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ESTABLISHMENT AND MAINTENANCE OF *BRASSICA ALBA* AND *SOLANUM LYCOPERSICUM* ON HYDROPONIC CULTURE AT LABORATORY CONDITION

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Abstract

Hydroponics culture offers immense benefits in plant research, making it a valuable and versatile tool in scientific investigations across plant biology, agronomy, horticulture and diverse fields of research. The present study has been carried out for the establishment of *Brassica alba* and *Solanum lycopersicum* on hydroponic culture in laboratory condition. Firstly, an ideal concentration of macro and micro nutrients was developed for both *B. alba* and *S. lycopersicum* seedlings. After germination of both seeds, seedling was carefully monitored over a 15-day observation period on seedling tray. Then transfer of two-week-old seedlings to hydroponic media resulted in successful adaptation for both species. *B. alba* displayed slow initial growth but progressed significantly with robust development in the long run. In contrast, *S. lycopersicum* adapted quickly and exhibited continuous growth throughout the observation period. By week 4, both species had matured, with *B. alba* plants showing larger roots and stems and the onset of flowering. Both *B. alba* and *S. lycopersicum* seedlings displayed distinct growth patterns in hydroponic culture. These findings contribute valuable insights into the growth dynamics and viability of these two plant species in hydroponic systems, providing important information for optimizing cultivation practices and improving agricultural productivity.

Key words: *Brassica alba*, Hydroponic culture, Macro and micro nutrients, *Solanum lycopersicum.*

Introduction

In the near future, the world is projected to face a significant population problem coupled with a growing concern about food shortage (Tomiyama et al. 2020). As the global population continues to expand, the demand for food is escalating at an unprecedented rate, placing immense pressure on traditional agricultural practices and diminishing arable land (Herdt 2004). Moreover, unpredictable climate patterns and resource constraints further exacerbate the challenges of meeting the nutritional needs of the growing population (Misra 2014). In this context, hydroponic culture emerges as a promising solution to address the impending food crisis (Armanda et al. 2019).

Hydroponics, a soilless cultivation technique, has emerged as an innovative and sustainable approach to modern agriculture, presenting a promising solution to the challenges posed by traditional farming practices

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(Demirtas and Akdogan 2015). The ability to control essential environmental factors, nutrient supply, and water availability in hydroponics enables researchers and farmers alike to optimize plant growth, resource utilization, and crop yields. Hydroponics involves growing plants in a nutrient-rich solution, either in an inert medium or directly in water, with their roots submerged or anchored (Khan 2018). This method eliminates the need for extensive soil preparation, reduces water consumption, and mitigates the risks associated with soil-borne diseases and pests (Swain et al. 2021). Moreover, hydroponic systems allow precise manipulation of nutrient concentrations and pH levels, resulting in increased nutrient uptake efficiency, accelerated growth rates, and enhanced overall plant health (Stegelmeier et al. 2022). These benefits make it an ideal system for cultivating high-value crops such as *Brassica alba* and *Solanum lycopersicum*, which are essential components of the human diet and contribute significantly to global food security.

B. alba, also known as white mustard, belongs to the Brassicaceae family and is widely cultivated for its leaves and seeds (Thomas et al. 2012). The plant possesses various bioactive compounds, including phenolics, glucosinolates, and flavonoids, which have been associated with numerous health benefits (Lietzow 2021). These compounds have attracted interest from the pharmaceutical and nutraceutical industries, fueling the need for efficient and sustainable cultivation methods like hydroponics (Jedynak and Kowalska 2011). *S. lycopersicum*, commonly known as tomato, is a highly popular and economically significant crop worldwide (Kumar et al. 2021). It is rich in vitamins, minerals and antioxidants, therefore, plays an important role in human nutrition and have been extensively studied for their potential health benefits (Dorais et al. 2008). Hydroponic cultivation of tomatoes not only provides opportunities for year-round production but also enhances fruit quality and yield, making it an attractive choice for sustainable agriculture (Lee et al. 2017).

The successful establishment and maintenance of hydroponic cultures of *B. alba* and *S. lycopersicum* depend on the optimization of several critical factors. These include nutrient formulation and concentration, light intensity and spectrum, temperature, pH level, aeration, and root zone environment (Furtner et al. 2007). Understanding the specific requirements of each plant species in a hydroponic setting is vital for achieving optimal growth and yield. Previous research on hydroponic cultivation has demonstrated the potential of this method for different plant species (Chow et al. 2017, Teodor et al. 2021), but its application to *B. alba* and *S. lycopersicum* requires species-specific investigations to develop tailor-made protocols. Moreover, while hydroponics offers numerous benefits, its successful implementation at the laboratory scale demands precision and attention to detail (Jain et al. 2019).

