, and a look of despair. He continues to stare at me as a young lady states that 30 thousand children died the night before from lack of food and proper care. She continues by introducing the boy by the name Britter and stresses his own battle for survival. The commercial then continues to a scene where the boy is fully clothed, smiling, and the tumor like lump once encompassing his mid-section has miraculously disappeared. The lady continues with an enlightened voice explaining that for only a penny a day the viewer at home can help another child like Britter regain their health and provide them the education needed to support them in the future.

Global poverty, malnutrition, hunger, and death – these are all issues which I had only seen on television and read in news articles. The commercial of the little boy beating the odds of death through the gracious viewers' donations was the way I viewed food security and sustainability. I began to wonder why there were so many people dying from hunger every day; surely, I had more than enough money in my piggy bank to feed a thousand people for a day. However, after many high school agriculture courses and dozens of research reports later I came to realize that food security is an enormous problem that cannot be solved with just a penny. Food insecurity intertwines with many global challenges such as degradation of natural resources and lack of education in a never ending web, which begins and ends with agriculture. Almost overnight, a passion formed within me to understand these links and make a positive change in the world around me. I realized I needed to gain substantial knowledge on these links, so I made it my personal mission to educate myself and as well as educate others about the links between agriculture productivity and food security. I discussed the importance of agriculture in a person's everyday routine with many audiences, and shared that passion through heading my FFA's service learning committee, which conducted many projects to enhance food security in my local community.

My FFA advisor saw the passion I had in learning more and taking action, so she took me aside to tell me about the World Food Prize organization. She was working on an opportunity to send two of our school's students to Iowa for the Global Youth Institute and she wanted me to be one of them. I was enthusiastic to discuss and meet people which were interested in the same subjects I was interested in. It wasn't until I experienced the Global Youth Institute for myself that I realized that my initial mission to create an impact was much bigger and more detailed than I had ever expected. Throughout the week I was constantly engaged with scientists, politicians, and some of the most influential people I have ever encountered. Every day I learned something new and my previous knowledge on the links between food security was accompanied by new links. Some of these links included government sanctions, health, education, and culture. At the end of the week I presented my speech on the links between Uganda's civil war, illiteracy and disease prevalence, and how they affected Ugandans' standard of living. I was amazed at the other students' essays, and even more in awe of the enthusiasm our panel showed when discussing the students' ideas and solutions. It was encouraging to speak with adults who were interested in my thoughts and who were so supportive of our academic and career ambitions. Before the students were dismissed from one of the most inspirational weeks of our lives, we were able to watch presentations given by the Borlaug-Ruan International interns from the summer before. Chills ran up my spine as I heard about stories and places I had only dreamed of experiencing.

The World Food Prize's Global Youth Institute was the only thing I could think about for the next week, and I soon found myself applying for an internship position. I was ecstatic when I received my letter telling me I would be spending the next two months at The World Vegetable Center in Tainan, Taiwan. The chance to apply the knowledge that I had accumulated in a real life setting had always been a huge aspiration.

AVRDC-The World Vegetable Center

AVRDC, an international nonprofit research and development institute is committed to alleviating poverty and malnutrition in the developing world through the increased production and consumption of nutritious and health-promoting vegetables (AVRDC). The *Asian Vegetable Research and Development Center* was founded on May 22, 1971 by the Asian Development Bank, Japan, Korea, Philippines, Thailand, United States of America, Vietnam, and the Republic of China (Taiwan) with a mandate to work in tropical Asia. Their 5 global themes are germplasm, breeding, production, marketing, and nutrition. Their headquarters are in Shanhua, Taiwan with regional offices in Thailand, Tanzania, India, Central and West Asia, as well as North Africa. Their outreach projects are stationed in Cameroon, Indonesia, and Bangladesh employing over three hundred staff with around fifty internationally recruited scientists and professionals.

The Improvement of Tropical Tomato Production in Asia and Africa

One of AVRDC's ongoing development projects in Asia and Africa focuses on tropical tomato production which works to combat poverty and micronutrient malnutrition. Their goals are to develop a high yielding, disease-resistant tomato variety to increase the productivity and incomes of tropical vegetable farmers, as well as provide opportunities for processing and off-season production. They also strive to deliver appropriate and relevant technologies that will ensure the sustainability of newly introduced safe vegetable cultivation methods, and provide a product with not only improved horticultural traits such as fruit shape, color, firmness, and taste which consumers look for in a product, but can also provide a person's full daily vitamin A requirements. In most tropical countries there is a high prevalence of vitamin A deficiency, which causes growth stunting in children and blindness in adults (AVRDC 1995). Worldwide, deficiencies in micronutrients such as vitamin A affect almost four times as many people as hunger. AVRDC screens and selects globally important as well as exotic and indigenous tomato varieties for essential micronutrients, antioxidants, other anticancer compounds, and disease and pest resistant genes. The center provides training in improved crop management techniques to reduce pesticide misuse and increase the efficiency of water and fertilizer usage. These implemented projects have notable outcomes such as the 'Golden Tomatoes', which a single fruit of this conventionally bred tomato variety contains three to six times more β-carotene than standard tomatoes. AVRDC's projects have also improved the profits of smallholder farmers in tropical regions by almost quadrupling their net incomes with off-season tomato production. Estimated net income during the winter season is $2,500-$3,000 USD/ha, while summer tomato production provides a net income of $8,000-$10,000 USD/ha (AVRDC). With this increase of income, farmers are able to sustain themselves, as well as their families, by providing the opportunity to increase their standard of living through education, housing, and dietary diversity.

The Effect of Tomatotone Fruit-Set Regulator on the Quality and Nutrient Content of Tomato Fruit Grown Under Protected Cultivation in Taiwan

Supervisors: Dr. Ray-yu Yang and Dr. Peter Hanson

Abstract

This study evaluated the quality and nutrient content of three tomato varieties with and without the application of the fruit-set regulator tomatotone. Evaluation took place in the off-season of Taiwan when unfavorable environmental conditions prevail. The trial was established in plastic houses with a random block design. The trial was sown on April 19th and transplanted to the field on May 20th. Tomatotone was sprayed on flower clusters according to established protocol between June 12th and July 6th. Fruit samples from four randomly selected plants were analyzed for quality and nutrient content. Statistical analysis was focused on the comparison of fruits with and without the application of tomatotone. The analysis of variance using SAS software indicated an insignificant ($P \geq 0.05$) variation in the means of nutrient content. Similar insignificant variation was observed in the quality content of the samples.

