Foliar Organic Fertilizer Enhanced Growth, Yield and Carotenoid Content of Carrot Plants (Daucus carota L.) Cultivated in the Lowland

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Abstract. Carrot is an increasingly important root vegetable in Indonesia, and it is commonly served as cooked mixed-vegetables or consumed freshly as salads or juices. Therefore, development of eco-friendly cultivation technology, including in lowlands, is important to meet the increased demand. This research analysed growth and yield of carrot plant in lowland in response to foliar-organic-fertilization as well as characterized the quality, carotenoid and sugar contents as well as hardness of the taproot. A Randomized completely block design (an RCBD) experiments was conducted in Bagik Polak Village, Labuapi District of West Lombok Regency (at ca. 45 m above mean sea level/amsl) from June to October 2020. During the course of the experiment, the carrot plants were treated with 6 concentration of foliar organic fertilizer, that were 0 ml/L (K0), 5 ml/L (K1), 10 ml/L (K2), 15 ml/L (K3), 20 ml/L (K4) dan 25 ml/L (K5). There was no chemical fertilization added to the plots, but chicken manure of 20 tons/ha was equally given to all treatments. Application of foliar organic fertilizer increased growth and yield of the carrot plant by increasing physiological responses of the carrot plant as shown by a decrease ratio of above to below ground biomass and increase in the leaf chlorophyll content. Interestingly, application of foliar organic fertilizer enhanced the sweetness, carotenoid contents of the carrot taproots compared to the control plants.

1. Introduction
Carrot (Daucus carota L.) is an increasingly important root vegetable in Indonesia. The carrot taproot is commonly consumed as a cook or fresh mixed vegetables or juices. It is suggested as a nutritious vegetable and characterized by a slightly bitter but sweet taste with a bright orange color. The carrot taproot is a well-known source of carotenoid and also contains protein, lipids, carbohydrates, several important minerals [1][2]and is rich in antioxidants [3].

The demand for carrot taproot is predicted to increase, including in West Nusa Tenggara (NTB) along with the increase in population, awareness to nutrition, income and popularity of Indonesia as a
tourism destination. On the other hand, the production of carrot in Indonesia has not changed significantly from 522,529 tonnes in 2015 to 537,341 tonnes in 2020 [4]. Therefore, attempts to increase carrot production or to maintain current production is still needed, and this may include extension of the production area to the lowlands.

A major limitation of carrot cultivation in the lowland is the daily temperature that is higher than the optimal ranges for taproot growth and development, of 18 - 21°C, and thus affecting taproot yield and quality [5][6]. Other factors influence growth and yield of carrot in lowland areas including selection of suitable variety and treatments to modify physiological responses towards faster taproot growth and development [7]. Several carrot varieties have been reported to show a good adaptation in the lowland including the Nantes, the New Nantes, the New Kuroda, and the local Indonesia variety of Gundaling [5][7][8][9][10]. These five varieties were able to grow and produce edible taproots in lowlands (at above 40 m asl) although the yield was still lower than their potential yields, for example 300 g per taproots with productivity of 25 – 30 Ton/ha for the Gundaling variety [11].

The yield of carrot is defined by the length and diameter of taproot, as morphologically the edible part of carrot is enlarged taproots which function as a storage organ [3][12]. The enlargement of root diameter is influenced by secondary growth of main root due to meristematic activity of cambium tissues particularly the expansion of phloem in the cortex [3][12]. These growth parameters are influenced by above soil growth (leaves), soil and air temperature, solar intensity and day length, the size of sink organ, the rate of assimilate distribution from leaf to root, and fertilization treatments[14][15][3][13].

In this research, the carrot plants were treated with foliar organic fertilizer (FOF) containing plant nutrition and plant growth regulator. The research was conducted to investigate the effect of different concentrations of FOF on physiological responses, yield and quality of carrot taproot cultivated in lowland, in order to develop eco-friendly cultivation of carrot in lowland.

