Ratio of ammonium and nitrate to response of chinese broccoli variety (*Brassica oleracea Var. Alboglabra*) in hydroponic culture

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Abstract. The objective of this study is to study the response of various chinese broccoli varieties to ratio of ammonium and nitrate and to determine the characters that have high heritability values. This research was conducted at the Screen House at the University of Hasanuddin Lecturer Residences, Tamalanrea Sub-district, Makassar from August to October 2019. This study was arranged by using nested design and randomized complete block design as its environmental design. Replication was set in nesting to each ratio of ammonium and nitrate. The main factor was 7 varities of chinese broccoli, namely Full White, New Veg Gin, Winsan, Yama F1, Sakura F1, Nemo, and Nova, while ratio of the ammonium and nitrate consisted of 4 levels, namely AB Mix, ammonium: nitrate (1: 4 ), ammonium : nitrate (1: 8) and ammonium: nitrate (1: 12). The results showed that the ratio of ammonium and nitrate which gave the high growth and production responses to chinese broccoli was ammonium: nitrate ratio of 1: 12 (171.38 g). Varieties that have high growth and production response to the ammonium and nitrate ratio was the chinese broccoli New Veg Gin (214.04 g). Characters that have high heritability are leaf numbers, leaf area, shoot fresh weight, and total weight.

1. Introduction

Cabbage (*Brassica oleracea* L.) is one of the important vegetable commodities and has many benefits for human health. The Central Statistics Agency [1] states that Cabbage production in Indonesia was in the range of 1.4 million tons. Production data from 2014 to 2018 shows values of 1,435,833 tons, 1,443,227 tons, 1,513,318 tons, 1,442,624 tons, and 1,407,940 tons, respectively.

Cabbage had several widely cultivated types, including the Chinese broccoli (*Brassica oleracea var. Alboglabra*). Chinese broccoli was one of the leafy and thick-stemmed vegetable plants that are popular in China. Chinese broccoli was rich in various vitamins, including vitamin A which is good for eye health. This green vegetable also contained isothiocyanate which is a cancer-fighting compound [2].

The demand for vegetables continued to increase was directly proportional to the higher economic value. However, its increase was not offset by the increase in the area of land used for growing vegetables. To over come this, proper planting techniques to increase crop productivity is necessary.
One planting technique that could save land use, but was able to produce quality healthy vegetables was a hydroponic planting technique [3].

Hydroponics is a farming technology using water, nutrition, and oxygen media [4]. The success of cultivation using a hydroponic system was determined by the media used, also determined by the nutrient solution provided [5]. Nutritional solutions in hydroponic systems were divided into two, namely nutrients containing macro elements (N, P, K, S, Ca, and Mg) and nutrients containing micro elements (Mn, Cu, Mo, Zn, and Fe) [6].

Chinese broccoli was a leafy vegetable that needs high amount of nitrogen for its growth [7]. Nitrogen was absorbed by plants in the form of ammonium and nitrate. Nitrogen uptake by plants in the form of ammonium was almost 100% would increase the availability of protein. Ammonium was more efficient than nitrate in increasing the greenness of leafy vegetables, but its negative impact could cause plants to gradually experience deterioration and a sharp decrease in dry weight due to damage to the root system. Otherwise, if absorption was almost 100% in the form of nitrate, the impact was only a portion of nitrate which assimilated in the root and some nitrate was transported to the stem. The presence of nitrates increased the concentration of K, Ca, Mg, and P in the roots and also made the plant have a higher carbohydrate and carboxylic content than ammonium. The negative impact was the accumulation of excess nitrate in the stems which were toxic to plants and sensitive to ammonium poisoning [8].