Additional Index words: fruit-set, tomatotone, βeta-carotene, Lycopene, Ascorbic Acid

Introduction

Tomatoes (*Lycopersicum Esculentum* Mill.) are a widely grown staple crop in many tropical regions such as Southeast Asia and Africa. Tomatoes are a vital source of nutrients and contain significant amounts of carotenoids such as lycopene, βeta-carotene (vitamin A), and ascorbic acid (vitamin C). Lycopene, which constitutes about 80-90% of the total carotenoid content of red-ripe tomatoes, is the most efficient among carotenoids through its lipid-soluble antioxidant activity and its oxidation activity which protects against peroxyl free radicals (potential mediators of tumor initiation and promotion). Remarkable inverse relationships between lycopene intake and risk have been observed in particular for cancers of the prostate, pancreas, and a certain extent of the stomach (Pavia and Russel 1999). On the other hand, β-carotene, a potent dietary precursor of vitamin A and a vital antioxidant, accounts for around 7% of tomato carotenoid content and is utilized in the protection against damage caused by sunlight (Mortensen and Skibsted 1997). Vitamin A deficiencies are highly prevalent in developing and developed countries, and they are known to cause stunting in children and blindness in adults. Ascorbic acid (vitamin C), while being a most effective antioxidant in plants, it is also an important phytochemical of tomato fruit. Studies have proposed the positive relationship between levels of ascorbic acid and growth development in tomato fruit, as well as health benefits including protection against immune system deficiencies, cardiovascular disease, prenatal health problems, and even skin wrinkling (Pavia and Russel 1999).

These three nutritional indicators make up the overall antioxidant activity (AOA) found in tomato fruit. Because tomatoes are a staple crop in many developing and already developed countries, higher AOA could potentially contribute to better human health worldwide. However, in tropical regions, tomatoes are mostly sown from October to November and are marketable from February to April. From March through September, tomatoes are practically not grown in tropical regions due to unfavorable environmental conditions of summer which reduce the vitality[1] of the plant, leaving a large span of time where tomato fruit is not incorporated into daily diets of farmers as well as consumers

1 capacity for survival; low vitality may cause sudden termination
2 a small naturally occurring hydrocarbon gas, responsible for ripening fruit and, contradictory, the cause of fatality in some plants

whom purchase these vegetables. During this period, the temperature (both day and night), humidity, rainfall, and light intensity, potential limiting factors of tomato production in the tropics, remain very high (Abdula and Verkerk 1968). The levels of ethylene[2] and the probability of floral abscission[3] are high after anthesis[4] when higher temperature conditions occur. High day and night temperatures above 34°-38° C have been studied and reported to limit fruit-set and impair the physiological process in the pistil, which results in floral or fruit abscission[3]. Alongside, studies of high light intensity was been observed to reduce the physiological process of the reproductive organ of the tomato by increasing the internal temperature. This increase in internal temperature causes a reduction in the vitality[1] of the plant causing the termination of the propagation[5] processes, providing the assurance of the plant's survival. Excess nutrients are now stored and utilized to increase the plan's vitality[1] instead of tomato fruit production. High humidity and rainfall levels also decrease the vitality[1] of the tomato plant by increasing the incidence of diseases such as tomato yellow leaf curl (TYLC), and bacterial wilt. Blossom end rot, a calcium deficiency, is caused by the sporadic uptake and inadequacy of water levels due to heavy rainfall and is also a limiting factor in the production of tropical tomatoes.

Agriculture researchers are working towards improving tropical tomato production by studying disease, pest, and temperate resistance and higher yielding tomato varieties. *The Asian Vegetable Research and Development Center* has extension projects in Asia and Africa introducing traditional as well as modernized cultivation methods that make production more efficient and increase net revenue. Due to many base limiting factors in tropical tomato production, some scientists encourage the utilization of synthetic photohormones such as para-chlorophenoxy acetic acid, commonly known as tomatotone. Tomatotone is an auxin which provides conditions to which a tomato plant can successfully complete the pollination and fertilization processes of reproduction, overall inducing fruit-set. Previous reports have found high levels of viability in tomatoes when auxin type fruit-set regulators replaced traditional reproduction methods (AVRDC 1993). In addition, a trial was produced where the application of pollen extracts to the floral ovary caused parthenocarpic[6] fruit also produced by the application of tomatone. This help form the suggestion that pollen grains consist of plant hormones similar to auxin. The pollen acts as a messenger, allowing the hormones access to the ovary and inducing fruit-set and growth.

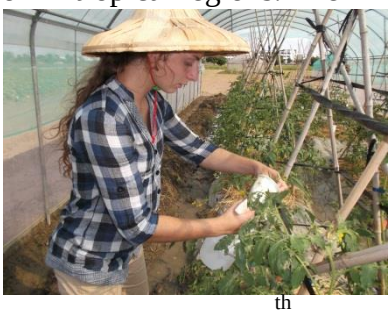
These findings are highly relevant for farmers, especially smallholder farmers, in developing countries such as Asia and Africa whose number of marketable tomato production spirals downward during the summer season. This technology allows farmers to increase their net yield and to grow off-season crops, overall increasing household revenue and the farmers' standard of living. While focusing on the supplier's incentives and increased ability to grow during the summer season, it is also noted that there will be an increased availability of these tomatoes to consumers. Improved intake of tomatoes will expectantly decrease diseases related to vitamin A and C deficiencies. However, studies on the application of auxin related substances to the stigmas of tomatoes and resulting parthenocarpic[6] fruit, as well as the lack of research on a fruit's nutrient content when this treatment is utilized makes that assumption unreliable. The lack of information on nutrient factors when tomatotone is utilized in off-season tomato production lead to this study. Because consumers assess the supplier's produce quality for purchase, it is also important to focus on the quality content of the tomato fruit when tomatotone is utilized. Indicators analyzed for quality content included pH, color (a/b), acid, and total soluble solids (°brix). Additionally, indicators analyzed for nutrient content included ascorbic acid (vitamin C), βeta-carotene (vitamin A), and lycopene.