The objective of this study is to establish and maintain hydroponic cultures of *B. alba* and *S. lycopersicum* under controlled laboratory conditions. By examining the growth, nutrient uptake, and physiological responses of these two important crops, we aim to shed light on the unique requirements of each species in hydroponics and provide valuable insights for the optimization of their cultivation in larger-scale commercial systems.

Materials and Methods

Collection of plant materials

Fresh, disease free seeds of *B. alba* and *S. lycopersicum* were collected from local market of Rajshahi, Bangladesh. These seeds were used for the current investigations.

Germination of *B. alba* and *S. lycopersicum* seeds

After collection, the *B. alba* and *S. lycopersicum* seeds were then surface sterilized and germinated in wet filter paper in petri dishes at 25±2°C in the dark for 3 days.

Maintenance of seedling

After germination the young seedlings were transferred to the seedling tray with natural coco pit, and maintained them for approximately two weeks.

Hydroponic culture room conditions

The hydroponic culture room was established by adding the alternative natural sunlight source with 15000 lux artificial light, controlled the photoperiods by 16 hours light and 8 hours dark with timer machine, regulate the temperature at 25±2ºC with AC and finally supply the oxygen (O_2) by artificial oximeter.

Preparation of hydroponic medium

To establish the hydroponic culture of *B. alba* and *S. lycopersicum*, the nutrients compositions are one of the most important factors. It significantly varies plants to plants, however in this investigation we adjust an appropriate concentration of macro (NH_4NO_3, KH_2PO_4, $CaCl_2$, $MgSO_4$, Fe-Na EDTA) and micro nutrients (H_3BO_3, $MnSO_4$, $(NH_4)_6Mo_7O_{24}$, $CoCl_2$) for the established of *B. alba* and *S. lycopersicum* hydroponic culture.

Transfer of seedling to hydroponic medium

The young seedlings were carefully picked up from seedlings tray after 2 weeks and roots were cleaned gently in running tap water. Three seedlings were immediately transferred in a small plastic pot and placed in hydroponic nutrient solution. The optimum concentration of macro and micro nutrients was used to establishment of hydroponic culture of *B. alba* and *S. lycopersicum.*

Maintenance and observation of plants in hydroponic culture

The hydroponic culture nutrients were continuously aerated and renewed after every five days. The plants were observed for eight weeks in hydroponic culture media.

Statistical analysis

The data were analyzed using MS Excel (version 2016), and all values were reported as the mean±SE. Duncan's multiple range test (DMRT) was employed with a significance level set at $p<0.05$, using SAS 9.1.3 software.

Results

Seed germination

The viability of *B. alba* and *S. lycopersicum* seeds was assessed through germination tests. The results demonstrated that *B. alba* seeds exhibited a high germination rate of 97.5% ± 0.64%, indicating good seed quality compared to the *S. lycopersicum* with 64.25±1.65% of germination rate (Fig. 1).

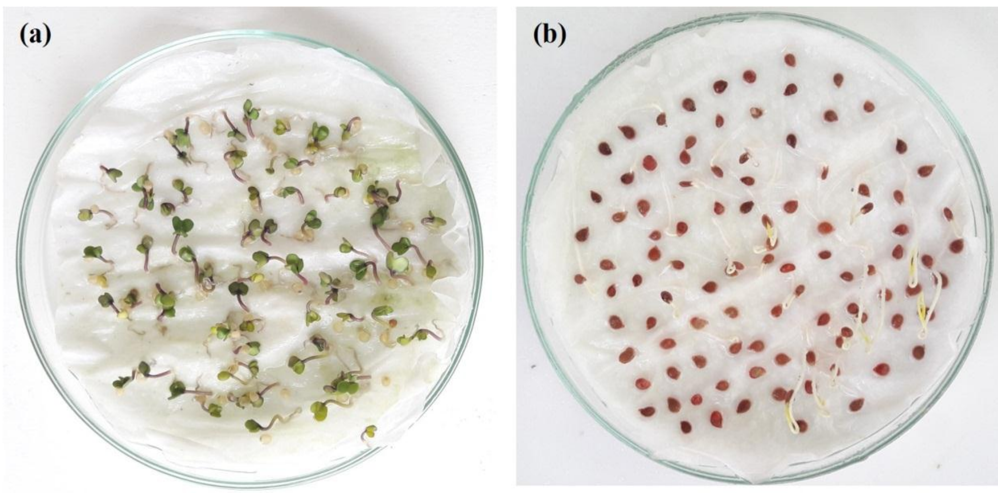

Fig. 1: Seed germination after 48 hours of (a) *B. alba*, and (b) *S. lycopersicum.*

