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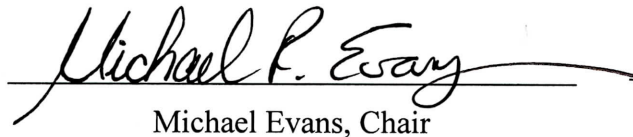
**Growth and Biomass Accumulation of Komatsuna Greens as Affected by Nutrient Solution
Electrical Conductivity**

An Undergraduate Honors Thesis
in the
Department of Horticulture


Submitted in partial fulfillment of the requirements for the
University of Arkansas
Dale Bumpers College of Agricultural, Food and Life Sciences
Honors Program

by
Leah P. Malvar

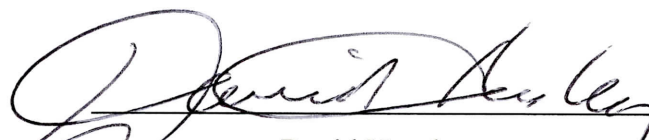
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Growth and Biomass Accumulation of Komatsuna Greens as Affected by Nutrient Solution Electrical Conductivity

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Abstract. The affects of different nutrient concentrations on komatsuna (*Brassica rapa* var. perviridis 'Komatsuna') grown in a nutrient film technique (NFT) hydroponic system were observed. Nutrient concentrations, measured by electrical conductivity (E.C.) in mS/cm, influenced plant height, leaf area, and plant fresh weight. The lowest measurements for each of these parameters were observed at the lowest E.C. of 1.0. mS/cm. As E.C. was increased from 1.0 to 1.2 mS/cm, measurements for shoot fresh weight and shoot height trended higher. Total leaf area increased as the E.C. was increased from 1.0 to 1.4 mS/cm, decreased as the E.C. was increased up to 1.6 mS/cm, and then increased again as the E.C. was increased further to 1.8 mS/cm. It was observed that as E.C. increased past 1.2 mS/cm, the incidence of cupping intensified, and leaves began to appear disfigured. This may have especially affected leaf area in higher E.C. treatment groups. Number of leaves per plant did not show statistical variance.

Subject Category: Nursery Crops

Growth and Biomass Accumulation of Komatsuna Greens as Affected by Nutrient Solution Electrical Conductivity

Additional Index Words. *Brassica rapa* var. *perviridis*, komatsuna, electrical conductivity, hydroponic, nutrient film technique

Introduction

Komatsuna (*Brassica rapa* var. *perviridis*) is an important fast-growing leafy vegetable (RHS, 2014), used especially in Japanese cuisine (Kamei, 1985). *Brassica* vegetables have been shown to have high antioxidative properties (Cartea et al, 2011), making komatsuna a nutritious leafy green. The plant's compact size and upright growth habit makes it a good candidate as a greenhouse crop for nutrient film technique (NFT) hydroponic systems. This type of system offers the most efficient fertilizer and irrigation application (Jensen, 2001 and Hayden, 2006). This results in the reduced emission of excess nutrients into the environment, and an economic return to growers as they improve on resource productivity (Porter and van der Linde, 1995). Additionally, NFT systems allow for a greater concentration of plants per square foot, allowing growers to increase their output (Resh, 2013). Using this method in a greenhouse lets growers offer fresh komatsuna year-round. NFT-grown komatsuna has been used in past studies to test solution amendments (Azad et al, 2013 and Islam et al, 2009) and metal accumulation in plant tissue (Mar et al, 2012), but little information is available regarding the fertility requirements of komatsuna grown hydroponically as a food crop. Therefore, the goal of this experiment was to contribute to the body of information that growers use in their production systems. Since greens are typically sold by weight (National Leafy Greens, 2009), the

objective was to determine the affect of fertilizer concentration as measured by electrical conductivity (E.C.) on the growth and development of komatsuna in an NFT system.

Material & Methods

The komatsuna crop was grown in 2 phases: Propagation and vegetative. Each phase lasted 3 weeks for a total of 6 weeks. At the start of the propagation phase, seeds obtained from Kitazawa Seeds in Oakland, California, were sown into a 162-cell Oasis ROOTCUBE® (phenolic foam) sheet. Each individual cell was 2.5cm x 2.5cm x 3.75cm. The sheet was placed into a propagation chamber with setpoints at 18° C for temperature and 70% for relative humidity. Seeds were checked twice a day: In the morning to irrigate, and in the afternoon to irrigate and for observation. Cells were irrigated with enough clear water to maintain 100% humidity at the seed site. During this phase, the number of new germinated seeds and total percent germination was documented. Once 80% of the seedlings had 2 true leaves (2 weeks after planting), they were moved into a greenhouse and acclimated to this new environment for 1 week. The greenhouse glazing consisted of double-wall polycarbonate and the structure was located in Fayetteville, AR (36° N, 94° W). Temperature set points were 24° C for cooling and 18° C for heating. During this final week in the propagation phase, the plants were irrigated with fertilizer solution (Table 1) diluted to an E.C. Of 0.6 mS/cm and a pH of 5.8. By the end of this phase, the plants had a minimum of 4 fully expanded true leaves.