3 the process in which a plant abandons fruit development, also known as bud drop
4 the stage at which a plant's flower is fully bloomed and sexually functional
5 to multiply by the process of natural reproduction
6 lack of seeds, seedless

Methods and Materials

Study Design

Treatments were set up in a three by two factorial, making six treatments total. There were three levels of variety (CHT2053, CLN3671, and CLN3751) with two levels of tomatotone treatment (with and without). Each treatment was replicated four times, totaling 24 plots. Plots were arranged in a randomized complete block design to minimize environmental influences. Each plot had eight plants, but measurements were taken on four randomly chosen plants. The trail was based in plastic houses which stimulated cultivation methods used during summer tomato production in tropical regions. The trail was sown on the 18th of April and transplanted in the plastic houses on the 16th of May. The trail was sprayed with the following chemicals to reduce disease and pest constraints: Terrazole 35% WP (bacterial wilt), Kasugamycin +cooper Oxychloride (early blight & bacterial spot), Benlate 50% WP (black leaf mold), Lannate 40% WP (tomato fruit-worm), Alert 10% EC (beet army worm), Chlorfuazuron 5% EC (tobacco cutworm), Abamectin(Avid) 2% EC (leaf miner), and Curzate 72% WP (black leaf mold). There was also a treatment of Complex Fertilizer No. 43 on June 18th.



Starting June 12th and ending July 6th, every two days, the plots were tended and flower clusters were assessed. Protocol for determining day of treatment application on flower clusters is as follows: the variety CHT2053 received treatment when its clusters had ≤ 4 blossoms achieve anthesis[4], and the varieties CLN3671 and CLN3751 received treatment when ≤ 3 blossoms achieved anthesis[4]. Appropriate, individual clusters were marked and sprayed at approximately 3 PM Chinese Standard Time with ≈ 1 mL para-chlorophenoxy acetic acid (tomatotone).

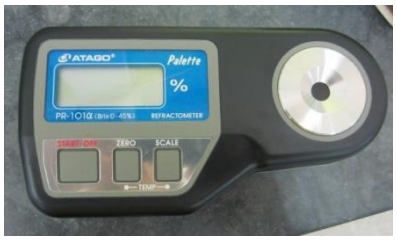
Sample Preparation

Tomatoes were sampled once at the fully red-ripe stage, varitiey CHT2053 approximately 69 days after transplant and CNL3671 and CNL3751 97 days, respectively. Four plants were randomly selected from each replication and a minimum of six fruits were harvested per plant depending on fruit size. Each sample consisted of >600 g fully ripened fruit harvested from a single plot. Fruits were cut, blended with a homogenizer, and filtered through gauze to remove skin and membranes. From each sample, six plastic bags were prepared, each containing 10-20 g of fresh tomato slurry later analyzed for quality and nutrient content. Remaining tomato slurry was centrifuged at 8000 rpm at 26°C for ten minutes to obtain the supernatant used to measure color and soluble solids concentration.

Quality Analysis

Total Titratable Acid Fresh tomato slurry was titrated with 0.05 N NaOH until pH reached 8.1. Acid content was measured using a digital buremeter and represented as citric acid equivalent (%, w/v). The experiment was done at room temperature (25°C).

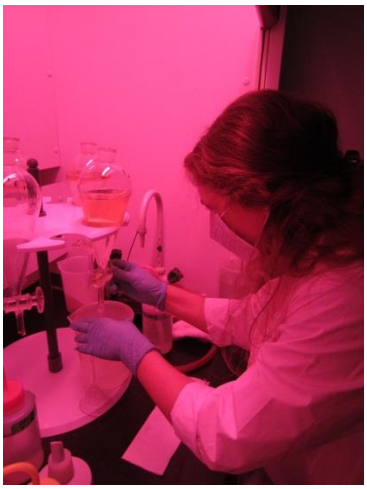
pH Fresh tomato slurry was measured using a digital pH meter at room temperature (25°C).



Solidity Concentration was measured with a digital refractometer (PR-101, Atago, Tokyo, Japan). Soluble solid values were represented as °brix.

Color Color was measured by a colorimeter (Nippon Denshoku Kogyo Co., Ltd. Osaka, Japan) on three scales represented as a, b and L. Color values of fresh tomato slurry were calculated as a/b using a red standard surface.

Nutrient Analysis



Beta-Carotene and Lycopene Ten g of fresh tomato slurry were blended with 100 mL hexane:acetone (6:4, v/v), and 300 ppm of 0.5 ml internal standard (*β*-apo-8' –carotenal-trans) in a homogenizer for six minutes. Acetone was then washed out five times with salt-saturated water. The hexane extract was filtered with a 0.45 µm filter. Analyses were performed using high-performance liquid chromatography (HPLC, Waters, Mass.) equipped with a 717 plus autosampler, 600 controller, 2487 detector (read at 436 nm) with a 125 × 4 mm LiChrospher® 100 RP-18e column, 5 µm (Merck, Darmstadt, Germany) under isocratic conditions at ambient temperatures. The mobile phase was acetoniltrile: methanol (75:25, v/v) at a flow rate of 1.5 mL/min. Commercial β-carotene and lycopene were used as standards.

Ascorbic Acid The determination of total ascorbic acid was on the basis of coupling 2,4 dinitrophenylhydrazine (DNPH) with the ketonic groups of dehydroascorbic acid through the oxidation of ascorbic acid by 2,6-dichlorophenolindophenol (DCPIP) to form a yellow-orange color in acidic conditions (Pelletier, 1985). Twenty g of frozen slurry was blended with 80 mL, 5% meta-phosphoric acid in a homogenizer and centrifuged. After centrifuging, 2 mL of the supernatant was poured into a 20 mL test tube containing 0.1 mL of 0.2% 2,6-DCPIP sodium salt in water, 2 mL of 2% thiourea in 5% meta-phosphoric acid and 1 mL of 4% 2, 4-DNPH in 9N sulfuric acid. The mixtures were kept in a water bath at 37 ºC for 3 hours followed by an ice bath for 10 minutes. Five mL of 85% sulfuric acid was added and the mixtures were kept at room temperature for 30 minutes before reading at OD 520 nm. 2,4-DNPH was added during the ice bath as a blank for a control. Commercial L-(+)-ascorbic acid (99% VC) was used as the standard.

