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Productivity, Pigment Composition and Chemical Characteristics of Kale *(Brassica oleracea L.)* Cultivated with Different Ages of Organic Nutrient Solutions under Aggregate Hydroponic System

Felix M. Salas[1*], Helen Mae N. Mejia[2] and Rosario A. Salas[2]

[1] *Department of Pure & Applied Chemistry*
Visayas State University, Baybay City, Leyte, Philippines
[2] *Department of Horticulture,*
Visayas State University, Baybay City, Leyte, Philippines.

Corresponding Author: fmsalas_dopac@yahoo.com or felix.salas@vsu.edu.ph

Abstract

This study was conducted to determine the growth and yield response of two varieties of kale in an aggregate hydroponic system under Visca agro-climatic condition, investigate the chemical characteristics of kale applied with different ages of organic liquid nutrient solutions, and assess the efficacy of organic liquid nutrient formulations for kale production in an aggregate hydroponic system following a split-plot randomized complete block design. The experiment was laid-out with varieties of kale as the main plot and organic nutrient solutions of different ages derived from acacia and moringa as the sub-plot with the following treatment designations replicated four times: T1- commercial inorganic nutrient solution (CINS), T2- 4 month old fermented acacia (FAC4), T3- 3 month old fermented acacia (FAC3), T4- 2 month old fermented acacia (FAC2), T5- 1 month old fermented acacia (FAC1), T6- 4 month old fermented moringa (FMY4), T7- 3 month old fermented moringa (FMY3), T8- 2 month old fermented moringa (FMY2), and T9- 1 month old fermented moringa (FMY1). The aggregate was composed of sterilized river sand and coconut coir mixture in 3:1 ratio by volume. Kale applied with one-month old moringa ferment significantly exhibited the best growth and yield (435.9g/plant) response. Kailaan variety of kale significantly showed greater number of leaves (12.31), but the Toscana variety significantly yielded (148.72 g/plant) better. Kale applied with a month old acacia and moringa ferments significantly gave the highest pigment composition regardless of variety except for the total carotenoid content of Toscana variety. The highest electrical conductivity was found on kale applied with commercial inorganic nutrient solution, 3- and 4-month old moringa ferments. The free radical scavenging activity was found significantly highest on kale cultivated with a month old acacia and moringa ferments. Redox potential was found lowest on kale applied with 4-month old moringa ferment to indicate better shelf-life and storability. In terms of variety, Kailaan possess better chemical characteristics in terms of electrical conductivity, free radical scavenging activity, and redox potential. Vitamin C content of kale was significantly influenced by the application of moringa ferments regardless of age particularly with Toscana variety. The overall result of the study suggests the applicability of acacia and moringa ferments as potential nutrient solutions for aggregate hydroponic production of kale which can primarily support the advocacy for climate smart organic farming system.

***Keywords**:* Acacia, Aggregate hydroponics, Chemical characteristics, Ferments, Kale, Moringa

1. Introduction

The tropical climate of the Philippines poses great challenge in vegetable production particularly for crops originating from the cooler environments such as the broccoli, cabbages, cauliflower, kale and lettuce (AVRDC, 1992). Productivity is highly influenced by unpredictable climatic conditions such as rainfall and day-time temperature. The challenges of the local and national vegetable industry relate to production, postproduction, marketing and infrastructure which cited the lack of novel information to sustain profitable yield (AARNET, 2006). In the advent of the changing climate, new methodologies of farming system must be adopted in order to sustain food security in the region. The adoption of protected cultivation and hydroponics offer a solution to climatic challenges despite high initial cost of constructing the structures (AVRDC, 1992; Baliyan, 2014). Hydroponics is a crop production technique using nutrient solutions without soil (F. Salas & R. Salas, 2013). Crops are grown with their roots in the nutrient solution or planted on a proper medium and nutrient solution is applied. It is becoming popular all over the world because of its concepts of higher productivity, superior quality, high degree of sanitation and improved water efficiencies, land and fertilizer use. This is an alternative system for growing crops that would overcome problems encountered in conventional field production such as soil acidity, salinity, soil borne-diseases, pests or disease inoculums that would decrease profit in crop production (Diputado *et al*., 2005). This production system is a viable alternative for growers in regions where production constraints such as unfavorable climate, land scarcity (due to urbanization), infertile soils (due to over-use of chemicals) limits field production. The enhancement of nutritional value of hydroponic vegetables is an important marketing edge in a competitive and growing population. Development of technologies which are economically competitive to conventional agriculture will determine the expansion of hydroponics (Ranawana*et al*., 2008) in the future.