On day 1 of week 4, the largest 80 plants were transferred into the NFT hydroponic system. Seedlings, still in the original Oasis cells, were placed into holes in the gulleys. Gulleys were set on a 3% slope and plants were spaced on 15-cm centers. Each of the 5 treatment groups had 16 single plant replications (2 gulleys of 8 plants each) and were grown in their own independent re-circulating system. The treatment groups were fertilized with one of the treatment fertilizer dilutions: 1.0, 1.2, 1.4,

1.6, and 1.8 mS/cm. Treatment groups were all housed in the same greenhouse bay, and shared solution tanks with other experiments that contained dandelion greens (*Taraxacum officinale*) and fancy-leaf lettuce (*Lactuca sativa*). Nutrient solution was circulated past the plant roots as a 3mm high film and returned to the solution reservoir in a closed-loop circuit. Reservoirs were adjusted for E.C. daily, and kept at a target pH of 5.8 (adjusted with citric acid as needed). The fertilizer solution used for all treatment groups was a custom recipe developed by the University of Arkansas Horticulture Department, shown in Table 1. The parts-per-million unit for each element was converted into units that could be weighed out and mixed with water (milligrams). The recipe shown in Table 1 is for an E.C. of 1.8 mS/cm, the E.C. at which the micro and macro elements exist at the parts-per-million shown. Parts-per-million changed as the solution was diluted or concentrated, but since all treatment groups used the same stock, the ratio of elements remained constant. A stock fertilizer solution of the Table 1 recipe was prepared for a 100x dilution in order to store it in the greenhouse. At such a high concentration, calcium will react with phosphates and sulfates to form precipitates that fall out of solution (Zumdahl, 2000). Therefore, these chemicals were kept separate. An A stock tank contained calcium and iron, and a B stock tank contained the phosphates and sulfates. It is an industry standard for stock A to include calcium and potassium, while phosphorous and micronutrients are kept in stock B (Evans, Unit 8). Equal parts of A and B stock fertilizer was added to the reservoir water for each treatment group, raising the E.C. until the target E.C. was achieved.

After 6 weeks of growth and observation, 5 replicate plants from each treatment group were randomly selected. Plant height (centimeters), shoot fresh weight (grams), number of leaves per plant, and total leaf area (cm²) was measured. The tallest single leaf was measured to determine plant height. Total leaves for each plant were counted, weighed fresh, and then photographed for digital image analysis (DIA) of leaf area (O'Neal et. al, 2002). DIA was accomplished using SigmaScan Pro (Systat

Software). An analysis of variance on biomass accumulation data was conducted in SAS to determine if significant differences occurred. Where significant differences occurred, an LSD test was conducted to determine significant differences between specific treatments.

Results

Within 24 hours, 14.8% of the seeds germinated (Fig 1, Day 1). By 48 hours, 65.4% more of the seeds were germinated for a total of 80.2% germination recorded for Day 2 (Fig 1). After this, the rate of germination declined significantly. On Day 3 there was 6.8% germination, 4.3% on Day 4, and 3.7% on Day 5 (Fig 1). No new germination was observed on Days 6 through 9, and only meager germination was observed (0.6% and 1.2%, respectively) on Days 10 and 11 (Fig 1).

Electrical conductivity influenced plant fresh weight, plant height, and leaf area (Table 2). Number of leaves per plant did not have statistical variance. According to SAS results, average plant mass for each of the 5 treatments fell into 2 groups. The first group consisted solely of the 1.0 E.C. treatment and had the least mass; the remaining 4 treatments were all together in the second group and had the greatest mass (Table 2). For plant height, there were 4 statistical groups. Tallest to shortest they were A (1.2 E.C.), AB (1.4 and 1.6 E.C.), BC (1.8 E.C.), and C (1.0 E.C.). Plants grown in an E.C. of 1.2 mS/cm had the tallest average height while those grown in the lowest E.C. of 1.0 mS/cm had the shortest average height (Table 2). Leaf area data consisted of 3 statistical groups (Table 2). From greatest to least (cm²) they were A (1.2, 1.4, and 1.8 E.C.), AB (1.6 E.C.), and B (1.0 E.C.).