Data Analysis

Quality and Nutrient Content Data was collected from nutrient and quality tests for statistical analysis. The Statically Analysis System (SAS) software was used to analyze the data from the six treatments that included three varieties treated with or without tomatotone which were all replicated four times. The MEANS Procedure was used to compare treatment, e.g. CLN3671-no tomatotone, replications for individual quality and nutritional traits. Traits between treatments were then deemed significantly

different by the Analysis Of Variance, i.e. ANOVA. Using the ANOVA, the F-value was calculated to determine probability of incidence. The separation of treatment means was carried out by the Least Significant Difference (LSD) at Alpha (5%) probability level. Means which were not significantly different from each other were t-grouped by a given letter. T-grouping was based on the p-value (i.e. probability) compared to the significance level. When the p-value was greater than the significance level, the differences among treatments were not significantly different ($P \geq 0.05$). Contrarily, if the p-value was less than the significance level, the results would deem significantly different ($P \leq 0.05$).

Results and Discussion

Due to severe flooding from Typhoons and heavy rains the trail lost a number of plants to bacterial wilt and tomato yellow leaf curl, which resulted in severely stunted plants throughout the experimental plot. Many tomato fruits were also lost to pest interference. However, the remaining plants still supplied a significant yield for samples which were used in the comparison of tomatotone treatments.

Percent Fruit-set data

Table1. Effect of tomatotone fruit set regulator on percent fruit-set of sources

Source	Sum of Squares	Mean Square	F Value	Pr>F
Rep	773.708691	257.902897	1.49	0.2574
Variety	7882.099353	3941.049677	22.78	<0.0001**
Treatment	755.526880	755.526880	4.37	0.0541*
Variety*Treat.	1242.205338	621.102669	3.59	0.0532*
Experimental error	2595.549229	173.036615		
Sampling error	13429.51401	186.52103		

** Significant at 1%
* Borderline significant at 5 %

Table 1 gives the results for mean comparison of percent fruit-set for the source interactions. The fruit-set means compared through variety effect is significantly different ($P \leq 0.01$). The percent fruit-set means compared through treatment interaction and varieties by treatment interaction are both border line significant ($P \leq 0.05$).

Table 2. Effect of tomatotone fruit set regulator on percent fruit-set of three tomato varieties

Variety	**PFRT**	
	W/out	With
CHT2053	44 ± 8.6 a	58 ± 11.6 a
CLN3751	31 ± 13.7 b	39 ± 8.6 b
CLN3671	32 ± 21.2 b	28 ± 14.2 c

LSD ($P \leq 0.05$) = 9.9129

Table 2 shows the results of the percent fruit-set for the 3 varieties' and their treatments. Varieties CHT2053 and CLN3751 were not significantly different ($P \geq 0.5$) while CLN3671 showed a significant difference ($P \leq 0.5$) between treatment and no treatment mean values. Mean comparison of percent fruit-set parameters between varieties showed significant differences ($P \leq 0.5$), CHT2053-with tomatotone being the highest.

Quality Indicator data

Table 3. Effect of tomatotone fruit set regulator on fruit pH of three tomato varieties

Treatment (Variety name-tomatotone)	Fruit pH
CHT2053-no tomatotone	4.12 A
CHT2053- tomatotone	4.10 A
CLN3751-no tomatotone	4.05 AB
CLN3671-no tomatotone	3.98 B
CLN3751- tomatotone	3.98 B
CLN3671- tomatotone	3.90 C
Overall treatment mean	4.02
LSD value (P<0.05)	0.08
Coefficient variation	1.25

Means followed by the same letter are not significantly different by Least Significant Difference (P=0.05)

Table 2 gives the results for mean comparison of pH for the 3 varieties' treatment. Varieties CHT2053 and CLN3751 were not significantly different ($P \geq 0.5$) while CLN3671 showed a significant difference

($P \leq 0.5$) between treatment and no treatment values. Mean comparison of tomato pH parameters between varieties showed significant differences ($P \leq 0.5$), CHT2053-no tomatotone being the highest.

Table 4. Effect of tomatotone fruit set regulator on fruit color of three tomato varieties

Treatment (Variety name-tomatotone)	Treatment mean (a/b)[1]
CLN3671-no tomatotone	1.77 A
CLN3671- tomatotone	1.75 A
CLN3751- tomatotone	1.66 A
CLN3751-no tomatotone	1.64 A
CHT2053- tomatotone	0.20 B
CHT2053-no tomatotone	0.19 B
Overall treatment mean	1.20
LSD value (P<0.05)	0.14
Coefficient variation	7.71

[1]Values for a and b were measured with a chromometer using a red standard surface. Immature green tomatoes have an a/b ratio less than 0. The a/b ratio increases to zero and above as the fruits ripen toward a dark red. Note that CHT2053 is a high beta-carotene variety and the fruit color is orange. Means followed by the same letter are not significantly different by Least Significant Difference (P=0.05)

Table 3 gives the results for mean comparison of color values for the 3 varieties' treatment. All varieties were not significantly different ($P \geq 0.5$) between treatment and no treatment values. Mean comparison of tomato color value parameters between varieties showed significant differences ($P \leq 0.5$), CLN3671-no tomatotone being the highest.