According to Muharja [9], in concocting hydroponic fertilizer for stem and leaf vegetables, the ratio of Nitrate to Ammonium was 9:1 meaning nine nitrates and one Ammonium, while the total N was 250 ppm, thus the nitrate concentration was 9/10 x 250 ppm = 225 ppm and 25 ppm Ammonium. So the ratio between nutrient ratios NO$_3^-$ and NH$_4^+$ is 225 ppm: 25 ppm. Based on the description, one of the steps to get a variety of Chinese broccoli grown well in hydroponic culture is to obtain the right ratio factors consisted of four levels: AB Mix (N1), 1: 4 (N2), 1: 8 (N3) and 1:12 (N4). While the Chinese broccoli variety factor (V) consisted of seven varieties, namely: Chinese broccoli Full White (V1), New Veg Gin (V2), Winsan (V3), Yama F1 (V4), Sakura F1 (V5), Nemo (V6) and Nova (V7). Each treatment was repeated 3 times and each test had 3 units, so that there were 252 experimental units.

2. Materials and methods

This research was conducted at the Screen House at the University of Hasanuddin Lecturer Residences, Tamalanrea sub-district, Makassar which took place from August to October 2019. The tools used were hydroponic installation, water machines, analytical scales, net pots, trays, buckets, measuring cups, rulers, cameras, thermometers, plastic trays, Total Dissolved Solids (TDS) meters, pH meters, Office stationery.

The materials used in this study were 7 varieties of Chinese broccoli seeds, Mixed nutrition AB, Calcium Nitrate (5Ca(NO$_3$)$_2$), NH$_4$NO$_3$, 10H$_2$O), Potassium Nitrate (KNO$_3$), Sulphate of Potash (K$_2$SO$_4$), Monopotassium Phosphate (KH$_2$PO$_4$), Magnesium Sulphate (MgSO$_4$.7H$_2$O), Ammonium Sulphate (ZA) ((NH$_4$)$_2$SO$_4$), Ammonium Nitrate (NH$_4$NO$_3$), Zwavelssuur Kali (ZK) (K$_2$SO$_4$.2MgSO$_4$), Potassium Chloride (KCl), FeEDTA (C$_{10}$H$_{12}$N$_2$O$_7$FeNa.3H$_2$O), FeEDDHA (C$_{10}$H$_{14}$N$_2$O$_8$FeNa), Boric Acid (H$_3$BO$_3$), ZnEDTA (C$_{10}$H$_{12}$N$_2$O$_7$Zn), MnEDTA (C$_{10}$H$_{14}$MnN$_2$O$_8$), CuEDTA (C$_{10}$H$_{14}$CuN$_2$O$_8$), Sodium Molybdate (Na$_3$MoO$_4$.2H$_2$O), Manganese Sulphate (MnSO$_4$.4H$_2$O), Zinc Sulphate (ZnSO$_4$.7H$_2$O), Cupri Sulfate (CuSO$_4$.5H$_2$O), NaOH, rockwool, label paper.

2.1. Experimental design

This study was arranged based on randomized complete block design with the nested design concept, where the replication nested to combination ammonium and nitrate ratio. Ammonium and nitrate (N) ratio factors consisted of four levels: AB Mix (N1), 1: 4 (N2), 1: 8 (N3) and 1:12 (N4). While the Chinese broccoli variety factor (V) consisted of seven varieties, namely: Chinese broccoli Full White (V1), New Veg Gin (V2), Winsan (V3), Yama F1 (V4), Sakura F1 (V5), Nemo (V6) and Nova (V7). Each treatment was repeated 3 times and each test had 3 units, so that there were 252 experimental units.
2.2. Data analysis

Data obtained from observations were analysis using two-way ANOVA according to Nested Design. A further test was conducted if there is significant effect of the treatments using Honest Significant Differences (Tukey’s test) \((\alpha = 0.05)\). In addition, heritability analysis also was carried out using following below equations in table 1 [10]:

| Sources of Diversity | Degree of Freedom | Mean Squared (MS) | Expectation value MS (A = fixed; B=fixed) |
|----------------------|------------------|-------------------|------------------------------------------|
| Nutrition (N)        | n-1              | MS 1              | \(\sigma^2_e + k\sigma^2_v + v\sigma^2_n\) |
| Varieties in Nutrition (V) | n(v-1) | MS 2              | \(\sigma^2_e + n\sigma^2_v\) |
| Error (e)            | nv(r-1)          | MS 3              | \(\sigma^2_e\) |

Notes replication \((r)\), nutrition \((n)\), varieties \((v)\), various environments \((\sigma^2_e)\), variety of nutrients \((\sigma^2_n)\), and variety of varieties (nested in nutrition) \((\sigma^2_v)\).

