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Comparative analysis of Chlorophyll concentration in different species of leafy vegetables cultivated in soil and hydroponic system

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***Abstract*— *Leafy vegetables are an important vegetable crop that grows easily under controlled conditions, such as in hydroponic. A plant's leaf colours can be used to indicate stress levels due to its adaptability to environmental changes. In this study, the samples were cultivated in the backyard of the Life Science department in Pandit Ravishankar Shukla University, Raipur, Chhattisgarh during January to April 2024. In this study, fresh mature leaves of soil-cultivated plants and hydroponically cultivated plants were taken for chlorophyll estimation. The sample was tested using an acetone solution (80%) and the information from the spectrum was calculated using the Arnon's method. The levels of Chl. a and Chl. b in soil-grown and hydroponically grown plants have been found to differ. Hydroponic cultivated plants show a high amount of total chlorophyll content as compared to soil-based plants and the reason behind the high level of chlorophyll content ina hydroponic system is controlled environmental conditions that mean precise control over light, temperature, and nutrient availability and are highly specific from species to species whereas, in a soil-based system, it is difficult to maintain such condition.*

I. INTRODUCTION

The chlorophyll contents in leafy vegetables have a considerable influence on their growth, as is commonly recognized. Chlorophyll concentration can be used to assess plant productivity and photosynthetic potential. The rate of photosynthesis in the plant is determined by the photosynthetic capacity per unit area of the leaf (Kozlowski *et al.* 1991), which is also shown by the chlorophyll concentration (Dickman & Kozlowski 1968). When it comes to leafy vegetables, color is an important component that influences consumer preferences and product quality assessment. Chlorophyll, the most common pigment in green plants, has become increasingly important in the human diet. It serves as both a nutritious food ingredient and a natural food colorant (Xue, L., & Yang, L. 2009).

Chl. a and *Chl.* b are accessory pigments, and various other types of chlorophyll are present in leafy vegetables. The empirical formulas for *Chl.* a and *Chl.* b are $C_{55}H_{72}O_5N_4Mg$ and $C_{55}H_{70}O_6N_4Mg$, respectively. Typically, *Chl.* a appears blue-green, while Chl.b appears yellow-green (Witham & Devlin 1997). The developmental stage of the photosynthetic system in plants is also indicated by the chlorophyll a and b ratio. It plays a crucial part in the formation and growth of leafy vegetables. The amount of chlorophyll in leaf tissue is influenced by nutrient availability and stresses such as drought, salinity, cold, heat, etc. However, nutrient availability and various stresses such as drought, salinity, cold, heat, etc. are factors that might also be responsible for color variation in eight different species of leafy vegetables. The present study was undertaken for a comparative analysis of chlorophyll concentration in soil-cultivated plants and hydroponic-cultivated plants in eight different species. *Raphanus sativus L*. (Mooli bhaji), *Chorchorus olitorius L*. (Chech bhaji), *Lathyrus sativus L*. (Lakhdi bhaji), *Carthamus tinctorius L*. (Kusum bhaji), *Amaranthus tricolor L*. (Lal bhaji), Mentha *piperital L.* (Peppermint), *Ipomea aquatica F*. (Karmata bhaji), and *Trigonella foenum-graecum L.* (Methi bhaji).

Literature reviewed and popularity of hydroponics is increasing day by day. Hydroponics uses dissolved nutrients in water, allowing plants to grow food closer to consumers. It produces superior quality, is not seasonal, and is environmentally friendly. Hydroponic systems, including nutrient film techniques, wick systems, and aeroponic systems, ensure plant production success. Hydroponic farming uses water, nutrients, and pest control to grow crops like lettuce, vegetables, herbs, and flowers. It saves 70-90% water, yields three times more, and uses 60% less fertilizer than traditional methods. Proper control is essential for environmental benefits.