Table 5. Effect of tomatotone fruit set regulator on fruit acid content of three tomato varieties

Treatment (Variety name-tomatotone)	Treatment mean Acid[1]
CLN3671- tomatotone	0.735 A
CLN3671-no tomatotone	0.715 A
CLN3751- tomatotone	0.685 A
CLN3751-no tomatotone	0.538 B
CHT2053- tomatotone	0.533 B
CHT2053-no tomatotone	0.475 B
Overall treatment mean	0.613
LSD value (P<0.05)	0.130
Coefficient variation	14.039

[1]Equivalent of citric acid

Means followed by the same letter are not significantly different by Least Significant Difference (P=0.05)

Table 4 gives the results for mean comparison of acid for the 3 varieties' treatment. Varieties CHT2053 and CLN3671 were not significantly different ($P \geq 0.5$) while CLN3751 showed a significant difference ($P \leq 0.5$) between treatment and no treatment values. Mean comparison of tomato acid parameters between varieties showed significant differences ($P \leq 0.5$), CLN3671 being the highest.

Table 6. Effect of tomatotone fruit set regulator on fruit solids (°brix) content of three tomato varieties

Treatment (Variety name-tomatotone)	Treatment mean (°brix)
CHT2053- tomatotone	7.68 A
CLN3671- tomatotone	7.35 AB
CHT2053-no tomatotone	6.90 A-C
CLN3671-no tomatotone	6.35 B-D
CLN3751- tomatotone	5.85 CD
CLN3751-no tomatotone	5.35 D
Overall treatment mean	6.58
LSD value (*P*<0.05)	1.20
Coefficient variation	12.15

Means followed by the same letter are not significantly different by Least Significant Difference test (*P*=0.05)

Table 5 gives the results for mean comparison of solids for the 3 varieties' treatment. All three varieties were not significantly different ($P \geq 0.5$) between treatment and no treatment values. Mean comparison of tomato pH parameters between varieties and treatments were significantly different ($P \leq 0.5$) for all six treatments, CHT2053-tomatotone being the highest.

Nutrient Indicator data

Table 7. Effect of tomatotone fruit set regulator on fruit ascorbic acid content of three tomato varieties

Treatment (Variety name-tomatotone)	Ascorbic acid (mg per 100 g fresh weight)
CLN3751- tomatotone	38.8 A
CLN3751-no tomatotone	37.0 A
CHT2053-no tomatotone	31.0 B
CHT2053- tomatotone	30.5 B
CLN3671- tomatotone	28.8 B
CLN3671-no tomatotone	27.8 B
Overall treatment mean	32.3
LSD value (*P*<0.05)	4.7
Coefficient variation	9.68

Means followed by the same letter are not significantly different by Least Significant Difference (*P*=0.05)

Table 6 gives the results for mean comparison of ascorbic acid for the 3 varieties' treatment. All varieties are not significantly different ($P \geq 0.5$) between treatment and no treatment values. Mean comparison of tomato pH parameters between varieties showed significant differences ($P \leq 0.5$), CHT2053 being the highest.

Table 8. Effect of tomatotone fruit set regulator on fruit beta-carotene content of three tomato varieties

Treatment (Variety name-tomatotone)	Beta-carotene (mg per 100 g fresh weight)
CHT2053- tomatotone	1.76 A
CHT2053-no tomatotone	1.74 A
CLN3671-no tomatotone	0.18 B
CLN3671- tomatotone	0.18 B
CLN3751- tomatotone	0.17 B
CLN3751-no tomatotone	0.13 B
Overall treatment mean	0.69
LSD value (*P*<0.05)	0.25
Coefficient variation	23.88

Means followed by the same letter are not significantly different by Least Significant Difference (*P*=0.05)

Table 7 gives the results for mean comparison of β-carotene content for the 3 varieties' treatment. All varieties were not significantly different ($P \geq 0.5$) between treatment and no treatment values. Mean comparison of tomato β-carotene content parameters between varieties showed significant differences ($P \leq 0.5$), CHT2053 being the highest.

Table 9. Effect of tomatotone fruit set regulator on fruit lycopene content of three tomato varieties

Treatment (Variety name-tomatotone)	Lycopene content (mg per 100 g fresh weight)
CLN3671- tomatotone	7.51 A
CLN3671-no tomatotone	7.51 A
CLN3751- tomatotone	6.85 A
CLN3751-no tomatotone	6.85 A
CHT2053- tomatotone	0.25 B
CHT2053-no tomatotone	0.22 B
Overall treatment mean	4.86
LSD value (*P*<0.05)	1.76
Coefficient variation	24.01

Means followed by the same letter are not significantly different by Least Significant Difference (*P*=0.05)

Table 8 gives the results for mean comparison of lycopene content for the 3 varieties' treatment. All varieties were not significantly different ($P \geq 0.5$) between treatment and no treatment values. Mean comparison of tomato lycopene content parameters between varieties showed significant differences ($P \leq 0.5$), CLN3671 being the highest.

Summary and Conclusion

The finding of significance for percent fruit-set among varieties presented in tables 1 and 2 does not indicate there is a difference between treatments with and without tomatotone. However, base limiting factors such as disease and pests make analysis inconclusive.

The finding of variation for traits among varieties presented in tables 3 through 9 does not indicate there is a difference between treatments with and without tomatotone. This most likely represents a situation in which extraneous factors more strongly influenced by the content difference between varieties, not on the tomatotone treatment itself. Treatments such that a valid comparison of differences between varieties as groups did not seem appropriate.

The objective of this trial was focused on comparing the effects of the fruit-set regulator tomatotone for each nutrient and quality trait: CLN3671-tomatotone vs. CLN3671- no tomatotone, CLN3751-tomatotone vs. CLN3751-no tomatotone, and CHT2053-tomatotone vs. CHT2053- no tomatotone. Findings suggest that there were no difference between nutrient content of tomato fruit treated with tomatotone and ones that were not treated. By accepting our null hypothesis, we can conclude that the tomatotone does not affect the nutrient content of tomato fruit. Likewise, the majority of the quality traits were not influenced by the application of auxin type fruit-set regulator tomatotone. However, the higher citric acid level of CLN3751 and the lower pH value of CLN3671 when the application of tomatotone was present have various possible explanations. Even though plots and plastic houses were close in proximity, the elimination of base limiting factors such as disease and pests were not fully achieved. Whether in these limiting factors influenced the citric acid and pH levels is difficult to determine.