Where,
\[
\sigma^2_p = \sigma^2_e + \sigma^2_v
\]
\[
\delta^2_e = MS3
\]
\[
\delta^2_g = (KT_g - KT_e)/k.
\]
\[
\delta^2_p = \delta^2_e + \delta^2_g
\]

Heritability and criterion values were calculated using the following formula:
\[
h^2_{bs} = (\sigma^2_g)/(\sigma^2_p) \times 100\%
\]
\(h^2_{bs}\) = heritability in a broad sense
\(\delta^2_g\) = variety of genotypes
\(\delta^2_e\) = variety of environments
\(\delta^2_p\) = variety of phenotypes

2.3. Observation parameters

- Plant height (cm) was measured from the base of the stem to the highest leaf tip at harvest (45 day after planting (DAP)).
- The number of leaves (strands) was done by counting the leaves of plants that had been fully opened. Observations were made at the time of harvest (45 DAP).
- Leaf area \((cm^2)\) was measured using the Petiole Leaf Area Meter application at harvest (45 DAP).
- Total weight \((g)\) was calculated by weighing all parts of the plant at harvest (45 DAP).
- Shoot fresh weight or production \((g)\) was calculated by weighing all parts of the plant except the root at harvest (45 DAP).

3. Results

3.1. Analysis of plant height, number of leaves, and leaf area

Tukey’s test results in table 2 showed that the ratio of ammonium to nitrate 1: 8 (N3) gives the highest average plant height (49.53 cm) and is significantly different from AB Mix (N1), while the ratio of ammonium: nitrate 1: 12 (N4) gives the average of the highest number of leaves (15.38 strands) and the widest leaf area (3795.89 cm2) and significantly different from other treatments except the ratio of ammonium: nitrate 1: 8 (N3) to the number of leaves.
Table 2. Average plant height, number of leaves and area of Chinese broccoli leaves in various ammonium and nitrate comparisons (45 DAP)

| Nutrition   | Plant Height (cm) | Number of Leaves (strands) | Leaf Area (cm²) |
|-------------|-------------------|----------------------------|-----------------|
| N1 (AB Mix) | 44.93 b           | 12.43 c                    | 2705.82 c       |
| N2 (1:4)    | 46.58 ab          | 13.88 b                    | 2976.98 bc      |
| N3 (1:8)    | **49.53 a**       | 15.10 ab                   | 3236.46 b       |
| N4 (1:12)   | 47.07 ab          | **15.38 a**                | **3795.89 a**   |

Tukey’s critical (0.05) 3.20

Numbers followed by the same letters in columns (a, b, c) mean not significantly different in the Tukey’s (α = 0.05) test. DAP = Days After Planting.

Tukey’s test results table 3 show that Full White (V1) variety gave the highest average plant height (54.68 cm) and was significantly different from other varieties except for New Veg Gin (V2). Yama F1 (V4) gave the average number of leaves (16.42 strands) and was significantly different from other varieties except for New Veg Gin (V2), while New Veg Gin (V2) gave the average widest leaf area (4787), 76 cm²) and significantly different from other varieties.

Table 3. Average plant height, number of leaves, and area of Chinese broccoli leaves in various Chinese broccoli varieties (45 DAP)

| Varieties          | Plant Height (cm) | Number of Leaves (strands) | Leaf Area (cm²) |
|--------------------|-------------------|----------------------------|-----------------|
| V1 (Full White)    | **54.68 a**       | 12.46 c                    | 3339.25 bc      |
| V2 (New Veg Gin)   | 52.96 ab          | 15.83 ab                   | **4787.76 a**   |
| V3 (Winsan)        | 45.03 cd          | 13.29 c                    | 2375.86 d       |
| V4 (Yama F1)       | 41.98 d           | 16.42 a                    | 1980.59 d       |
| V5 (Sakura F1)     | 41.36 d           | 13.46 c                    | 2904.22 c       |
| V6 (Nemo)          | 48.23 bc          | 14.25 bc                   | 3447.44 b       |
| V7 (Nova)          | 44.95 cd          | 13.67 c                    | 3416.38 b       |

Tukey’s critical (0.05) 4.89

Numbers followed by the same letters in columns (a, b, c) mean not significantly different in the Tukey’s (α = 0.05) test. DAP = Days After Planting.