Kale (*Brassica oleraceae* L.) is one of the most important promising vegetables in the Philippines and in Asia for health and wellness. It is rich in vitamins, minerals, dietary fibers and other phytochemicals (Marxen *et al*., 2007; Srinivasan, 2010). It contains antioxidants that can help reduce the risks associated with cancers and neurodegenerative diseases (Fang *et al*., 2002). In addition, kale is a good source of glucosinates, vitamin E, and manganese. (http://www.ngb.org/gardening/fact_sheets/fact_details.cfm?factID=21). The rich chemical substances of glucosinolates and the methyl cysteine sulfoxidesin kale have the ability to activate detoxifying enzymes in the liver that help neutralize potentially carcinogenic substances. Moreover, there are 10-15 glucosinolates present in kale and other Brassicas appear to decrease the occurrence of a wide variety of cancers, including breast, bladder and ovarian cancers. Another unique compound, organosulfur is well known for its carotenoids, especially lutein and zeaxanthin. These carotenoids function like sunglass filters and prevent the eyes from overexposure to ultraviolet light. Thus, studies have shown the protective effect of these nutrients against the risk of cataracts, where increased eye cloudiness leads to blurred vision. Eating lutein-rich foods like kale could lower the risk for new cataracts by 50% (http://whfoods.org/genpage.php?tname=foodspice&dbid=38#summary).

It can help alleviate hunger and poverty in the region by providing extra income, nutritional security and health benefits (Bautista & Esguerra, 2007). The major quality factor in leafy vegetables is the roughage content or its dietary fiber which could be maintained by keeping the foliage healthy with good fertilizer and irrigation program. Preliminary studies conducted at the Visayas State University (VSU) have shown some potentials of indigenous materials (Casillano & Salas, 2013; Pobadora & Salas, 2013) to augment soil fertility most of them are just wasted in agricultural fields. However, it is really difficult to grow vegetables in problematic soils. On the other hand, it has also been shown that hydroponics is capable of producing high quality and safe vegetables particularly in areas where soil borne diseases are prevalent and obnoxious. The utilization of abundant local resource materials such as the Acacia and Moringa leaves as fertilizer options for marginal farmers can be tapped for organic agriculture. Moreover, nutritional quality can be improved specially in terms of vitamins and minerals using hydroponics with proper management of plant nutrition.

This study was conducted to determine the productivity of kale in an aggregate hydroponic system under Visca agro-climatic condition, investigate the pigment composition of kale applied with different ages of organic liquid nutrient solutions, and assess the influence of organic liquid nutrient formulations for kale production in terms of electrical conductivity, free radical scavenging activity, redox potential, and vitamin C content under an aggregate hydroponic system.

2. Materials and Methods

2.1 Preparation Liquid Nutrient Solutions

Leaves of Acacia (*Samanea saman* Merr.) and Moringa (*Moringa oleifera* L.) were collected at the main campus of the Visayas State University, Visca, Baybay City, Leyte in the Philippines. The leaves of Acacia and Moringa were subjected to fermentation process with molasses and water in a 1:1:1 ratio by weight inside a plastic drum covered with cheesecloth. The ferments were harvested after a month. The fermentations were done in four batches at one month interval. After harvesting the fourth batch of ferments, these were diluted with water at a ratio of 1:32 by volume prior to its application as nutrient solution for kale production in an aggregate hydroponic system. The commercial complete fertilizer (16-16-16) was used as the source of inorganic nutrient solution for this particular study.