II. MATERIAL AND METHODS

Eight different species of leafy vegetables namely *Raphanus sativus L*. (Mooli bhaji), *Chorchorus olitorius L*. (Chech bhaji), *Lathyrus sativus L*. (Lakhdi bhaji), *Carthamus tinctorius L*. (Kusum Bhaji), *Amaranthus tricolor L*. (Lal bhaji),*Mentha piperital L.* (Peppermint), *Ipomea aquatica F*. (Karmata bhaji), and *Trigonella foenum-graecum L.* (Methi bhaji) were selected for the present study. The samples were cultivated in the backyard of the Life Science department in Pandit Ravishankar Shukla University, Raipur, Chhattisgarh (India) during January to April the year 2023-2024. In this experiment, fresh mature leaves of soil-cultivated plants and hydroponically cultivated plants were taken for chlorophyll estimation. One gram leaf from each species is measured and grounded using a mortar and pestle after being chopped into small bits. After that, 0.5 g of ($MgCo3$) powder and 20 ml of 80% acetone were added, and the mixture was carefully ground using the technique of (Kamble et al. 2015). After that, the mixture was incubated for three hours at 4ºC. The mixture was centrifuged at 2500 rpm for 5 min and the supernatant was transferred to a 100 ml volumetric flask the volume was made up to 100ml with the addition of 80% acetone and the solution was used for chlorophyll estimation (Fig.1). The absorbance of solutions was measured at 645 nm and 663 nm in SYSTRONICS Spectrophotometer 106 taking the 80% acetone solution as blank (Sadasivam & Manickam 1996).The reading was taken in a triplicate sample and the average was considered for the calculation of chlorophyll content. The chlorophyll a, b, and a + b (total chlorophyll) contents were calculated by applying the following (Arnon 1949) formulae:-

$$\text{Chlorophyll a (mg /g tissue)} = \frac{12.7\ (A663) - 2.69\ (A645) \times V}{1000 \times W}$$

$$\text{Chlorophyll b } (mg\ g\text{-}1 \text{ tissue}) = \frac{22.9\ (A645) - 4.68\ (A663) \times V}{1000 \times W}$$

$$\text{Total chlorophyll } (mg\ g\text{-}1 \text{ tissue}) = \frac{20.2\ (A645) - 8.02\ (A663) \times V}{1000 \times W}$$

Where, A = absorbance at a specific wavelength

V = final volume of chlorophyll extract in 80% acetone

W = fresh weight of tissue extracted

III. RESULT AND DISSCUSION

Table 1. Chlorophyll concentration in eight different leafy vegetable species in soil.

S. No.	Name of leafy vegetables	O.D. Reading		Soil Cultivated Plants		
		645 nm	663 nm	*Chl.*a (mg g^{-1})	*Chl.*b (mg g^{-1})	Total Chl (mg g^{-1})
1	***Raphanus Sativus L.***	0.443 ± 0.001	0.202 ± 0.001	0.137	0.919	1.056
2	***Chorchorus trilocularis L.***	0.431 ± 0.0005	0.117 ± 0.003	0.0326	0.932	0.964
3	***Lathyrus sativus L.***	0.212 ± 0.0005	0.134 ± 0.0015	0.113	0.422	0.535
4	***Carthamus tinctorius L.***	0.379 ± 0.0015	0.106 ± 0.0015	0.0326	0.818	0.850
5	***Amaranthus tricolor L.***	0.256 ± 0.001	0.172 ± 0.0011	0.149	0.505	0.655
6	***Mentha arvensis***	0.418 ± 0.0005	0.109 ± 0.0005	0.0259	0.906	0.931
7	***Ipomea aquatica F.***	0.053 ± 0.0025	0.024 ± 0.001	0.0162	0.110	0.126
8	***Trigonellafoenum- graecum L.***	0.559 ± 0.001	0.140 ± 0.01	0.0274	1.21	1.241

Table 2. Chlorophyll concentration in eight different leafy vegetable species in hydroponics.

S. No.	Name of leafy vegetables	O.D. Reading		Hydroponic Cultivated Plants		
		645 nm	663 nm	*Chl.*a (mg g^{-1})	*Chl.*b (mg g^{-1})	Total Chl (mg g^{-1})
1	***Raphanus Sativus L.***	0.558 ± 0.002	0.138 ± 0.003	0.0251	1.213	1.237
2	***Chorchorus trilocularis L.***	0.773 ± 0.002	0.206 ± 0.002	0.0536	1.673	1.726
3	***Lathyrus sativus L.***	0.297 ± 0.012	0.139 ± 0.008	0.096	0.615	0.711
4	***Carthamus tinctorius L.***	1.205 ± 0.002	0.284 ± 0.005	0.0365	2.626	2.661
5	***Amaranthus tricolor L.***	0.613 ± 0.002	0.139 ± 0.001	0.0116	1.338	1.349
6	***Mentha arvensis***	0.689 ± 0.001	0.151 ± 0.002	0.006	1.507	1.512
7	***Ipomea aquatica F.***	0.517 ± 0.002	0.120 ± 0.005	0.0133	1.127	1.140
8	***Trigonellafoenum-graecum L.***	0.617 ± 0.003	0.195 ± 0.001	0.0816	1.321	1.402