In the development and screening of improved tropical tomato varieties and improved cultivation methods, nutritional qualities are of great importance as far as human health is concerned. Off-season tomato production is a positive step for establishing agricultural sustainability. Technologies such as auxin type fruit-set regulator are a vital resource for many smallholder farmers in developing countries. It provides a convenient and inexpensive way to ensure success of crops. Success in crops provides the opportunity to increase one's standard of living through education, housing, and dietary diversity through higher net revenue. Therefore, this study showed the importance of the availability of data about tomatoes cultivated with tomatotone under unfavorable conditions. The findings of the study show that tomatotone treated tomato fruits are not significantly different in nutrient or quality content to untreated fruits. These data obtained will be useful for tomato farmers in tropical regions, and it can be used to promote the health benefits of their produce.

Personal Reflection

My eight-week Borlaug-Ruan international internship was an experience that I will forever cherish. Taiwan's beauty and culture enriched my summer and continuously kept me craving for more. The forests of palm trees and the comforting warmth of the summer, Taiwan was my tropical paradise. I spent most of my weekends traveling, visiting temples, soaking in culture, and trying to learn mandarin. In south Taiwan on the luxurious beaches of Kenting to the night lights and foothills of Taipei in the north, traveling was always an extraordinary adventure. Morning, evening, night, Monday, Tuesday, Thursday – street markets were everywhere, and I couldn't get enough! I used markets to practice my mandarin by asking farmers and venders about their products and in return they let me explain the work of AVRDC and my summer internship. I received constant stares and picture requests. Although I knew it was not common for locals to see Western girls venturing around the island, all the attention made me feel like a celebrity. People always introduced themselves to me and I would discuss my work at AVRDC when I knew they could understand. I asked my new friends about tradition and the life-style of people living in Taiwan. I would listen in awe as they spoke with profound passion and love for their country. I was very fond of the Taiwanese for their patriotism and their forever mindfulness of the simplicities that life had to offer.

I spent my weekends roaming the island, cheering on my colleagues at the Dragon Boat Festival, and enjoying every adventure. However, my fondest memory was in a place I have been familiar with ever since I could remember. One Sunday, Jen, a friend from work, asked me if I wanted to spend the day with her and her boyfriend. That morning, we met at Tainan train station. We walked through the city and then to attended mass where over 50 people belted songs of worship in Mandarin. Not understanding a syllable that was sung but feeling God's evident presence evoked a feeling, which gives me chills till this day. Jen translated the pastor's sermon, and I soon felt like his message was written just for me. He spoke about finding your place in other's lives whether that be a mother, daughter, friend, or follower in Christ. I left that morning yearning to find my small place in the big world I call home. Little had I known, I had already begun my quest the moment I had stepped off my plane and into the place I would call home for the next two months.

When I first arrived at AVRDC I was completely lost, figuratively and literally. I did not know the first thing about experimental design, lab research, or statistical analysis. Strangers who soon turned into life-long friends took me under their wings and gave me wings of my own. However, because they expected me to contribute as much work as regular researchers did, I learned to be independent and responsible for my own studies. Although I spent some of my week days submerged in research papers, encyclopedias, progress reports, and online journals, I spent most of the days submerged in knee high mud tending to the field. Other days were spent in my lab coat working on my analytical methods. I became mesmerized by the work of AVRDC in their mission to alleviate poverty and malnutrition. Not only by their work in the lab, but by their extension projects to introduce and teach smallholder farmers improved cultivation methods do they give sustainable agriculture a whole new meaning. The feeling that my research benefited the Center's projects was and still is quite an honor.

While at the World Vegetable Center, I attended weekly presentations and took part in conversational debates about politics and current research at daily coffee breaks. I was able to speak with many outstanding scientists and learn about their research. I even had to opportunity to partake in a number of radio interviews with the directors of AVRDC and a young lady from *Health on Earth*, a public service radio station located in Montreal. We discussed AVRDC's work on a global and local

scale. To see people with interests ranging from research and development to economics and statistics who came from different countries from around the world to work in unison for a cause greater than themselves was very humbling. I then came to the conclusion that one person's research alone was not the solution in solving malnutrition and poverty. It was evident that contributions made by entire organizations such as AVRDC and all of the stakeholders concerned are the answer to overcoming these barriers which undermine global sustainability and good nutrition. Collaboration, education, implementation, and development projects such as the ones utilized by AVRDC are key answers in the fight against hunger. I have become an advocate for the work done by organizations such as AVRDC by continuing my education in the field of agriculture and genetics. By following in the footsteps of these noble researchers and organizations, hopefully, my generation will have the answers to finally defeat global poverty and malnutrition. In order for our generation of future scientists, policy makers, farmers, and global citizens to overcome the threat of poverty and food insecurity, I believe we need to think as one, plan as one, and work as one to optimize each person's skills and knowledge for the benefit of the greater good.

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Appendix

The SAS System

Obs	treat	rep	plot	pH	brix	acid	color	vitC	beta	lyco
1	V1T0	1	ST4	4.14	7.6	0.49	0.25	30	2.19	0.32
2	V1T0	2	ST7	4.14	6.1	0.43	0.18	30	1.43	0.20
3	V1T0	3	ST14	4.08	6.0	0.48	0.14	29	1.43	0.13
4	V1T0	4	ST20	4.12	7.9	0.50	0.20	35	1.89	0.24
5	V1T1	1	ST5	4.11	7.1	0.49	0.18	29	1.68	0.18
6	V1T1	2	ST8	4.09	7.0	0.50	0.18	30	1.58	0.25
7	V1T1	3	ST16	4.10	8.3	0.56	0.21	29	1.87	0.28
8	V1T1	4	ST22	4.09	8.3	0.58	0.23	34	1.89	0.28
9	V2T0	1	ST1	4.00	5.9	0.62	1.44	37	0.14	7.16
10	V2T0	2	ST11	4.10	4.5	0.38	1.60	35	0.12	6.97
11	V2T0	3	ST13	4.07	5.7	0.55	1.74	40	0.15	7.80
12	V2T0	4	ST24	4.01	5.3	0.60	1.76	36	0.12	5.45
13	V2T1	1	ST6	3.98	5.4	0.63	1.65	39	0.14	7.11
14	V2T1	2	ST10	4.09	5.0	0.56	1.80	36	0.20	7.79
15	V2T1	3	ST17	3.95	6.5	0.70	1.60	42	0.17	6.71
16	V2T1	4	ST21	3.89	6.5	0.85	1.57	38	0.16	5.78
17	V3T0	1	ST2	3.91	7.2	0.68	1.76	28	0.29	10.67
18	V3T0	2	ST9	4.03	5.0	0.61	1.74	23	0.14	7.05
19	V3T0	3	ST18	3.97	7.7	0.95	1.73	35	0.14	5.34
20	V3T0	4	ST23	4.02	5.5	0.62	1.86	25	0.15	6.97
21	V3T1	1	ST3	3.88	6.7	0.66	1.67	25	0.14	7.19
22	V3T1	2	ST12	3.87	6.3	0.63	1.75	26	0.14	7.69
23	V3T1	3	ST15	3.98	7.3	0.77	1.88	29	0.16	6.23
24	V3T1	4	ST19	3.86	9.1	0.88	1.69	35	0.27	8.94