Maintenance of seedling

The young seedlings of *B. alba* in seedling tray were too weak, small and thick leaves and shoots were observed at day-2. However, at day-4 age of seedling become slight swollen, green, and stronger. Additionally, at day-8 it became greener and more swollen, and leaves number and size were increased. At day-11 it became more mature, at day-13 it was very good in condition for transferring, day-15 it was suitable for transferring with greener, large leaves, shoot and enlarged roots (Fig. 2).

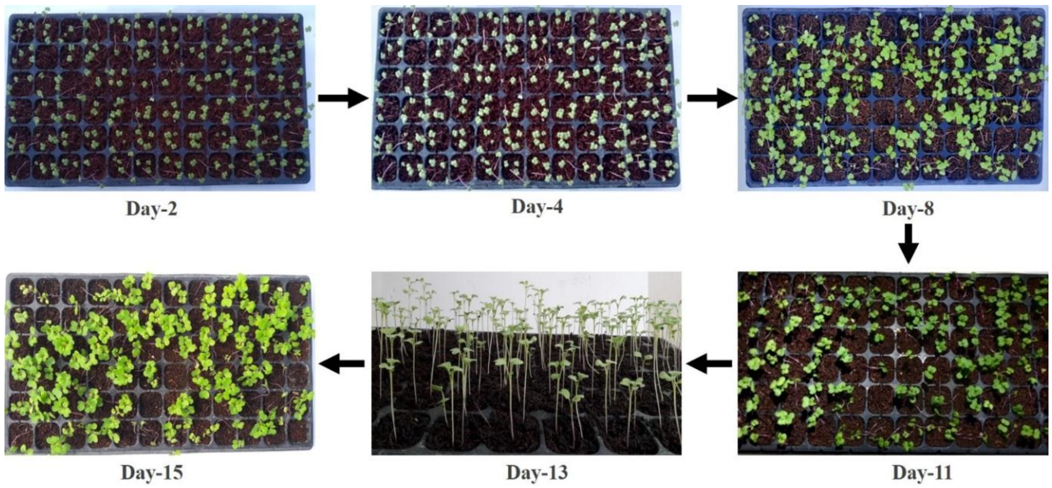

Fig. 2: Maintenance of *B. alba* seedlings throughout 15 days of observation.

Similarly, *S. lycopersicum* young seedlings were weak, small and thin leaves and shoots at day-2 and thereafter it was gradually increased leaves number and size with large shoots that makes it stronger throughout the 15 days of observation (Fig. 3).

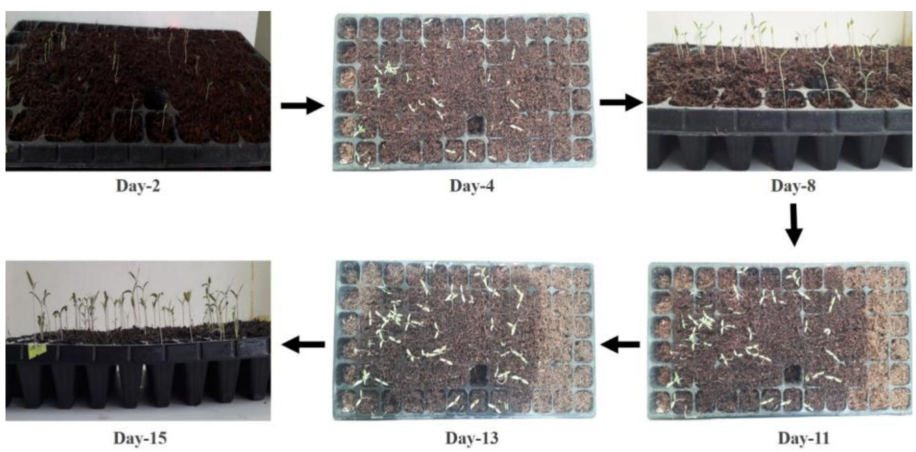

Fig. 3: Maintenance of *S. lycopersicum* seedling throughout 15 days of observation.