3.2. Analysis of shoot fresh weight and total fresh weight

Tukey’s test results table 4 showed that the ratio of ammonium to nitrate 1:12 (N4) gave an average of the heaviest shoot fresh weight (171.38 g) and the heaviest total fresh weight (196.40 g) and is significantly different from AB Mix (N1).

Table 4. Average shoot fresh weight and total fresh weight of Chinese broccoli in various ammonium and nitrate comparisons (45 DAP)

| Nutrition          | Shoot Fresh Weight (g) | Total Fresh Weight (g) |
|--------------------|-------------------------|------------------------|
| N1 (AB Mix)        | 152.88 b                | 173.92 b               |
| N2 (1:4)           | 162.29 ab               | 184.39 ab              |
| N3 (1:8)           | 165.36 ab               | 185.58 ab              |
| N4 (1:12)          | **171.38 a**            | **196.40 a**           |

Tukey’s critical (0.05) 16.13

Numbers followed by the same letters in columns (a, b) mean not significantly different in the Tukey’s (α = 0.05) test. DAP = Days After Planting.
Tukey’s test results table 5 show that the New Veg Gin (V2) variety gave the heaviest shoot fresh weight average (214.04 g) and the heaviest total fresh weight (245.69 g) but was significantly different from other varieties except for Full White (V1).

**Table 5.** Average shoot fresh weight and total fresh weight of root of various chinese broccoli varieties (45 DAP).

| Varieties       | Shoot Fresh Weight (g) | Total Fresh Weight (g) |
|-----------------|------------------------|------------------------|
| V1 (Full White) | 191.04 ab              | 220.61 ab              |
| V2 (New Veg Gin)| 214.04 a               | 245.69 a               |
| V3 (Winsan)     | 138.75 de              | 160.29 de              |
| V4 (Yama F1)    | 125.46 e               | 139.87 e               |
| V5 (Sakura F1)  | 145.67 de              | 163.29 de              |
| V6 (Nemo)       | 173.29 bc              | 193.73 bc              |
| V7 (Nova)       | 152.58 cd              | 172.02 cd              |

Tukey’s critical (0.05) 24.64 27.54

Numbers followed by the same letters in columns (a, b, c, d, e) mean not significantly different in the Tukey’s (α = 0.05) test. DAP = Days After Planting.

### 3.3. Heritability Analysis

Table 6 show that the high heritability value was owned by 12 parameters. The highest heritability values above 80% were found in the leaf area parameters (90.75%), shoot fresh weight (83.68%) and total fresh weight (84.77%).

**Table 6.** The heritability values of several varieties of Chinese broccoli in the ratio of ammonium and nitrate

| No.  | Parameter          | Heritability Value (%) | Explanation |
|------|--------------------|------------------------|-------------|
| 1    | Plant height       | 63.52                  | High        |
| 2    | Number of Leaves   | 51.22                  | High        |
| 3    | Leaf Area          | 90.75                  | High        |
| 4    | Shoot Fresh Weight | 83.68                  | High        |
| 5    | Total Fresh Weight | 84.77                  | High        |

Noted: H > 50% (high).

### 4. Discussion

Nitrogen could be absorbed by plants in the form of NH₄⁺ and NO₃⁻. Chinese broccoli was a vegetable that requires high nitrogen in its growth. According to Damayanti et al. [11], nitrogen was one of the elements that were needed by plants to grow and develop. Nitrogen supply in plants would make plants grow rapidly, especially in the vegetative phase which includes the growth of stems, branches and leaves.