The SAS System

---------- treat=V1T0 ----------

The MEANS Procedure

Variable	N	Mean	Std Dev	Minimum	Maximum
rep	4	2.5000000	1.2909944	1.0000000	4.0000000
pH	4	4.1200000	0.0282843	4.0800000	4.1400000
brix	4	6.9000000	0.9899495	6.0000000	7.9000000
acid	4	0.4750000	0.0310913	0.4300000	0.5000000
color	4	0.1925000	0.0457347	0.1400000	0.2500000
vitC	4	31.0000000	2.7080128	29.0000000	35.0000000
beta	4	1.7350000	0.3728717	1.4300000	2.1900000
lyco	4	0.2225000	0.0793200	0.1300000	0.3200000

---------- treat=V1T1 ----------

Variable	N	Mean	Std Dev	Minimum	Maximum
rep	4	2.5000000	1.2909944	1.0000000	4.0000000
pH	4	4.0975000	0.0095743	4.0900000	4.1100000
brix	4	7.6750000	0.7228416	7.0000000	8.3000000
acid	4	0.5325000	0.0442531	0.4900000	0.5800000
color	4	0.2000000	0.0244949	0.1800000	0.2300000
vitC	4	30.5000000	2.3804761	29.0000000	34.0000000
beta	4	1.7550000	0.1502221	1.5800000	1.8900000
lyco	4	0.2475000	0.0471699	0.1800000	0.2800000

---------- treat=V2T0 ----------

Variable	N	Mean	Std Dev	Minimum	Maximum
rep	4	2.5000000	1.2909944	1.0000000	4.0000000
pH	4	4.0450000	0.0479583	4.0000000	4.1000000
brix	4	5.3500000	0.6191392	4.5000000	5.9000000
acid	4	0.5375000	0.1090489	0.3800000	0.6200000
color	4	1.6350000	0.1482116	1.4400000	1.7600000
vitC	4	37.0000000	2.1602469	35.0000000	40.0000000
beta	4	0.1325000	0.0150000	0.1200000	0.1500000
lyco	4	6.8450000	0.9954731	5.4500000	7.8000000

The SAS System

---------- treat=V2T1 ----------

The MEANS Procedure

Variable	N	Mean	Std Dev	Minimum	Maximum
rep	4	2.5000000	1.2909944	1.0000000	4.0000000
pH	4	3.9775000	0.0838153	3.8900000	4.0900000
brix	4	5.8500000	0.7681146	5.0000000	6.5000000
acid	4	0.6850000	0.1239624	0.5600000	0.8500000
color	4	1.6550000	0.1021437	1.5700000	1.8000000
vitC	4	38.7500000	2.5000000	36.0000000	42.0000000
beta	4	0.1675000	0.0250000	0.1400000	0.2000000
lyco	4	6.8475000	0.8397768	5.7800000	7.7900000

---------- treat=V3T0 ----------

Variable	N	Mean	Std Dev	Minimum	Maximum
rep	4	2.5000000	1.2909944	1.0000000	4.0000000
pH	4	3.9825000	0.0550000	3.9100000	4.0300000
brix	4	6.3500000	1.3025616	5.0000000	7.7000000
acid	4	0.7150000	0.1596872	0.6100000	0.9500000
color	4	1.7725000	0.0596518	1.7300000	1.8600000
vitC	4	27.7500000	5.2519838	23.0000000	35.0000000
beta	4	0.1800000	0.0734847	0.1400000	0.2900000
lyco	4	7.5075000	2.2507536	5.3400000	10.6700000

---------- treat=V3T1 ----------

Variable	N	Mean	Std Dev	Minimum	Maximum
rep	4	2.5000000	1.2909944	1.0000000	4.0000000
pH	4	3.8975000	0.0556028	3.8600000	3.9800000
brix	4	7.3500000	1.2369317	6.3000000	9.1000000
acid	4	0.7350000	0.1138713	0.6300000	0.8800000
color	4	1.7475000	0.0946485	1.6700000	1.8800000
vitC	4	28.7500000	4.5000000	25.0000000	35.0000000
beta	4	0.1775000	0.0623832	0.1400000	0.2700000
lyco	4	7.5125000	1.1281364	6.2300000	8.9400000

The SAS System
The ANOVA Procedure
Class Level Information

Class	Levels	Values
rep	4	1 2 3 4
treat	6	V1T0 V1T1 V2T0 V2T1 V3T0 V3T1

Number of Observations Read 24
Number of Observations Used 24

The SAS System
The ANOVA Procedure

Dependent Variable: pH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	0.15070000	0.01883750	7.50	0.0005
Error	15	0.03770000	0.00251333		
Corrected Total	23	0.18840000			

R-Square	Coeff Var	Root MSE	pH Mean
0.799894	1.247093	0.050133	4.020000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	3	0.01130000	0.00376667	1.50	0.2554
treat	5	0.13940000	0.02788000	11.09	0.0001

The SAS System
The ANOVA Procedure

Dependent Variable: color

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	12.16978333	1.52122292	177.83	<.0001
Error	15	0.12831250	0.00855417		
Corrected Total	23	12.29809583			