2.2 Evaluation of the efficacy of liquid nutrient solutions

The different nutrient solutions were tested on kale under an aggregate hydroponic system. The experimental evaluation was conducted following a split-plot randomized complete block design with two varieties of kale as the main plot and organic nutrient solutions of different ages as the sub-plot. The different treatments were replicated four times as follows: T1 = commercial inorganic nutrient solution (CINS), T2 = 4-month old fermented acacia (FAC4), T3 = 3-month old fermented acacia (FAC3), T4 = 2-month old fermented acacia (FAC2), T5 = 1-month old fermented acacia (FAC1), T6 = 4-month old fermented moringa (FMY4), T7 = 3-month old fermented moringa (FMY3), T8 = 2-month old fermented moringa (FMY2), and T9 = 4-month old fermented moringa (FMY1). The nutrient solutions were applied in the morning and in the afternoon through drip irrigation. Growth and yield responses of kale such as plant height, number of leaves, root weight, and yield were gathered.

2.3 Pigment composition of kale

A gram of each representative sample of freshly harvested kale was weighed in an analytical balance, placed in glass tubes and soaked in 10 milliliter of 80% acetone for two hours. The absorbance readings of the filtrates were taken at 662, 645, and 470 nm wavelengths using an ultraviolet-visible spectrophotometer. *Chlorophyll*s A, B, total *chlorophyll* and total carotenoids were calculated according to Dere *et al*. (1998).

2.4 Electrical conductivity of kale

Representative samples of freshly harvested kale were cut into small pieces, weighed in an analytical balance, blended with distilled water at a 1:10 weight-volume ratio for a minute, sonicated for a minute, allowed to stand for another minute, and then filtered. The electrical conductivity of the filtrate was determined with the use of an Oakton Multimeter expressed in microSiemens.

2.5 Free radical scavenging activity of kale

A gram of each representative sample of kale was blended with 10 milliliters of 95% ethanol for a minute and then sonicated for another minute. The extracts were filtered and tested for its free radical scavenging activity by reacting it with 2,2-diphenyl-1-picrylhydrazyl radical for an hour under dark condition and then analyzed through an ultraviolet-visible spectrophotometer set at 517 nm wavelength (Prakash, 2007). The result of the assay was expressed in percent scavenging in reference to the absorbance reading of the unreacted DPPH radical.

2.6 Redox Potential of kale

A gram of freshly harvested representative sample of kale was blended with distilled water at a ratio of 1:10 weight by volume, then allowed to stand for a minute. The oxidation-reduction potential of the filtrate was measured with the use of an Oakton Multimeter expressed in millivolts.

2.7 Vitamin C analysis of kale

A gram of freshly harvested representative sample of kale was blended with distilled water at a ratio of 1:10 weight by volume, then sonicated for another minute before filtration. The vitamin C content was analyzed by titrating the filtrate with standardized iodine solution until the appearance of a faint blue endpoint with starch indicator.

2.8 Statistical Analysis

Analysis of variance (ANOVA) was used to determine the significant effects on the productivity, pigment composition, and chemical characteristics of kale cultivated with different ages of organic liquid nutrient solutions. The differences between treatments were assessed further using the Tukey's Honesty Significant Difference (HSD) Test at 5 % level.

