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# Effect of Hydroponic and Conventional Production Systems on Plant Growth Performance and Nitrate Content of Green Coral Lettuce (*Lactuca sativa* var. *Crispa*)

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**Abstract:** Overfertilization on leafy vegetables could accumulate high nitrate content. Exceeded recommended limit of nitrate content can cause detrimental effects on the environment and human health, such as methemoglobinemia and stomach cancer. Green coral lettuce (GCL) is a leafy vegetable commonly grown under various production systems. Production system and physiological age have affected the growth and accumulation of nitrate levels in most leafy vegetables. Therefore, this study aims to determine the effects of hydroponic and conventional production on the growth performance and nitrate concentration of GCL at different harvest ages. This research was conducted in a randomized complete block design with a factorial arrangement of treatments. A stagnant hydroponic was prepared using stock A and B complete Hoagland nutrient solutions as liquid fertilizer. A commercial biofertilizer (NPK 8: 8: 8) was applied at the rate of 100 g per plant. Plant growth performance, including plant height, number of leaves, and leaf length, was measured at 7, 14, 21, 28, 31, 34, 41, and 44 days after transplanting (DAT). The fresh weight and nitrate content were measured at 31, 34, 41, and 44 DAT. The results showed hydroponic GCL exhibited higher plant height than conventional GCL. However, both productions were not significantly affected regarding the number of leaves, leaf length, and fresh weight. At 41 and 44 DAT, the hydroponic GCL was markedly higher in nitrate content than conventional. This study found that conventional production was recommended for GCL because lower in nitrate content compared to hydroponic and fair in growth performance.

**Keywords:** Plant height, number of leaves, leaf length, harvest age

## 1. Introduction

Lettuce is a green leafy vegetable belonging to the Asteraceae family. As reported by FAO (2019), world production of lettuce in 2018 was more than 27 million tons, and those were primarily from Asia (15 million tons) and the United States (3 million tons). Lettuce is one of Malaysia's top 10 largest vegetable crops (DOA, 2018). Lettuce is an important dietary vegetable primarily consumed fresh as salads. In addition, the consumption of lettuce provides many health benefits attributed to the presence of vitamin C, phenolic compounds, and fiber content (Mulabagal et al., 2010).

In Malaysia, lettuce is produced through hydroponic, organic, and conventional systems (openfield). According to Zhang & Yang (2017), the lettuce growth rate was higher using hydroponic solution compared to organic production. The major problems of the hydroponic output were selective depletion of ions and associated changes in the pH of the solution that occurs as the roots continue to absorb nutrients (Magwaza et al., 2020). Lettuce maintained in pure solution culture continues to thrive if the nutrient solution is replenished regularly. Generally, a hydroponic system provides promising sustainable food production (Barbosa et al., 2015). Guilherme et al. (2015) stated that hydroponic lettuce offers higher yields and more effective water use, a more environmentally-controlled ecosystem than conventional systems. Some researchers recorded varied vegetable yields under different production systems such as hydroponic, organic, and

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conventional (Matthew et al., 2011). Yosoff et al. (2015) reported that the hydroponic and organic systems performed similarly in the yield and quality of lettuce. Nazaryuk et al. (2002) suggested that the production system has a bearing on nitrate content in the plant due to different types, amounts, and frequency of fertilizer application.

Nitrate is one of the primary nitrogen sources available to higher plants, including vegetables. However, over-fertilization may cause high nitrate accumulation in plants, especially leafy vegetables (Yosoff et al., 2015). Leafy vegetables such as lettuce grown under different production systems may accumulate different nitrate concentrations, reaching the levels potentially toxic to humans if they exceed the maximum limit. Nitrate accumulation in lettuce is affected by the texture of the soil and the source of fertilizer-N (Gunes et al., 1995). The accumulation of nitrate varies between different parts of the plant and the plant's physiological age. The highest concentration of nitrates is typically observed in the outer leaves of most lettuce types (Abu-Rayyan et al., 2004).

To date, there are a few studies have been investigated hydroponic, conventional and organic lettuce production in Malaysia. Therefore, this study was conducted based on the following objectives: i) to determine the effects of hydroponic and conventional production on the growth of green coral lettuce (GCL); and ii) to determine the effect of the production system (hydroponic and conventional) and harvest age on nitrate accumulation in the GCL.

## 2. Methodology

### 2.1 Experimental Site

The practical site was conducted in Kampung Hulu Sebuyau, Sarawak (geographical coordinates: 1.5171° N, 110.9341° E) and characterized by constant high temperature (27 °C or higher).

### 2.2 Planting Material

GCL was selected as planting material. Three seed packets of GCL were purchased from Square Acres Nursery at Puchong, Selangor. Each package of seeds was tested on germination before sowing. For this test, a piece of filter paper was placed in a petri dish and labeled. A sterile distilled water was sprayed to the filter paper to keep it moist. After that, thirty seeds of GCL from each packet were placed onto the moistened filter paper. The lid was closed and incubated in a seed germinator for ten days. At the end of the incubation period, the percentage of germinated seed was calculated. The seed batch packet with over 85% germination rate was chosen for the sowing and planting process.