2. Materials and method
2.1. Experimental design, place and time of the experiment
The experiment was designed according to Randomized Completely Block Design (RCBD) with one factor of FOF concentration in 6 treatments, that were: 0 ml/L (K1), 5 ml/L(K2), 10 ml/L (K3), 15 ml/L (K4), 20 ml/L and 25 ml/L (K5), in triplicates. The FOF used was NASA FOF with additional of 1ml/L of Hormonik (except for the K1).

The experiment was conducted in Bagik Polak, Village of Labuapi District, West Lombok Regency (at ± 41 m above mean sea levels/ amsl), from Mei to October 2020. The carrot variety examined in this experiment was the Gundaling, an Indonesia variety originated from Berastagi village of South Sumatera. This variety was selected as it was grown well and produced edible taproots in our previous studies [8][9][10]. The seed used is obtained from Main Seed Production Institute (Balai Benih Induk/BBI) Kuta Gadung, Berastagi, North Sumatera.

2.2. Plot preparation, planting and crop maintenance
Before the plantation, the land used for the experiment were ploughed (twice, in a week interval) and 18 planting beds, each of 1 m x 2 m x 0,3 m (length x width x height) were made with 6 planting beds per block. The distance between each bed in the block was 30 cm, and intra block was 40 cm. Before planting, insecticide Furadan 3G (2 kg/Ha or 2 g/bed) and chicken manure (20 ton/Ha or 2 kg/bed) was applied, and the land was watered.

The seed planting was undertaken a day after preparation of the planting bed. Before planting, the seed was gently squeezed to separate them, and then mixed with washed fine sand (1:1, v/v). The seed were poured finely in the planting rows (each row with 20 cm distance), and then covered with thin layer of sand, and then watered. At the age of 4 weeks after planting, the plants in each row were thinned, by removing the plants outside the planting space and leaving 5 equal size of plant in each row (with 20 cm distance), and thus there were 50 plants in each bed at 20 cm x 20 cm planting space. The plants were maintained adequately with similar maintenance, except for FOF application as
treated. The plants were regularly watered by surface irrigation every 2 weeks. During the course of experiments, the plots were weeded and fixed 3 times, and pest control was done by application of biopesticide *Beauveria bassiana* and *Metharizzium anisopiliae* three times at age of 4, 7 and 10 weeks after planting (wap). Treatment with FOF NASA + Hormonic was undertaken 4 times, every 2 weeks, started at 4 wap to 10 wap, with concentration as treated, 1 L per plot (20 ml per plant). The plant was harvested at the age 85 day after planting (dap), by manual harvesting.

2.3. *Parameters observed*

Growth and yield parameter observed were plant height, number of leaves, ratio of fresh biomass of leaves to taproot, ratio of plant fresh biomass to taproot biomass, total leaf chlorophyll, yield, sugar content in taproot, carotenoid content, taproot hardness, and taproot dry weight. All parameters were examined in the plant samples (5 plants per bed selected randomly). Chlorophyll content was measured in the fully expanded leaves (leaf number 3 from the apex), collected just before harvest. The leaves were pooled, and placed between wetted tissue, the lamina of 1 g was taken, wrapped with aluminium foil and kept in the refrigerator (at ca. -20°C) until required.

2.4. Extraction and measurement of total leaf chlorophyll

To extract the chlorophyll, the leaf tissues was ground in mortar and pestle and homogenized with 2 mL extraction buffer (mixture of ammonium hydroxide 0,1 N and acetone (1:9, v:v)). The mixture was transferred into reaction tube, and extraction buffer (3 ml) was added to the mortar and pestle, and the mixture was transferred to the tube. The tube was covered by aluminium foil, and incubated in the freeze (at ca 4 – 8 °C) for 2 hours. The mixture were homogenised by centrifugation for 10 minutes, and then 3 ml of chlorophyll solution was transferred to glass cuvette and the absorbance was read in spectrophotometer at λ 663 nm and 645 nm.