Adjustments the nutrition for hydroponic culture

To grow a plant in hydroponic culture it required appropriate concentrations of macro and micro nutrients. In our study we developed an ideal concentration of macro and micro nutrients for the hydroponic culture of *B. alba* and *S. lycopersicum* as shown in Table 1.

Table 1. Concentration and required amounts of different micro and macro nutrients used for establishment of hydroponic culture.

Solution	Concentration	Required amount per 1 litter (gm)	50x stock (gm)
Macro nutrients (mM)			
NH_4NO_3	1.0	0.080	4
KH_2PO_4	0.4	0.054	2.7
$CaCl_2$	3.0	0.332	16.6
$MgSO_4$	1.5	0.180	9
Fe-NaEDTA	0.2	0.0734	3.67
Micro elements (µM)			
H_3BO_3	14	0.00086	43
$MnSO_4$	5.0	0.00075	37.5
$(NH_4)_6Mo_7O_{24}$	0.7	0.00081	40.5
$CoCl_2$	0.1	0.00001298	0.649

Seedling transfer to hydroponic medium

The two weeks old seedlings were carefully collected and washed with clean running tap water, twisted with fresh foam, and placed on hydroponic culture medium pot. Prior to transfer, 500 ml culture medium was poured in plastic pot and connected with an oximeter line for air circulations (Fig. 4). Air was supplied to the hydroponic media for 4 weeks.

Fig. 4: Transfer process of *B. alba* and *S. lycopersicum* seedlings into hydroponic culture.

Evolution of *B. alba* growth in hydroponic medium

The *B. alba* plants were successfully survived on hydroponic culture medium as shown in Fig. 5. At the first week there was significant changes was noticed however first 3 days there was no significant changes was observed due to adaptation of plants in hydroponic culture. At the second week, there were some characteristic features developed in *B. alba* plants under hydroponic condition including fresh and green leaves, formation of nodes and internodes, increased number of leaves and larger roots. Plant height was significantly increased after three weeks, additionally first flower bud was observed in that time (Table 2). A mature larger plant with strong roots and stem was developed after four weeks in hydroponic culture. Flower in main raceme started to open and older petals was falling during the 4th week on hydroponic culture (Fig. 5).

Table 2. Growth parameters of *B. alba* at different week intervals.

No. of weeks	Plant height (cm)	Root length (cm)	Number of leaves
1	7±3	3.53±0.85	4
2	12±3	7.53±0.65	8
3	17±2	10.5±2.12	11
4	25±4	15.5±2.59	14

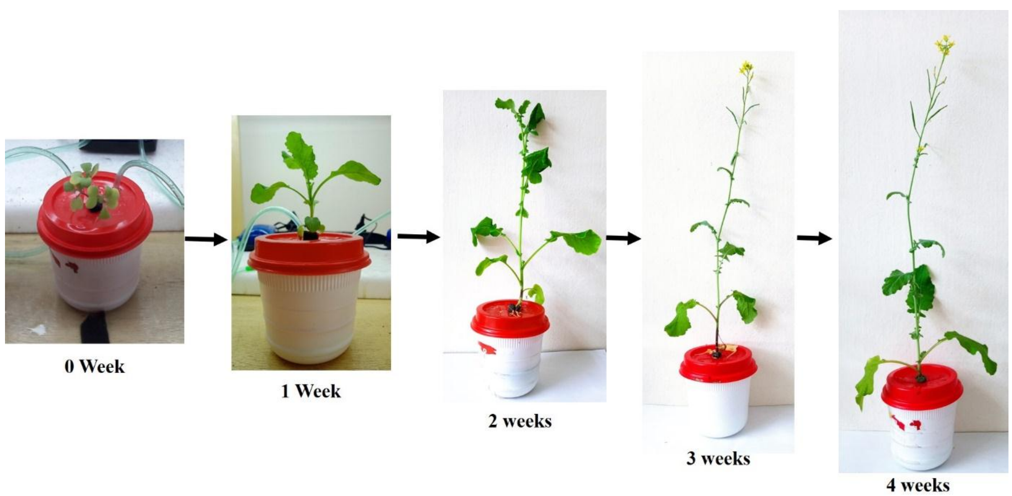

Fig. 5: The development of *B. alba* on hydroponic culture medium throughout four weeks.