### 2.3 Preparation for Hydroponic and Conventional Production

Hydroponic GCL was grown in a stagnant hydroponic set under a rain shelter, and conventional lettuce was grown in polybag at Kampung Hulu Sebuyau, Sarawak. Green coral lettuce seeds are sowed on a wet sponge (2.5 cm × 2.5 cm). After two weeks of sowing, the seedlings were transplanted into a 20 L planting container containing 50 mL stock A and 50 mL stock B complete Hoagland nutrient solutions as liquid fertilizer. The water salinity, expressed in electrical conductivity (EC), was maintained at 1.3-1.5 EC throughout the plant growth. The seeds were sown in two seed trays (30 cells/tray) containing peat moss substrate for conventional systems. After two weeks, the seedlings were transplanted to the 8' × 8' polybag with a distance of each polybag was 10 cm. General agronomic practices such as weeding, watering, pest control, and fertilizer application were carried out. The plants were watered twice a day as required using manual method and harvested after 30-45 days of transplanting (DAT). Commercial biofertilizer (NPK 8: 8: 8) was applied at the rate of 100 g per plant at 10 DAT, and fertilizer application was repeated every two weeks.

### 2.4 Plant Growth Measurement of GCL

The samples were selected from each replication for plant height, the number of leaves, leaf length, fresh weight, and nitrate content. Plant height, the number of leaves, and leaf length were measured at 7, 14, 21, 28, 31, 34, 41, and 44 DAT. Fresh weight and nitrate content were measured at 31, 34, 41 and 44 DAT.

a) *Plant Height*
   GCL plants were selected from each replication for plant height. Plant height was measured from the surface of the growing media to the top of the lettuce using a measuringtape in centimeters cm).
b) *Number of Leaves*
   The number of leaves was calculated by the leaves numbers manually.
c) *Leaf length*
   The leaf length was measured in the middle of the leaf, and three leaves on each tree were randomly selected.
d) *Fresh Weight*
   The fresh GCL was harvested carefully and washed with running tap water. Then, it was blotted dried using a soft paper towel and immediately measured using an analytical balance.

*e) Nitrate Content*

Lettuce extract was be collected from young leaves. Each part was chopped individually, and only 10 g of the chopping lettuce was ground using pestle and mortar. The paste would be extracted into cotton wool to obtain the cell sap. The nitrate content of the cell sap was determined using a nitrate meter (Cardy Twin Nitrate Meter, Spectrum Technologies Inc., USA) as described by Hochmuth (1994). The glass electrode of the meter was calibrated with buffers at 2000 and 150 ppm $NO_3$ before use.

## 2.5 Experimental Design and Statistical Analyses

The experiment was conducted using a randomized complete block design with two factorial arrangements (two types of production system × eight harvest ages) with four replications. The nitrate content determination was carried out in the factorial treatment of (two production systems x four harvest ages). The data were analyzed using ANOVA, and the significant means were separated by the least significant difference (LSD) test at $P \leq 0.05$ (SAS Institute, 1999).

## 3. Result and Discussion

## 3.1 Plant Height

The plant height of conventional and hydroponic GCL was increased when the harvest age increased (Fig. 1). Plant height increased gradually with the delayed harvesting period, and the highest was recorded at 44 DAT. It was similar to Yosoff et al. (2015), who studied the effects of the different production systems (hydroponic and organic) and harvesting age on the butterhead lettuce. At the growing stage of 31 and 44 DAT, the plant height of hydroponic production was significantly higher than conventional production systems. This is supported by Takagaki et al. (2002), who explained that hydroponic plants were easily absorbed the nutrients provided in liquid form comparedto solid fertilization that speeding the plant growth. Moreover, Guilherme et al. (2015) also support that the hydroponic production of lettuce is higher in plant growth than the conventional or organic production system.

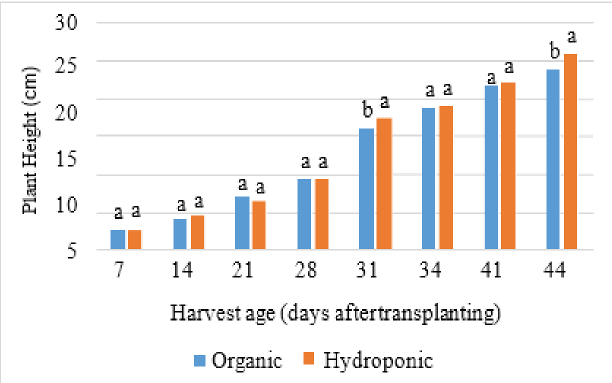


**Fig. 1: Effect of production systems and harvest age on plant height of green coral lettuce.** Mean values between production systems within harvest age followed by the same letter are not significantly different at $P>0.05$ using the LSD test

## 3.2 Number of Leaves and Leaf Length

In this study, production systems did not significantly affect the number of leaves (Table 1). These findings are consistent with Daiss et al. (2008), who reported that production systems resulted in no significant differences in certain growing parts of Swiss chard (leafy vegetable), including leaves. Generally, leaf numbers increased with a longer growing period due to natural plant growth and development over time. The number of leaves declined at the 44 DAT, and this probably the plant was entering the senescence stage. In agreement with Lim & Vimala (2012), the mean of leaf length was slightly increased at the senescence stage and showed no new leaf growth. Lettuce leaf length was also not significantly affected by the production system. There were no interaction effects between the production system × harvest age on the number of leaves of GCL.