The study revealed that the chlorophyll *Chl.*(a + b) in soil-cultivated plants ranges from 0.0162 to 0.149 mg g^{-1} and in hydroponic-cultivated plants ranges from 0.006 to 0.096 mg g^{-1}, and *Chl. b* in soil-cultivated plants ranges from 0.110 to 1.21 mg g^{-1} and in hydroponic-cultivated plants ranges from 0.615 to 2.626 mg g^{-1}. The total chlorophyll *Chl.* (*a* + *b*) in soil-cultivated plants ranges from 0.126 to 1.241 mg g^{-1} and in hydroponic-cultivated plants ranges from 0.711 to 2.661 mg g^{-1} in eight leafy vegetable species. From the above result, it is also seen that *Trigonella foenum-graecum L.* has the highest concentration of *Chl. a* and *Chl.b*. *Ipomea aquatica F*. has the lowest concentration of *Chl. a* and *Chl. b among* the eight species in soil-cultivated plants, whereas in hydroponic-cultivated plants, *Carthamus tinctorius L*. has the highest concentration of *Chl. a* and *Chl. b*. *Lathyrus sativus L.*has the lowest concentration of *Chl. a* and *Chl. b* among the eight species. The highest total chlorophyll content in the soil-cultivated plant is shown by *Trigonella foenum-graecum L.* (1.241 mg g^{-1}) whereas in hydroponics, *Carthamus tinctorius L.* (2.661 *mg g-1*$^{-1}$) shows the highest total chlorophyll content and The lowest total chlorophyll content in the soil-cultivated plant is shown by *Ipomea aquatica F* (0.126 mg g^{-1}) whereas in hydroponics, *Lathyrus sativus L*. (0.711 *mg g*$^{-1}$) shows the lowest total chlorophyll content.

Raphanus sativus L.The total chlorophyll content in the soil-based system is 1.056 mg g^{-1}, whereas in a hydroponic system, it is 1.237 mg g^{-1}, which is 0.181 mg g^{-1} higher than the soil-base system. The chlorophyll content in the soil-based system is 0.137 mg g^{-1}, whereas in the hydroponic system it is only 0.0251 mg g^{-1}, which is 0.111 mg g^{-1} less than the soil-based system. The *Chl.* b content in the soil-based system is 0.919 mg g^{-1}, whereas in the hydroponic system, it is 1.213 mg g^{-1}, which is 0.294 mg g^{-1}, higher than the soil-base system.

Chorchorus olitoriusL, The total chlorophyll content in the soil-based system is 0.964 mg g^{-1}, whereas in a hydroponic system, it is 1.726 mg g^{-1}, which is 0.762 mg g^{-1}, higher than the soil-base system. The *Chl. a* content in the soil-based system is 0.0326 mg g^{-1}, whereas in the hydroponic system it is 0.0536 mg g^{-1}, which is 0.021 mg g^{-1} higher than the soil-based system. The *Chl. b* content in the soil-based system is 0.932 mg g^{-1}, whereas in a hydroponic system, it is 1.673 mg g^{-1}, which is 0.741 mg g^{-1} higher than the soil-base system.

Lathyrus sativum L, The total chlorophyll content in the soil-based system is 0.535 mg g^{-1}, whereas in a hydroponic system, it is 0.711 mg g^{-1}, which is 0.176 mg g^{-1} higher than the soil-base system. The *Chl. a* content in the soil-based system is 0.13 mg g^{-1}, whereas in the hydroponic system it is only 0.096 mg g^{-1}, which is 0.017 mg g^{-1} less than the soil-based system. The *Chl. b* content in the soil-based system is 0.442 mg g^{-1}, whereas in a hydroponic system, it is 0.615 mg g^{-1}, which is 0.173 mg g^{-1}, higher than the soil-base system.