3. Results and Discussion

3.1 Productivity of kale applied with different ages of organic liquid nutrient solutions

Table 1 shows the growth and yield response of kale as affected by the different ages of organic liquid nutrient solutions in an aggregate hydroponic system. The plant height of kale was significantly enhanced with the application of fermented moringa regardless of its fermentation age and variety of kale. Although, comparable plant height were obtained on kale applied with commercial inorganic nutrient solution (CINS), three-month old and two-month old fermented acacia. This indicates sufficient supply of nutrients from these ferments to cause longitudinal development of meristematic cells (Llegunas Jr & Salas, 2015). The presence of nitrogen, potassium, and phosphorus in acacia and moringa ferments surely was responsible for plant height enhancement (Mante & Mante Jr, 2016) in kale. Significantly highest number

Table 1. Growth and yield response of kale as affected by the different ages of organic liquid nutrient solutions in an aggregate hydroponic system

Treatments	Plant height (cm)	Number of leaves	Root weight (g)	Yield (g/plant)
Nutrient Solutions:				
T1 (CINS)	37.63a	13.54a	22.33c	128.89c
T2 (FAC4)	28.76b	9.62b	4.95d	48.33d
T3 (FAC3)	31.68a	10.39b	5.61d	56.17d
T4 (FAC2)	29.14ab	10.84b	4.83d	59.72d
T5 (FAC1)	28.31b	9.20b	34.80b	327.10b
T6 (FMY4)	29.64ab	10.34b	6.06d	51.89d
T7 (FMY3)	32.53a	11.23a	6.17d	60.72d
T8 (FMY2)	31.74a	11.28a	7.45d	63.78d
T9 (FMY1)	34.11a	10.90a	44.60a	435.90a
CV (%)	9.22	11.53	15.93	12.60
Varieties of Kale:				
Kailaan	33.31	9.33b	16.82	148.72a
Toscana	29.71	12.31a	13.58	125.17b
CV (%)	8.22	10.52	15.26	10.61

of leaves was also found in kale applied with fermented moringa particularly with FMY ages 1-3 months. This means that fermented moringa is better than the fermented acacia in terms of leaf development particularly on Toscana variety of kale. The leaves intercept sunlight for its photosynthetic activity which can result to efficient production of metabolites for the total development of the plant. Root weight was found significantly highest on kale applied with one-month old moringa ferment (FMY1) regardless of variety. The same trend was also observed on kale applied with acacia ferments although a month old acacia ferment indicated a bit inferior result than the month old moringa ferment. Phosphorus is responsible for the development of root system of the plant (Villegas,. A better root system is expected to better absorb nutrients for plant growth and development. This means that a month old moringa ferment possesses available phosphorus necessary for root development than a more aged ferment.

Prolonged fermentation might have caused degradation of nutrients into less available forms (Marschner, 1995). In other words, timing of ferment preparation and planting schedule should always be part of the planning calendar to sustain better if not the best kale productivity of the season. A well developed root system affords better uptake and translocation of necessary nutrients for plant development (Palada & Ali, 2007). In this particular study, kale cultivated with one-month old moringa ferment did not only showed the best horticultural characteristics, but also manifested the highest yield which is significantly different from those applied with commercial inorganic nutrient solutions and other nutrient solutions with Kailaan exhibiting the higher yield. This only indicates that Kailaan kale cultivated with one-month old moringa ferment in an aggregate hydroponic system is feasible for adoption by farmers and entrepreneurs.

3.2 Pigment composition of kale applied with different ages of organic liquid nutrient solutions

Table 2 shows the pigment composition of kale as affected by the different ages of organic nutrient solutions. Kale cultivated with one-month old acacia and moringa ferments showed the highest *chlorophyll* A content with comparable values on kale applied with commercial inorganic nutrient solution. This means that only the one-month old acacia and moringa ferments could give comparable results with inorganic nutrient solutions. In other words there can be impairment of uptake with either nitrogen or magnesium (Marschner,

Table 2. Pigment composition of kale as affected by the different ages of organic liquid nutrient solutions in an aggregate hydroponic system