**Table 1: Main and interaction effects of production systems and harvest age on the number of leaves and leaf length of green coral lettuce**

| Factors | Number of leaves | Leaf length |
|---|---|---|
| Production systems (P) | | |
| Organic | 3.18 a$^{z}$ | 8.85 a$^{z}$ |
| Hydroponic | 3.12 a | 8.82 a |

| | | |
|---|---|---|
| Harvest age (DAT) | | |
| 7 | 2.05 e | 1.64 g |
| 14 | 2.51 de | 2.20 f |
| 21 | 2.89 dc | 3.30 e |
| 28 | 3.11 bc | 5.98 d |
| 31 | 3.63 ab | 11.43 c |
| 34 | 4.00 a | 13.45 b |
| 41 | 4.00 a | 15.72 a |
| 44 | 4.00 a | 17.05 a |
| Significance | | |
| P × DAT | ns | ns |

[z]Means with the same letters within a column and each factor are not significantly different at $p>0.05$ using the LSD test. [ns], not significant at $P>0.05$.

## 3.3 Fresh Weight

Production systems did not significantly affect the fresh weight (Table 2). In contrast, according to Rahman et al. (2018), hydroponic cultivation has a greater fresh weight of lettuce and other vegetative growth. As expected, the fresh weight of GCL increased with a longer growing period. It corroborates with Michael et al. (2010) that the fresh weight of red lettuce 'Veneza Roxa' was increased by prolonging the growing period.

**Table 2: Main and interaction effects of production systems and harvest age on the fresh weight of green coral lettuce**

| Factors | Fresh Weight |
|---|---|
| Production system (P) | |
| Organic | 13.75 a[z] |
| Hydroponic | 12.44 a |
| Harvest age (DAT) | |
| 31 | 6.75 c |
| 34 | 12.50 b |
| 41 | 16.13 a |
| 44 | 17.00 a |
| Significance | |
| P × DAT | ns |

[z]Means with the same letters within a column and each factor are not significantly different at $P>0.05$ using the LSD test. [ns], not significant at $P>0.05$.

## 3.4 Nitrate Content

Nitrate content in both production systems was below the maximum nitrate level (MNL) for the European Commission (Fig. 2). At 41 and 44 DAT, the hydroponic GCL was significantly higher in nitrate content than the conventional system. In this study, the major problems of hydroponic production were selective depletion of ions and associated changes in the pH of the solution that occurs as the roots continue to absorb nutrients (Yosoff et al., 2015). According to Hopkins & Hüner (2008), lettuce was grown conventionally containing soil colloids to maintain a reservoir of soluble nutrients in the soil without luxurious nitrate consumption. In this study, the nitrate content in hydroponic lettuce was higher than conventionally grown. Lettuce maintained in pure solution culture would thrive if the nutrient solution is replenished regularly.

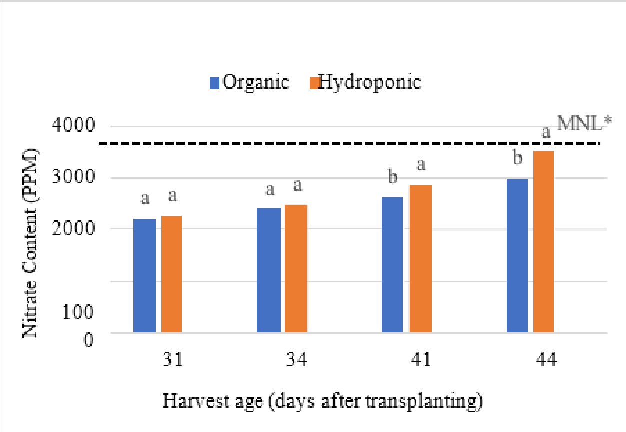


**Fig. 2: Effect of production systems on nitrate content of green coral lettuce. Mean values between production systems within harvest age followed by the same letter are not significantly different at *P*>0.05 using the LSD test.** *MNL= Maximum nitrate limit

## 4. Conclusion

In this study, hydroponic GCL exhibited higher plant height than conventional GCL. However, both productions were not significantly affected by the number of leaves, leaf length, and fresh weight. Nitrate content in hydroponic GCL was higher than conventional at the later harvesting ages. Thus, conventional production was recommended for GCL because lower in nitrate content compared to hydroponic and fair in growth performance.

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