The ratio of ammonium and nitrate, which is 1:12, gave a higher yield when compared to the ratio of ammonium and nitrate which had a lower nitrate content, namely AB Mix 1: 4 and 1: 8. According to Damayanti et al. [11], the nitrogen content of the AB Mix nutrition was 27.7% (24% NO₃⁻ and 3.7% NH₄⁺). It was in line with the opinion of Muharja [9] which states that the administration of large amounts of nitrate to create compact cells so that plants stand tall had high resistance to disease and fungus attacks, many nitrates would also cause good taste.

The highest number of leaves (table 2) was found in the ratio of ammonium and nitrate 1: 12. The increase in the number of leaves was influenced by the ratio of ammonium and nitrate. The exact ratio of NH₄⁺ to NO₃⁻ is true in the sense that the ammonium: nitrate ratio is 1: 12, which was expected to increase plant growth. The nutrients absorbed by the roots were then transported to the leaves. This
was in line with the opinion of Hasiholan et al. [8] that the proper comparison of \( \text{NH}_4^+ \) concentrations with \( \text{NO}_3^- \) was considered to be able to encourage the increased synthesis of leaf chlorophyll in plant tissues so that the photosynthetic and carbohydrate activity of photosynthesis also increased.

The highest shoot fresh weight and total fresh weight of chinese broccoli (table 4) showed that with the ratio of ammonium and nitrate which had more nitrate content, which is 1:12, could increase the fresh weight of shoots. Thus it could be concluded that the lower the nitrate content in the ratio of ammonium and nitrate, the fresh weight of chinese broccoli shoots also decreased.

Shoot fresh weight and total fresh weight were influenced by root growth factors, number of leaves, and leaf area. The more the number of leaves, it would show the higher shoot fresh weight. Shoot fresh weight included stems and leaves, which means the accumulation of photosynthesis and was influenced by nutrient availability. The wider the leaf area, the more sunlight would be received on the plant. The highest leaf area (table 2) showed that increasing the leaf area would increase shoot fresh weight. It was in line with the opinion of Rawi [12] stated that with a high leaf area, the light would be more easily accepted by the leaves well so that the weight of each shoot increased and production also increased.

The difference in plant response showed was due to differences in the genetic traits of the several varieties tested. Varieties were genetic populations of plants that had different vegetative growth patterns. If there were differences in plant populations grown in the same environmental conditions, the differences were differences that originate from the genes of individual members of the population. This was in line with the opinion of Magdalena et al. [13] stating that differences in genotypes would cause differences in the shape and nature of plants which include the shape and function of plants so as to produce diversity in plant growth and yield.

New Gin Veg varieties were the best yield compared to other varieties, were seen from the heaviest shoot fresh weight (214.04 g) and the heaviest total fresh weight (245.69 g) (Table 5). The shoot fresh weight was supported by the widest leaf area parameters (Table 3) could be seen in the description of chinese broccoli varieties which showed that New Gin Veg variety had a large stem and weight per plant of 300 g. Large stems and weights per plant were factors that influence the fresh weight of shoots and chinese broccoli production.

Heritability was a prediction that measures the phenotypes that appear as a result of the reflection of genotypes or the relationship between genetic diversity and the variety of phenotypes. The estimated value of heritability indicated whether a character was controlled by genetic factors or environmental factors, so it could be seen as the extent to which these characters could be passed on to subsequent offspring [9].

Characters that had high heritability values for characters indicate that genetic factors play a greater role in expressing the appearance of these characters compared to environmental factors. Otherwise, if heritability was low, it was estimated that environmental factors play a role more than genetic factors [14]. Syukur et al. [9] added that the criteria for alleged heritability of \( h^2 <20\% \) (low), 20% <\( h^2 <50\% \) (moderate), \( h^2 >50\% \) (high)

5. Conclusion
Based on research that has been carried out, Ammonium and nitrate ratios provided high growth and production response to chinese broccoli with ammonium: nitrate ratio of 1:12 (171.8 g). Varieties that have high growth and production responses in chinese broccoli are New Veg Gin (214.04 g). Characters that have high heritability values were seen from plant height, the number of leaves, leaf area, shoot fresh weight, and total fresh weight.

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