Treatments	Chlorophyll A (ppm)	Chlorophyll B (ppm)	Total Chlorophyll (ppm)	Total Carotenoids (ppm)
Nutrient Solutions:				
T1 (CINS)	**29.05a**	17.14b	46.19b	**8.40a**
T2 (FAC4)	15.18c	6.19d	21.37d	3.67b
T3 (FAC3)	22.07b	9.08c	31.14c	**6.21a**
T4 (FAC2)	15.94c	5.93d	21.86d	4.62b
T5 (FAC1)	**32.50a**	**23.30a**	**55.80a**	**8.50a**
T6 (FMY4)	16.59c	6.70d	23.29d	4.91b
T7 (FMY3)	17.05c	6.65d	23.70d	4.86b
T8 (FMY2)	17.12c	8.99c	26.11d	4.89b
T9 (FMY1)	**32.70a**	**24.60a**	**57.30a**	**8.20a**
CV (%)	9.58	9.58	9.58	11.64
Varieties of Kale:				
Kailaan	22.31	13.19	35.50	6.74a
Toscana	21.74	10.93	32.67	5.32b
CV (%)	9.52	9.85	9.70	11.64

1995) that are very essential for the structural development and constitution of *chlorophyll* in plants. *Chlorophyll* A plays an important role in light interception from the sun for the photosynthetic activity of the plant. The best light interception is found on plants with high *chlorophyll* A content (Young, 1991). *Chlorophyll* B and total *chlorophyll* contents were found significantly highest on kale cultivated with one-month old moringa ferment though comparable with the result on one-month old acacia ferment. A good *chlorophyll* B content can support better light interception to support and sustain the photosynthetic function of *chlorophyll* A (Grubben & Denton, 2004). The *chlorophyll* contents of kale were enhanced by one-month old age acacia and moringa ferments regardless of kale variety. In other words, the application of a month-old moringa ferment could result to greener kale harvest which is preferable by most vegetable consumers. Total carotenoids were found significantly highest on kale cultivated with either CINS, FAC1 and FMY1. This indicates better quality than the kale cultivated with other nutrient solutions or treatments. In other words, these two ferments can be a potential substitute for commercial inorganic nutrient solution on kale production in an aggregate hydroponic system. With respect to variety, Kailaan variety of kale signified higher total carotenoid content and quality as well.

3.3 Chemical characteristics of kale as affected by the ages of organic liquid nutrient solutions

Table 3 shows the chemical characteristics of kale as affected by the ages of organic liquid nutrient solutions in an aggregate hydroponic system. Kale cultivated with FMY3, FMY4 showed significantly highest electrical conductivity which is comparable in kale applied with commercial inorganic nutrient solution. Electrical conductivity measures the electrolytic activity of the food commodity as a reflection of the micronutrient uptake of the plant. The result indicated the presence of micronutrients in moringa ferments and their availability particularly in three and four-month old ferments. Moringa leaves are rich in micronutrients (Salas *et al.*, 2016) which are made available with microbial oxidation particularly under a prolonged fermentation. However, this was not observed with the application of acacia ferments. It is possible that the uptake of micronutrients in acacia were interfered by the presence of its phytochemicals. Chelation of metallic ions is possible with secondary plant metabolites and other natural products (Reejo *et al.*, 2014). The free radical scavenging activity was found significantly greatest on kale cultivated with one-month old ferment of either acacia or moringa. This shows that organic ferments can enhance the antioxidant power of kale vegetable particularly on a month-old ferment. In addition, prolonging further the fermentation seemed to inhibit the free radical scavenging activity of kale. The application of commercial inorganic nutrient solution did not enhance the antioxidant power of kale as it shows low FRSA values. The best redox potential was manifested by kale applied with four-month old moringa ferment (FMY4) which showed the lowest value of 2.4 millivolts. A lower redox potential translates into longer shelf-life and better storability (Benada, 2008). The redox potential of kale was significantly reduced as the age of moringa ferment was increased. On the other hand, comparable redox potential was observed on kale applied with acacia nutrient solution regardless of fermentation age until the third month. Four-month old acacia ferment (FAC4) gave a lower redox potential of kale, however, with values still higher on kale applied with a four-month old moringa. In terms of kale varieties, Toscana exhibited significantly higher electrical conductivity, free radical scavenging activity, and redox potential than Kailaan to demonstrate better micronutrient, antioxidant, and inferior storage qualities. Longer shelf-life of kale commands better opportunity for distribution and market, and less likely to be wasted (Boko & Salas, 2015). Vitamin C content of kale was significantly and best influenced by the application of moringa nutrient solution regardless of fermentation age, although those plants cultivated with one (FMY1) to two-month (FMY2) old moringa ferments exhibited