2.5. Extraction and measurement of total carotenoid

The total carotenoid in the taproot was extracted and analysed by using a 5 g sample (17). The sample was ground in mortar and pestle, and aliquots of 2 g was transferred into a 15-mL centrifuge tube, and 5 mL of methanol and 1 mL of 30% methanolic potassium hydroxide (KOH) was added. The sample was mixed by vortexing and incubated for 15 min on ice, and then centrifuged for 5 min at 2500 × g at room temperature. The supernatant was transferred into a 50-mL centrifuge tube, and then carotenoid was extracted with 8 mL of an extraction buffer (mixture of hexane : acetone: 1 : 1, v:v) twice. The organic fractions were combined and 25 mL of saturated aqueous sodium chloride solution was added to the organic fraction, and the mixture shaken and the supernatant of hexane phase (upper phase) was transferred into a 50-mL centrifuge tube. The lower aqueous phase was re-extracted with 8 mL of extraction buffer and combined with the first extract. The volume of extracts were weighed exactly for volume determination, then a 1 mL aliquot was evaporated, re-dissolved in the extraction buffer and the absorbance was read in spectrophotometer at λ 450 nm. Carotenoid concentration is calculated (mol/L) is calculated by A450 x dilution factor x diameter of cuvette x 135310, and then converted to mg/100 g fresh sample. The degree of sweetness was determined by refractometer, and taproot hardness was determined by penetrometer.

3. Results and discussion

Application of FOF significantly altered the physiological responses of carrot plant as shown by plant height, the number of leaves, the ratio fresh leaves to biomass, ratio of fresh taproot to plant fresh biomass, total leaf chlorophyll, yield, degree of sweetness, carotenoid content, but has no significant effect on length of taproot and taproot hardness.

The height and the number of leaves of carrot plants in the lowland at the age of 12 was treated with different concentration of FOF is shown in Figure 1.
Figure 1. Application of FOF at concentrations above 10 ml/L increases the plant height (A) and the number of leaves (B) of carrot plants in lowland. The data was recorded at 12 wap, n=3.

Treatment with FOF influenced the carrot plant's growth as shown by the plant height and the number of leaves at 12 wap, but the influence was concentration dependency. The impact of FOF treatment was marked at concentration above 10 ml/L. Carrot plants treated with concentration of 10 ml/L had a higher but not significantly different effect with the height of plants treated without and with other FOF concentration. However, the plants treated with FOF at concentration 15 ml/L and higher shown significantly higher plants than the control or FOF concentration of 5 ml/L. Similarly, the plants treated with FOF at concentration of 10 ml/L to 25 ml/L had a higher number of leaves that the control plant and plant treated with 5 mL/L FOF (Figure 1).

| FOF Concentration (mL/L) | Ratio of fresh canopy to plant fresh biomass (%) | Ratio of fresh taproot to plant fresh biomass (%) | Total chlorophyll (mg/g fresh weight) |
|--------------------------|-----------------------------------------------|-----------------------------------------------|------------------------------------|
| 0                        | 53.8 b                                        | 46.2 a                                        | 8.9 a                              |
| 5                        | 48.7 a                                        | 51.3 b                                        | 8.7 a                              |
| 10                       | 46.8 a                                        | 53.1 b                                        | 10.4 b                             |
| 15                       | 45.6 a                                        | 54.4 b                                        | 10.6 b                             |
| 20                       | 46.2 a                                        | 53.8 b                                        | 11.4 b                             |
| 25                       | 45.7a                                         | 54.3 b                                        | 9.7 ab                             |