R-Square	Coeff Var	Root MSE	color Mean
0.989566	7.704720	0.092489	1.200417

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	3	0.01451250	0.00483750	0.57	0.6461
treat	5	12.15527083	2.43105417	284.20	<.0001

The SAS System
The ANOVA Procedure

Dependent Variable: acid

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	0.34151667	0.04268958	5.76	0.0018
Error	15	0.11121667	0.00741444		
Corrected Total	23	0.45273333			

R-Square	Coeff Var	Root MSE	acid Mean
0.754344	14.03921	0.086107	0.613333

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	3	0.09473333	0.03157778	4.26	0.0231
treat	5	0.24678333	0.04935667	6.66	0.0019

The SAS System
The ANOVA Procedure

Dependent Variable: brix

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	23.49333333	2.93666667	4.60	0.0054
Error	15	9.58625000	0.63908333		

Corrected Total	23	33.07958333			

R-Square	Coeff Var	Root MSE	brix Mean
0.710206	12.15088	0.799427	6.579167

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	3	7.52125000	2.50708333	3.92	0.0299
treat	5	15.97208333	3.19441667	5.00	0.0068

The SAS System
The ANOVA Procedure

Dependent Variable: vitC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	476.5000000	59.5625000	6.10	0.0014
Error	15	146.4583333	9.7638889		
Corrected Total	23	622.9583333			

R-Square	Coeff Var	Root MSE	vitC Mean
0.764899	9.676559	3.124722	32.29167

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	3	68.7916667	22.9305556	2.35	0.1137
treat	5	407.7083333	81.5416667	8.35	0.0006

The SAS System
The ANOVA Procedure

Dependent Variable: beta

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	13.43761667	1.67970208	61.63	<.0001
Error	15	0.40884583	0.02725639		
Corrected Total	23	13.84646250			

R-Square	Coeff Var	Root MSE	beta Mean
0.970473	23.88356	0.165095	0.691250

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	3	0.10637917	0.03545972	1.30	0.3106
treat	5	13.33123750	2.66624750	97.82	<.0001

The SAS System
The ANOVA Procedure

Dependent Variable: lyco

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	262.5411333	32.8176417	24.06	<.0001
Error	15	20.4562292	1.3637486		
Corrected Total	23	282.9973625			

R-Square	Coeff Var	Root MSE	lyco Mean
0.927716	24.01021	1.167796	4.863750

Source	DF	Anova SS	Mean Square	F Value	Pr > F
rep	3	3.6736458	1.2245486	0.90	0.4651
treat	5	258.8674875	51.7734975	37.96	<.0001

The SAS System
The ANOVA Procedure
t Tests (LSD) for pH

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	15
Error Mean Square	0.002513
Critical Value of t	2.13145
Least Significant Difference	0.0756

Means with the same letter are not significantly different.

t Grouping		Mean	N	treat
	A	4.12000	4	V1T0
	A			
	A	4.09750	4	V1T1
	A			
B	A	4.04500	4	V2T0
B				
B		3.98250	4	V3T0
B				
B		3.97750	4	V2T1
	C	3.89750	4	V3T1

The SAS System
The ANOVA Procedure
t Tests (LSD) for color

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	15
Error Mean Square	0.008554
Critical Value of t	2.13145
Least Significant Difference	0.1394

Means with the same letter are not significantly different.

t Grouping	Mean	N	treat
A	1.77250	4	V3T0
A			
A	1.74750	4	V3T1
A			
A	1.65500	4	V2T1
A			
A	1.63500	4	V2T0
B	0.20000	4	V1T1
B			
B	0.19250	4	V1T0

The SAS System
The ANOVA Procedure
t Tests (LSD) for acid

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	15
Error Mean Square	0.007414
Critical Value of t	2.13145
Least Significant Difference	0.1298

Means with the same letter are not significantly different.

t Grouping	Mean	N	treat

A	0.73500	4	V3T1
A			
A	0.71500	4	V3T0
A			
A	0.68500	4	V2T1
B	0.53750	4	V2T0
B			
B	0.53250	4	V1T1
B			
B	0.47500	4	V1T0

The SAS System
The ANOVA Procedure
t Tests (LSD) for brix

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	15
Error Mean Square	0.639083
Critical Value of t	2.13145
Least Significant Difference	1.2049

Means with the same letter are not significantly different.

t Grouping			Mean	N	treat
A			7.6750	4	V1T1
A					
B	A		7.3500	4	V3T1
B	A				
B	A	C	6.9000	4	V1T0
B		C			
B	D	C	6.3500	4	V3T0
D		C			
D		C	5.8500	4	V2T1
D					
D			5.3500	4	V2T0

The SAS System
The ANOVA Procedure
t Tests (LSD) for vitC

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	15
Error Mean Square	9.763889
Critical Value of t	2.13145
Least Significant Difference	4.7095

Means with the same letter are not significantly different.

t Grouping	Mean	N	treat
A	38.750	4	V2T1
A			
A	37.000	4	V2T0
B	31.000	4	V1T0
B			
B	30.500	4	V1T1
B			
B	28.750	4	V3T1
B			
B	27.750	4	V3T0

The SAS System
The ANOVA Procedure
t Tests (LSD) for beta

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	15
Error Mean Square	0.027256
Critical Value of t	2.13145
Least Significant Difference	0.2488

Means with the same letter are not significantly different.

t Grouping	Mean	N	treat
A	1.7550	4	V1T1
A			
A	1.7350	4	V1T0
B	0.1800	4	V3T0
B			
B	0.1775	4	V3T1
B			
B	0.1675	4	V2T1
B			
B	0.1325	4	V2T0

The SAS System
The ANOVA Procedure
t Tests (LSD) for lyco

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	15
Error Mean Square	1.363749
Critical Value of t	2.13145
Least Significant Difference	1.7601

Means with the same letter are not significantly different.

t Grouping	Mean	N	treat
A	7.5125	4	V3T1
A			
A	7.5075	4	V3T0
A			
A	6.8475	4	V2T1
A			
A	6.8450	4	V2T0
B	0.2475	4	V1T1
B			
B	0.2225	4	V1T0