Table 3. Chemical characteristics of kale as affected by the different ages of organic liquid nutrient solutions in an aggregate hydroponic system

Treatments	Electrical conductivity (μS)	Free radical scavenging activity (%)	Redox potential (mV)	Vitamin C content (%Asc)
Nutrient Solutions:				
T1 (CINS)	**0.60a**	3.95e	2.85c	0.67c
T2 (FAC4)	0.56b	11.79c	2.75c	0.65c
T3 (FAC3)	0.56b	23.41b	3.65a	0.74b
T4 (FAC2)	0.46c	23.29b	3.85a	0.74b
T5 (FAC1)	0.46c	**75.80a**	3.75a	0.74b
T6 (FMY4)	**0.59a**	3.20e	**2.40d**	**0.82a**
T7 (FMY3)	**0.60a**	7.03d	2.75c	**0.85a**
T8 (FMY2)	0.54b	23.91b	3.20b	**0.86a**
T9 (FMY1)	0.54b	**75.30a**	3.50b	**0.86a**
CV (%)	1.66	3.74	1.07	3.26
Varieties of Kale:				
Kailaan	0.51b	24.02b	3.02b	0.81a
Toscana	0.57a	31.01a	3.36a	0.72b
CV (%)	1.66	3.74	1.07	3.26

higher vitamin C content numerically. Kailaan variety of kale has significantly higher vitamin C content and this finding support judicious choice for its consumption for health and wellness.

Nevertheless, the overall result of this study clearly indicates the beneficial effects on growth, yield, pigment composition, and vitamin C content of kale cultivated with moringa ferment as nutrient solution in an aggregate hydroponic system particularly with Kailaan variety. Furthermore, the application of moringa ferment greatly influenced the chemical characteristics of kale such as electrical conductivity, free radical scavenging activity, and redox potential particularly using one-month old moringa ferment on Toscana variety. Technological innovations which are economically competitive to open-field agricultural systems will eventually determine the future expansion of hydroponics.

4. Conclusions

Based on the findings of the study, the following conclusions can be drawn:

1.Kale can be well grown and produced in an aggregate hydroponic system under Visca agro-climatic condition;

2.The application of one-month old acacia and moringa ferments produced the best yield, pigment composition, and vitamin C content of kale (particularly with Kailaan) in an aggregate hydroponic system;

3. Electrical conductivity and redox potential of kale were best influenced by the application of four-month old moringa ferment as nutrient solution in an aggregate hydroponic system;

4. The application of one-month old acacia or moringa ferment significantly enhanced the free radical scavenging activity of kale particularly on Toscana variety; and

5. Vitamin C content was best influenced by the application of moringa ferments regardless of age particularly on Kailaan variety of kale.

Recommendations

The following recommendations are hereby suggested for future considerations:

1. The production of kale in an aggregate hydroponic system should be promoted for technological adoption under Visca agro-climatic condition;

2. A month old moringa ferment is hereby recommended as organic nutrient solution for kale production in an aggregate hydroponic system for best yield, pigment composition, free radical scavenging activity,

and vitamin C content;

3. Standardization and development of affordable, environment-friendly innovative moringa nutrient solution for hydroponic kale production; and

4. Application of moringa ferments in other horticultural crops under different agro-climatic conditions.

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