After eight weeks on hydroponic culture of *B. alba* the seeds were harvested and stored for next germination (Fig. 6).

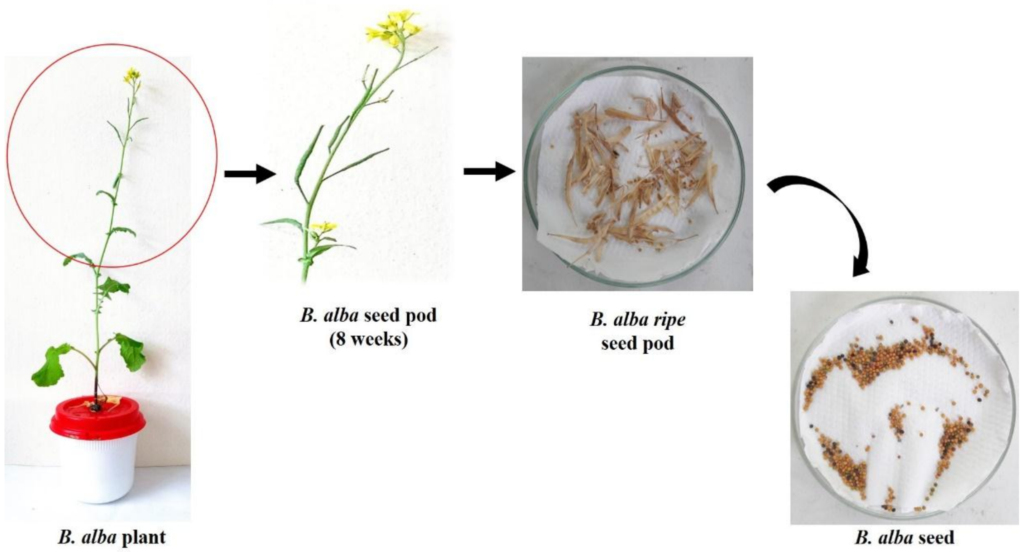

Fig. 6: The seeds of *B. alba* were harvested from eight-week old plants on hydroponic culture.

Evolution of *S. lycopersicum* growth in hydroponic medium

The *S. lycopersicum* young plants were successfully adapted on hydroponic culture medium at very first week. During that time, fresh green leaves developed, and the roots and shoots had started becoming stable.

The nodes and internodes started to extend with increased plant height, number of leaves and root length after two weeks on hydroponic culture (Table 3). First branching of plants was observed at 3rd week. Additionally, plants become stronger and mature with larger leaves, shoot and roots (Fig. 7).

Table 3. Growth parameters of *S. lycopersicum* at different week intervals.

No. of weeks	Plant height (cm)	Root length (cm)	Number of leaves
1	4±0.5	2.55±0.65	8
2	10±2.5	6.57±0.85	12
3	16±2.8	9.5±2.25	16
4	20±3.5	15.65±3.29	19

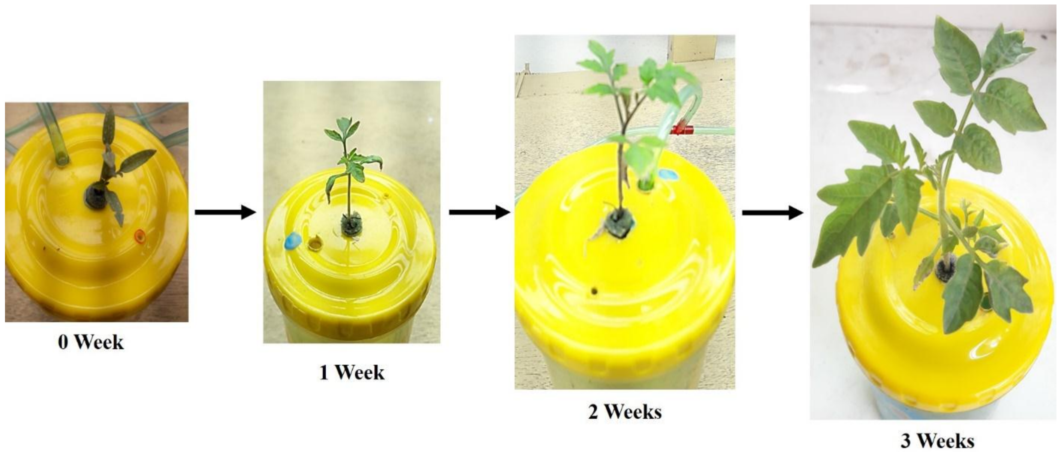

Fig. 7: The development of *S. lycopersicum* on hydroponic culture medium throughout four weeks.