Discussion

Electrical conductivity in the vegetative phase influenced plant height, leaf area, and plant fresh weight. Plants grown in an E.C. of 1.2 mS/cm were the only ones that performed well for all three

parameters. In contrast, those plants grown in the lowest E.C. of 1.0. mS/cm consistently had the lowest numbers for all three parameters. In the case of shoot fresh weight, the 1.2 E.C. treatment group marked the E.C. at which mass plateaued. The 1.2 E.C. treatment group was also the apex of plant height (Fig 3). Results for leaf area were the least consistent. As E.C. increased from 1.0 mS/cm to 1.4 mS/cm leaf area increased from 2310 cm² to 3872 cm². When the E.C. increased to 1.6. mS/cm, leaf area dipped down to 3203 cm², then went up again (3367 cm²) at the highest E.C. of 1.8 mS/cm (Fig 2). This inconsistency may be attributed to the incidence of cupping observed in plants grown in solutions more concentrated than 1.2 mS/cm. While outside of the scope of this project, it is believed to be a symptom of salt stress as the leaf malformation did not occur in the 1.0 and 1.2 E.C. treatment groups. The influence of salt stress on komatsuna plant uniformity is a possible topic for further research.

Conclusion

While similar research has been done on other leafy crops (Both et al, 1996; Parks and Murray, 2011; Samarakoon et al, 2006), this is the first study dedicated to komatsuna E.C. Weight is the primary description by which leafy greens are sold to retailers, and therefore the most relevant parameter in this study to the industry. However, other descriptions of plant physiology such as leaf area and plant height may provide insight into the overall habit and form of the plant. This is especially relevant to post-harvest packaging (Brecht, 1995; Cantwell and Suslow, 2002; Kim, 2005). Crops that have the same fertilizer, light, temperature, and humidity requirements often can share greenhouse space, so this research contributes to the knowledge of greens production by allowing hydroponic growers to grow komatsuna with other crops that have similar fertilizer E.C. requirements. According to this study, komatsuna plants grown in an E.C. of 1.2 mS/cm were the most uniform, had the greatest height and leaf area, and were in the statistical grouping that had the greatest mass. Therefore, growers should

maintain an E.C. of 1.2 mS/cm during vegetative stage in an NFT system for maximum komatsuna growth.

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Table 1. Parts per million of essential elements in the fertilizer solution.

Macro Nutrients		Micro Nutrients	
Nutrient	ppm	Nutrient	ppm
NH ₄ ⁺	8.5	S	75
NO ₃ ²⁻	169	Cu	0.13
P	48.7	Fe	4
K	212.3	Mn	0.5
Ca	192	Zn	0.09
Mg	47.79	Mo	0.07
		B	0.5

^zParts-per-million for each mineral element is for a solution with an E.C. 1.8 and a pH of 6.1.

Table 2. Growth of greenhouse-grown komatsuna greens using different fertilizer concentrations in a nutrient film technique system.

Electrical Conductivity (mS/cm)	Shoot fresh weight (g)	Shoot height (cm)	Total leaf area (cm ²)
1	152.6	49.7	2310
1.2	257.3	61.6	3872
1.4	267.2	58.8	3699
1.6	296.9	59.4	3203
1.8	263.8	54.0	3367
Significance	*	**	*
LSD($\alpha=0.05$)	81.5	6.8	968

*, ** Significant at the P>F of 0.05 or 0.01 level, respectively.