The value was the mean of triplicates with 5 plant samples per block. The number followed by different letters was significantly different at 95% confidence level.
The proportion of plant canopy (above soil fresh biomass) to fresh plant biomass in carrot plants treated with FOF decreased, and the proportion was lower in plants treated with FOF at concentrations of 10 mL/L to 25 mL/L. Plants with a significantly highest proportion of canopy were plants that were not treated with FOF, while plants with the lowest proportion of canopy were plants treated with FOF at concentrations of 10 mL/L to 25 mL/L. In contrast to the proportion of canopy and fresh biomass, treatment with FOF increased the proportion of fresh tuber biomass to fresh plant biomass. Plants with a higher proportion of fresh tuber biomass were those treated with FOF at concentrations of 10 mL/L to 25 mL/L, with no significant difference between these concentrations, while the plants with the lowest proportion of fresh tuber biomass were control plants (without treatment Plus), which was not significantly different with the FOF treatment at concentration of 10 mL/L. In addition, FOF treatment also affected the total chlorophyll content of carrot leaves. Leaf chlorophyll contents increased with FOF application up to a concentration of 20 mL/L, while leaf chlorophyll contents in carrots treated without FOF and with 25 mL/L were not significantly different (Table 1).

![Figure 2](image)

**Figure 2.** Application of FOF at concentrations 10 mL/L – 20 mL/L increased carrot yield (A) but did not alter the carrot length (B).

In addition to increasing plant growth, treatment with FOF also increased tuber yield, carotenoid content and tuber sweetness, but did not significantly affect tuber length and tuber hardness (Figure 2 and Table 2). Significantly higher yields of carrot tubers were obtained in the treatment with FOF at concentrations of 10 mL/L to 20 mL/L. Treatment with FOF concentrations of 5 mL/L and 25 mL/L gave tubers yields that were not significantly different from the control treatment and other
concentration treatments. The yield of tubers in the control treatment was 3668.3 g/m² while with the FOF application, it ranged from 4155 g/m² to 5320 g/m². Assuming the area used for planting is 70 percent of the land area, conversion of the yield in the lowlands (with an environmentally friendly cultivation system) as reported in this paper in the control treatment was 25.68 tons/ha, the FOF 5 mL/L treatment was 29.09 tons/ha, FOF 10 mL/L was 37.24 tons/ha, FOF 15 mL/L was 36.66 tons/ha, FOF 20 mL/L was 36.35 tons/ha and FOF 25 mL/L was 33.12 tons/ha. Carrot tubers produced in environmentally friendly planting in the lowlands (with and without FOF) have lengths ranging from 15.1 – 17.6 cm. In addition, tubers produced from plants treated with FOF were sweeter than control plants, with the level of sweetness increasing as the concentration of FOF increased. In addition, tubers produced from carrots in an environmentally friendly cultivation system had a slightly lower hardness index (had crunchier tubers) (Table 2).

Table 2. Carotenoid contents, sweetness and hardness taproots from carrot plants grown in the lowland and treated with different concentration of FOF

| FOF concentration (mL/L) | Carotenoid content in taproots (mg/g fresh weight) | Taproot sweetness (°brix) | Taproot hardness (mm/g/s) |
|--------------------------|--------------------------------------------------|---------------------------|--------------------------|
| 0                        | 14.1 a                                           | 9.5 a                     | 2.0                      |
| 5                        | 14.5 a                                           | 10.3 bc                   | 1.9                      |
| 10                       | 17.9 b                                           | 10.1 b                    | 2.0                      |
| 15                       | 18.3 b                                           | 10.4 bc                   | 1.7                      |
| 20                       | 19.9 b                                           | 10.7 c                    | 1.8                      |
| 25                       | 19.4 b                                           | 11.4 d                    | 2.0                      |

The value was the mean of triplicates with 5 plant samples per block. The number followed by different letters was significantly different at 95% confidence level.

In Indonesia, carrot plants can grow optimally in the highlands, and in NTB the centre for carrot production is the Sembalun area in East Lombok Regency, which is located at an altitude of 400-1,400 m above mean sea level (m amsl). The limited area of the highlands is one of the reasons for the development of carrot cultivation, including environmentally friendly cultivation systems, in the lower plains, at areas with higher temperature which affected the growth and productivity [5][7][10][18][15]. These researches have demonstrated that several varieties of carrot plants have the potential to be cultivated in the medium and lowlands. In addition to the temperature, the yield and quality of carrot taproot are influenced by nutrient availability and soil physical properties where the plants are cultivated [19][20][21][22].