Carthamus tinctorius L, The total chlorophyll content in the soil-based system is 0.850 mg g^{-1}, whereas in a hydroponic system, it is 2.661 mg g^{-1}, which is 1.811 mg g^{-1}, higher than the soil-base system. The *Chl. a* content in the soil-based system is 0.0326 mg g^{-1}, whereas in the hydroponic system it is only 0.0365 mg g^{-1}, which is 0.0039 mg g^{-1} higher than the soil-based system. The *Chl. b* content in the soil-based system is 0.818 mg g^{-1}, whereas in a hydroponic system, it is 2.626 mg g^{-1}, which is 1.808 mg g^{-1}, higher than the soil-base system.

Amaranthus tricolor L, The total chlorophyll content in the soil-based system is 0.655 *mg g-1,* whereas in a hydroponic system, it is 1.349 mg g^{-1}, which is 0.694 mg g^{-1} higher than the soil-base system. The Chl. *a* content in the soil-based system is 0.149 mg g^{-1}, whereas in the hydroponic system it is only 0.0116 mg g^{-1}, which is 0.1374 mg g^{-1} less than the soil-based system. The Chl. *b* content in the soil-based system is 0.505 mg g^{-1}, whereas in a hydroponic system, it is 1.338 mg g^{-1}, which is 0.833 mg g^{-1}, higher than the soil-base system.

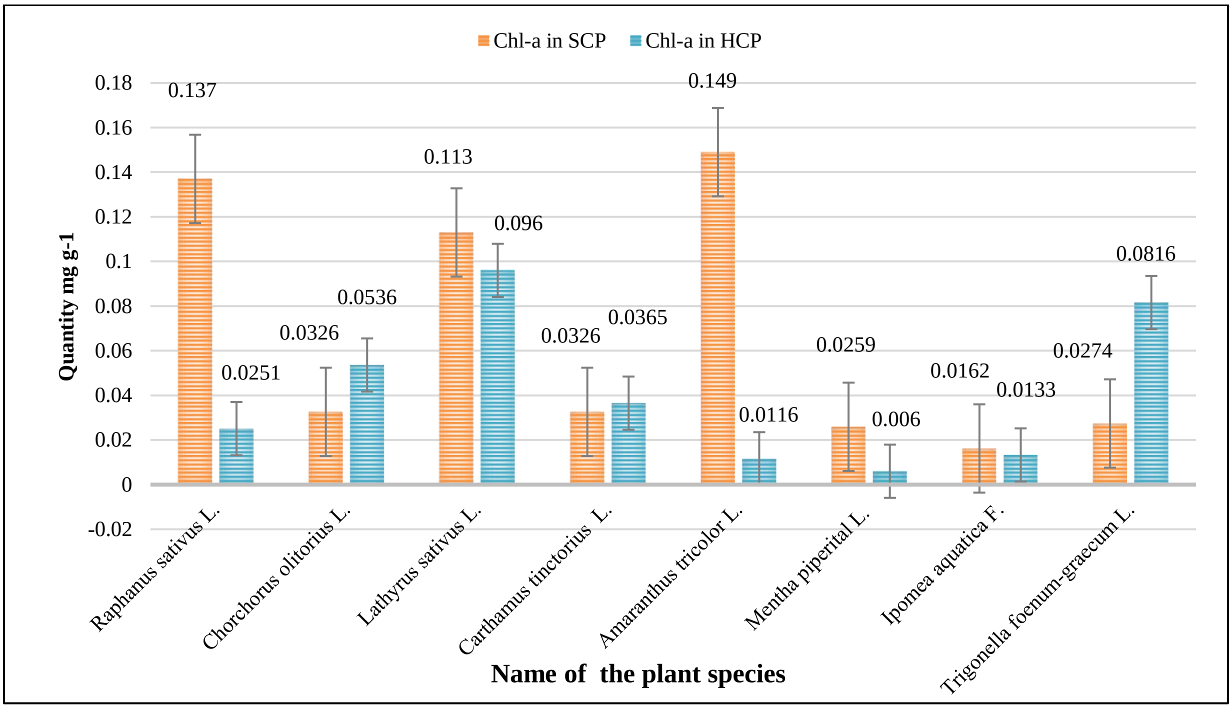
Mentha piperital L, The total chlorophyll content in the soil-based system is 0.931 mg g^{-1}, whereas in a hydroponic system, it is 1.512 mg g^{-1}, which is 0.581 mg g^{-1}, higher than the soil-base system. The *Chl. a* content in the soil-based system is 0.0259 mg g^{-1}, whereas in the hydroponic system it is only 0.006 mg g^{-1}, which is 0.0199 mg g^{-1} less than the soil-based system. The *Chl. b* content in the soil-based system is 0.906 mg g^{-1}, whereas in a hydroponic system, it is 1.507 mg g^{-1}, which is 0.601 mg g^{-1}, higher than the soil-base system.