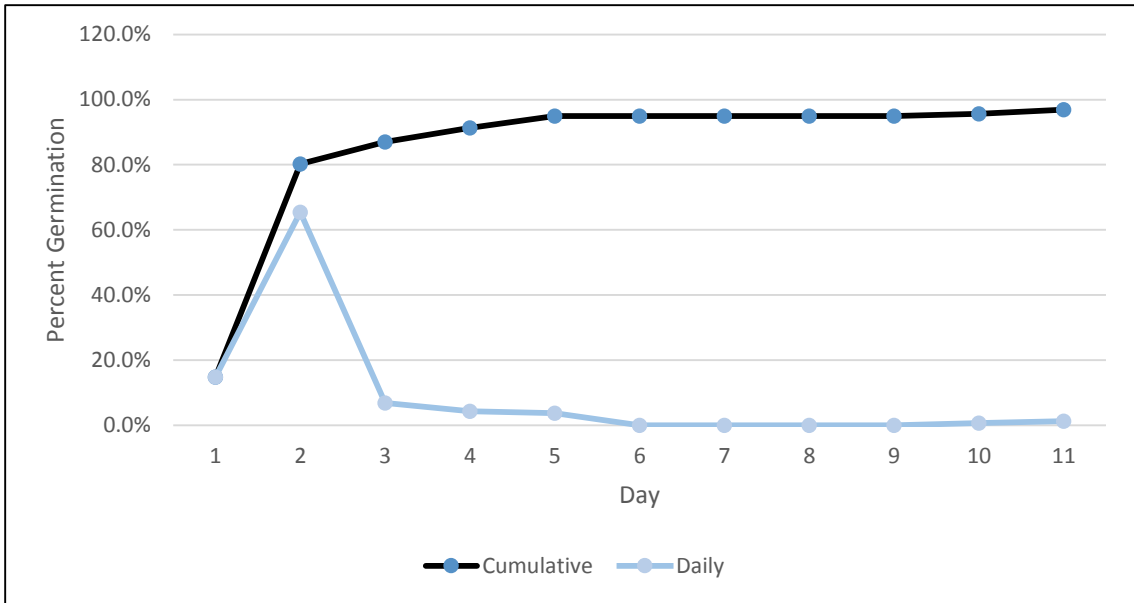


Fig 1. Daily and cumulative germination percentage of komatsuna. Based upon the germination of 162 seeds germinated in phenolic foam cubes at the following standard germination conditions of 24 hrs of daylength per 24 hrs, temperatures of 18°C day/18°C night, and relative humidity of 70%.