Carrot plants can produce good quality tubers, characterised by physical performance such as straight taproot without branch and crack. These properties were obtained in loose soil with good drainage, in condition of no excess water and nitrogen fertilizer [20][23][19]. In addition to adequate soil management, improvement of soil physical properties can be done with organic fertilization [20][21][19]. Research results show that carrot yields can be increased by combining chemical fertilization with organic fertilizers [20][22][7][19].

Application of manure can affect the soil properties, and many reports suggested that application of 20 tons - 40 tons/ha manures are required for carrot plantation. The suitable dose is depending on the location (the initial soil property, the fertilization package and cultivation system applied. The yield of carrots with a dose of chicken manure of 20-40 tons/ha in the lowland and medium lands was reported between 10-20 tons/ha [7][28][15][20]. This yield is still lower than the potential yield and yield of carrots in the highlands.

In this study, carrot cultivation in the lowlands was carried out using environmentally friendly cultivation methods which included the use of organic fertilizers (given through the soil and through the leaves) and pest control using biological agents, with the aim of producing a good quality taproot which are safe for fresh consumption and with high yields. The area used in this experiment had a low low C-organic content (1.45%), low total-N content (28.10 ppm), moderate total P content (44.91
ppm), and high total K content (27.66 ppm, and this indicates the the soil has low productivity and soil fertility. Soil has a good productivity if the organic matter content ranges from 8 to 16% [21]. Therefore, in this study, the chicken manure were added as much as 20 tons/ha in order to increase the levels of organic matter and the manure can also provide nutrition for carrot plants.

The application of FOF in this study, increased plant growth (upper and lower part of the plant), increased carbohydrate translocation to the lower part of the plant, increased leaf chlorophyll content which had an impact on increasing yield and sweetness level of taproots, with optimal concentrations of 10-15 mL/L. The FOF used is claimed to contain severa plant growth regulators including auxin, cytokinin and gibberellin (in the Hormonic). In addition, the FOF is also claimed to contain macro and micro nutrients including N (0.12%), K (0.31%), P₂O₅ (0.03%), S (0.12%), Ca (60.4 ppm, Cl (0.29 %), Mg (16.88 ppm), Mn (2.46 ppm), Fe (12.89 ppm), Cu (< 0.06 ppm), Zn (4.71 ppm), Na (0.15 %), B (60.84 ppm), Si (0.01%), Co (0.05 ppm), Al (6.38 ppm), NaCl (0.98%), Se (0.11 ppm), As (0.11 ppm), Cr (< 0.06 ppm), Mo (< 0.2 ppm), SO₄ (0.35 %) with pH 7.5 [24]. These data shown that the FOF mainly contains the micro nutrient and plant growth regulator. The presence of micro-nutrients is necessary because micro-nutrients act as cofactors in the enzymatic activity of plant metabolism [25]. In the available form, Manganese (Mn²⁺) and boron (H₂BO₃⁻) play a role in controlling most plant physiological activities, such as leaf chlorophyll levels, activator of photosynthetic enzymes, respiration, amino acid biosynthesis, lignin and plant growth hormones [26]. Increased in the physiological responses of carrot plants in lowland to application of FOF in this study (as shown by increased growth and chlorophyll levels) is suggested to drive higher yield, a higher carotenoid content and sugar content of the taproot.

4. Conclusion
Application of FOF increased the physiological responses of carrot plants to high temperatures in lowland. The carrot plant treated with FOF had a significantly lower ratio of above grown to total biomass and higher ratio of below ground to total biomass. The plant treated with FOF had a higher number of leaves and chlorophyll concentration. This data indicates that application of FOF shifted the photosynthetic accumulation from growth-related organ to the storage organ. In addition, the FOF treatment increased yield and taproot quality as shown by an increase in the carotenoid content and degree of sweetness. The positive effect of FOF was concentration dependently with suitable concentration of 10 to 20 mL/L.

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