Ipomea aquatica F, The total chlorophyll content in the soil-based system is 0.126 mg g^{-1}, whereas in a hydroponic system, it is 1.140 mg g^{-1}, which is 1.014 mg g^{-1}, higher than the soil-base system. The *Chl. a* content in the soil-based system is 0.0162 mg g^{-1}, whereas in the hydroponic system it is only 0.0133 mg g^{-1}, which is 0.0029 mg g^{-1} less than the soil-based system. The *Chl. b* content in the soil-based system is 0.110 mg g^{-1}, whereas in a hydroponic system, it is 1.127 mg g^{-1}, which is 1.017 mg g^{-1}, higher than the soil-base system.

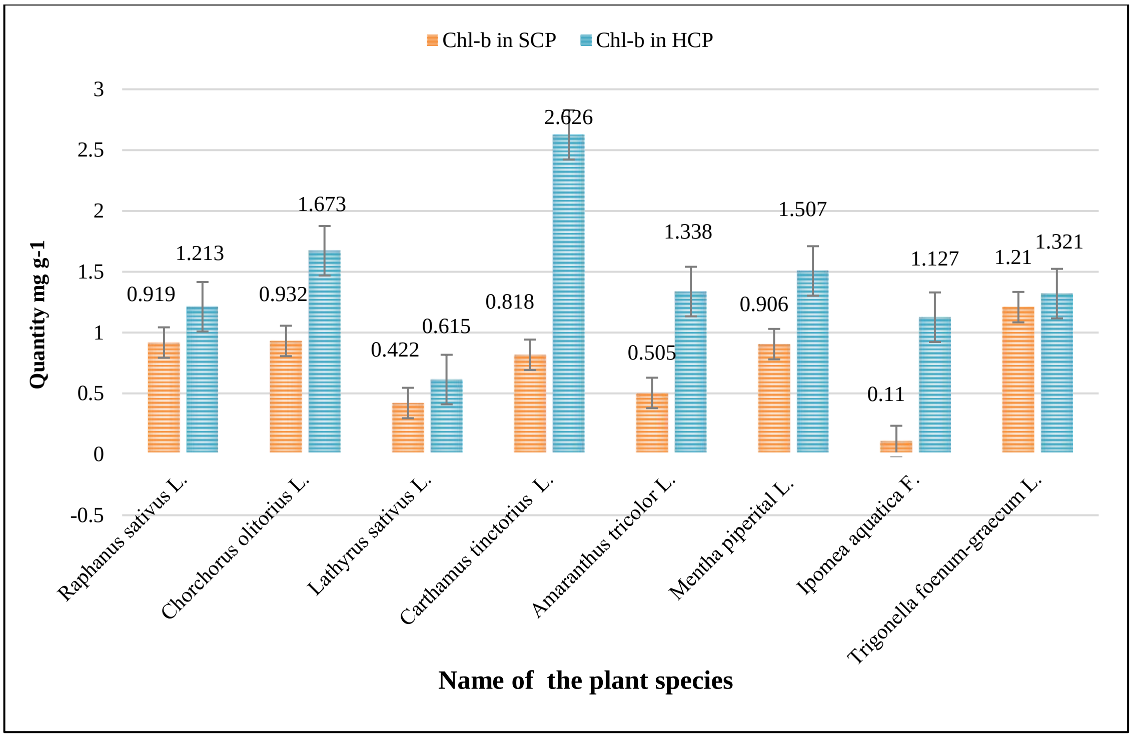
Trigonella foenum-graecum L, The total chlorophyll content in the soil-based system is 1.241 mg g^{-1}, whereas in a hydroponic system, it is 1.402 mg g^{-1}, which is 0.161 mg g^{-1} higher than the soil-base system. The *Chl. a* content in the soil-based system is 0.0274 mg g^{-1}, whereas in the hydroponic system it is only 0.0133 mg g^{-1}, which is 0.0141 mg g^{-1} less than the soil-based system. The *Chl. b* content in the soil-based system is 1.21 mg g^{-1}, whereas in a hydroponic system, it is 1.321 mg g^{-1}, which is 0.111 mg g^{-1} higher than the soil-base system.