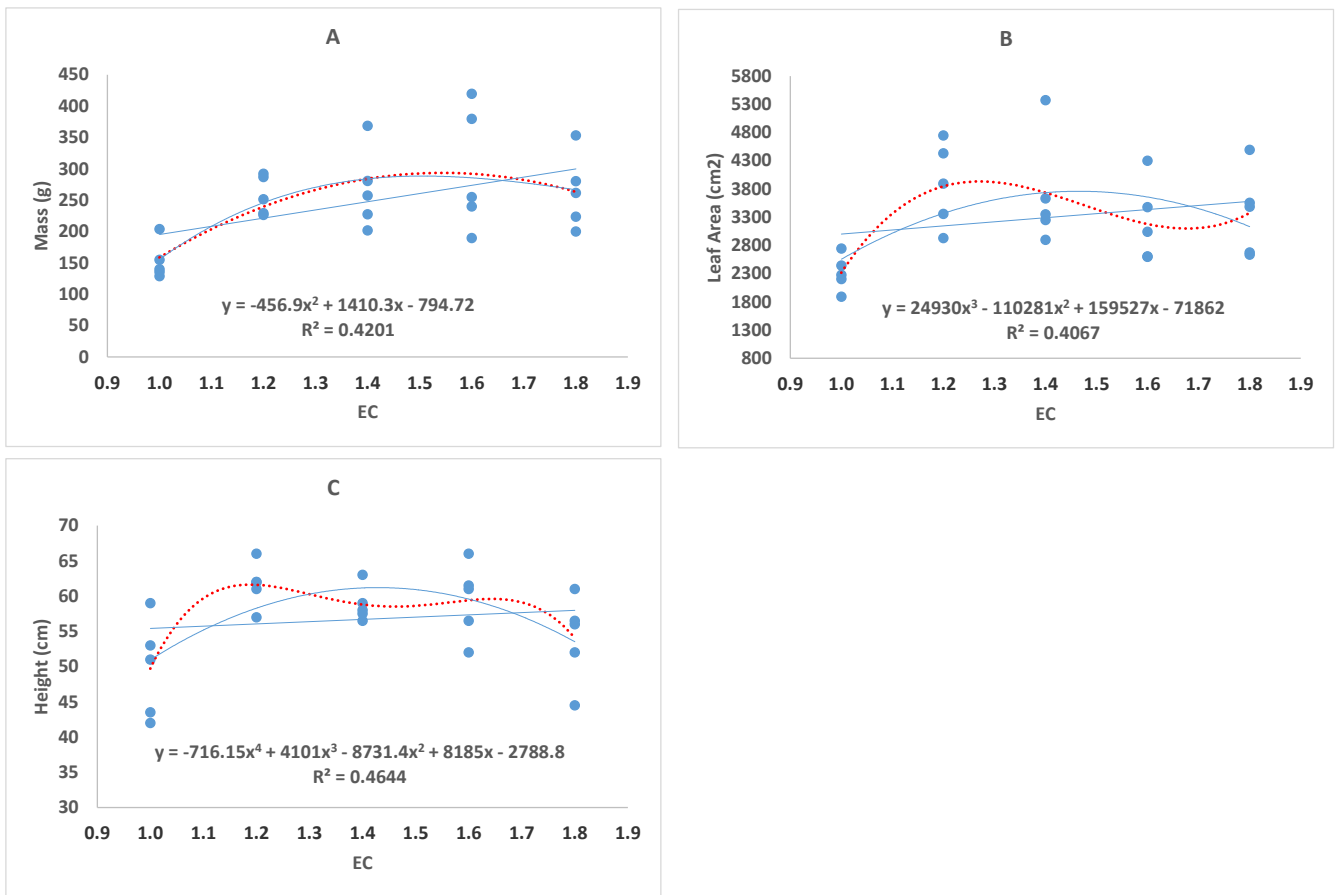


Fig 2. Trends of biomass accumulation and growth for A) plant mass, B) plant leaf area, and C) plant height. Each dot equals 1 replicate sample plant. Red trendlines are the best fit and representative of R^2 .

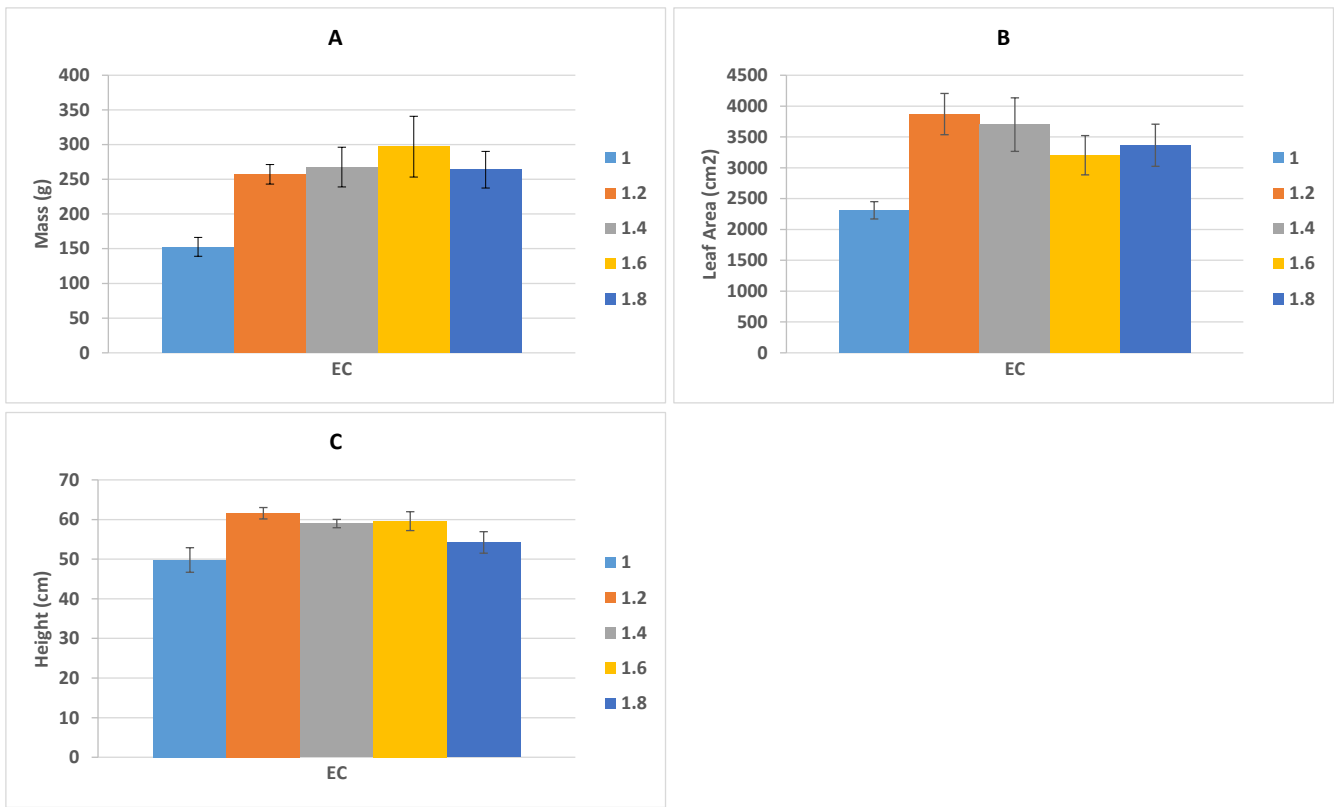


Fig 3. The influence of nutrient solution electrical conductivity on plant growth of komatsuna for A) plant mass, B) plant leaf area, and C) plant height. Each bar represents the mean of 5 single replicate plants and error lines represent the standard deviation of the means.