Discussion

In plant research, the hydroponics culture of plants offers immense advantages including precise nutrient control, elimination of soil-related issues, increased growth rates and yields, consistent experimental conditions, resource efficiency, and the ability to study plant responses to controlled environmental factors (Mourouzidou et al. 2023, Ragaveena et al. 2021). These benefits make hydroponics a valuable tool in plant biology, agronomy, horticulture, and various other fields of scientific research. Therefore, in this research, we successfully establishment and maintenance of hydroponic cultures of *B. alba* and *S. lycopersicum* under laboratory conditions providing an efficient and controlled environment for plant growth and research.

There are several factors that influenced the establishment of hydroponic culture, among this the room condition and appropriate concentrations of nutrients are one of the most significant concerns (Teodor et al. 2021). In our study, we used 15000 lux light intensity as alternative sunlight source for both *B. alba* and *S. lycopersicum* for 16 hours day and 8 hours night. Previously Lee et al (2016) used metal halide lamps as natural light supplement which generated c. 400 µmol photons m^{-2} s^{-1} for 16 hours/day (Lee et al. 2016). In hydroponic culture, temperature and oxygen supply are crucial factors for plant growth and nutrient uptake. Appropriate temperature ensures optimal metabolic processes, while sufficient oxygen promotes root health and efficient nutrient absorption. Additionally, we used air conditioning (AC) system for regulating the temperature with 22±2ºC same as previous study and oximeter for suppling oxygen.

The important of macro and micro nutrients concentrations in hydroponic culture lies in providing essential elements for plant growth and development. Macro nutrients (e.g., nitrogen, phosphorus, potassium) are needed in larger quantities, supporting overall plant health, while micro nutrients (e.g., iron, zinc and manganese) are required in smaller amounts, playing vital roles in specific biochemical processes for optimal growth (Nkcukankcuka et al. 2021, Pearson et al. 2023). In this study, an appropriate concentration of five macro nutrients such as NH_4NO_3, KH_2PO_4, $CaCl_2$, $MgSO_4$, and Fe-Na EDTA and four micro nutrients including H_3BO_3, $MnSO_4$, $(NH_4)_6Mo_7O_{24}$, and $CoCl_2$ were used for establishment of *B. alba* and *S. lycopersicum* hydroponic culture (Table 1).

Prior to the establishment we check the viability of *B. alba* and *S. lycopersicum* seed and results exhibited significantly germination rate whereas the *B. alba* showed better activity than *S. lycopersicum* seeds (Fig. 1). After seed germination, the seedlings were maintaining for two weeks in seedling tray (Fig. 2 and 3) and finally transferred into hydroponic culture pot containing macro and micronutrients (Fig. 4). The growth of both *B. alba* and *S. lycopersicum* plants were significantly increased compared with soil cultivation (Campiglia et al. 2015, Hoque et al. 2022). In traditional soil culture about 110 to 150 days (Raboanatahiry et al. 2021) are required to get fully mature plant of *B. alba* however in hydroponic culture it takes only 56 days (Fig. 5). Similarly, the hydroponic culture of *S. lycopersicum* greatly reduced their life cycle form 80 days (Shankramma et al. 2016) to 21 days (Fig. 7). This reduction of life cycle of both plants greatly enhanced the plant research. Moreover, the growth of both *B. alba* and *S. lycopersicum* was significantly increased in hydroponic culture with enlarge root, stem and increased number of leaves compared to the traditional soil culture.

Conclusion

In this research, we developed an enhanced hydroponic culture room concerning light, temperature, oxygen supply and appropriate concentrations of macro and micronutrients for the successfully establishment of *B. alba* and *S. lycopersicum* plants in hydroponic culture. The hydroponic culture of both *B. alba* and *S. lycopersicum* plants significantly reduced their life cycle that could be play a valuable rule in plant biology, agronomy, horticulture and various other fields of scientific research.

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