IV. CONCLUSION

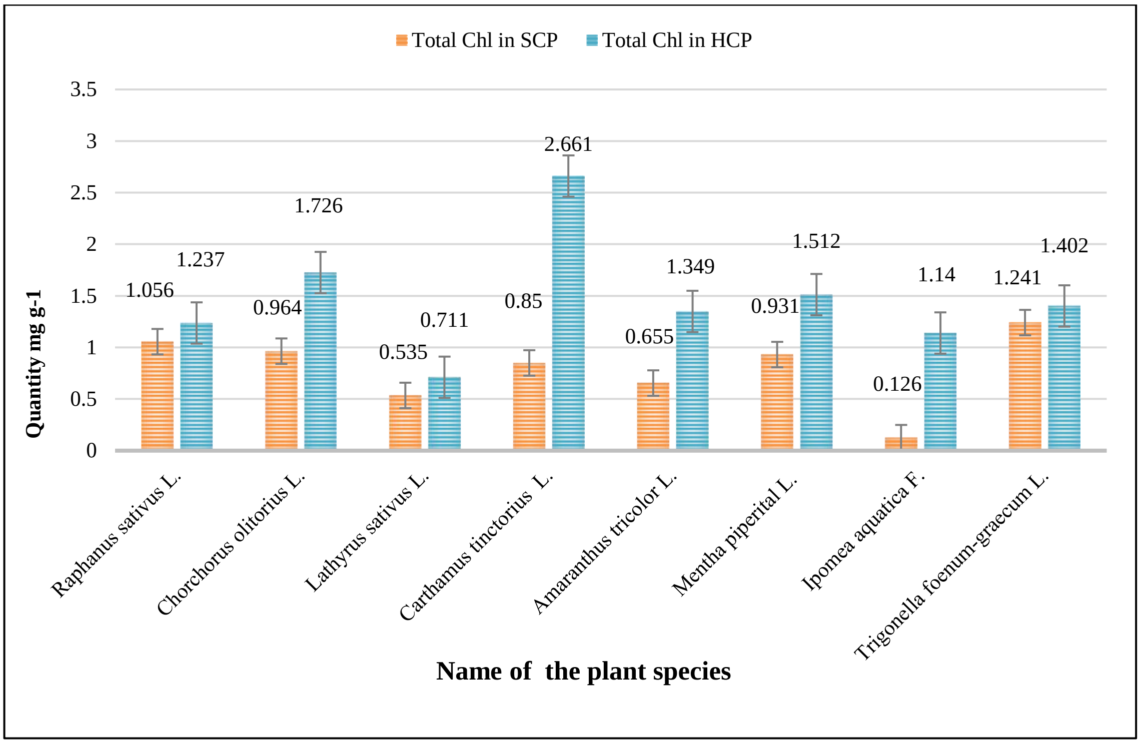
The study provides reliable data on chlorophyll content for a comparative analysis of soil and hydroponically cultivated plants in eight different species of leafy vegetables. The quantitative analysis of photosynthetic pigments showed that hydroponically grown plants of all eight species exhibit a stable and high total chlorophyll content compared to soil-based plants. In terms of chl*b*, hydroponically cultivated plants show higher chl*b* values than those grown in soil. However, the amount of chl*a* is higher in soil-based plants for certain species such as *Raphanus sativus* L., *Lathyrus sativus* L., *Mentha piperita* L., and *Ipomea aquatica* F. This difference occurs due to beneficial adaptations made by the plants. Furthermore, the chlorophyll content can be used as an indicator of plant health stress and nutritional deficiencies. These findings may be helpful for further comparative studies in soil and hydroponic cultivation.



Graph 1. The variation of chlorophyll a content in soil-cultivated plants and hydroponic-cultivated plants



Graph 2. The variation of chlorophyll b content in soil-cultivated plants and hydroponic-cultivated plants



Graph 3. The variation of Total chlorophyll content in soil-cultivated and hydroponic-cultivated plants

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