

Full Length Research Paper

A COMPARATIVE STUDY OF GROWTH PARAMETERS FOR LEAFY VEGETABLES CULTIVATED IN SOIL AND HYDROPONIC SYSTEMS

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ABSTRACT

This study investigates several preliminary growth parameters in seven species of edible green leafy vegetables, a popular source of dietary components in Asian countries like India, China, Sri Lanka, and Bangladesh, focusing on hydroponics, an innovative technique that reduces productivity costs in developing countries and pharmaceutical industries. Controlling climate factors had a positive impact on plant survival and growth. Using LEDs, automated temperature control units, and humidity was found to be crucial in the hydroponic system. This study focused on seed initiation time and seed viability ratio as preliminary growth parameters. The study found that seed initiation time (SIT) in soil-based and hydroponic cultivation systems was earliest in *C. arietinum* (3 days), followed by *A. viridis* L. (6 days), *C. olitorious* L. (7 days), *T. foenum-graecum* L., *S. oleracea* L. (9 days), *C. sativum* L. (11 days), and *M. arvensis* L. (15 days). In this study on a total of 900 seeds for different plant species, it was found that hydroponics had a higher percentage viability ratio for leafy vegetables, with *M. arvensis* having almost doubled the viability rate in hydroponics, influenced by indoor facilities and environmental parameters. The overall impact of hydroponics was significant over the preliminary growth parameters in seven different edible green leafy plants.

Keywords: Growth parameter, green leafy vegetables, hydroponics, soil, seed initiation time, seed viability ratio.

1. INTRODUCTION

Nutrition is crucial for living organisms, and agriculture faces challenges in India due to high population density, growing demand, climate, and seasonal dependency (Jarapala, 2017). Green leafy vegetables are popular for their essential and medicinal values, and regular consumption helps avoid micronutrient deficiencies and diseases like vision problems, skin health, cardiovascular disease, and hormonal imbalance. Greens are a significant dietary component in Asian countries like India, China, Sri Lanka, and Bangladesh. Climate and geographical conditions, such as global warming and seasonal dependency, make it difficult for humans to survive. Advanced techniques and understanding plant species' nutritional requirements can help develop effective strategies. Environmental factors like air, water, light, humidity, and temperature also play a role (Jerusha *et al.*, 2021; Das *et al.*, 2022).

In Chhattisgarh (India), tribal people rely on agriculture for their livelihood and nutritional needs. Leafy vegetables are healthy, easily available sources of vitamins, minerals, carbohydrates, amino acids, and proteins (Kumari, 2020; Shukla *et al.*, 2022). They also have therapeutic value and secondary metabolites that provide disease cures. Hydroponics is an innovative technique that reduces productivity costs by producing a large number of vegetables. Despite its popularity among farmers in India, it is not widely adopted. Hydroponics is increasingly recognized for its effectiveness in cultivating herbs and plant species in developing countries like India, Bangladesh, Pakistan, and Sri Lanka. It can be practiced indoors or outdoors and can be used for indoor greenhouses (Kratky *et al.*, 1988; Albahro *et al.*, 2008; Guo *et al.*, 2019; Maiti *et al.*, 2020).

2. MATERIALS AND METHODS

2.1 Selection of leafy plants: The study analyzed seven leafy vegetables, *Amaranthus viridis L.*, *Trigonella foenum-graecum L.*, *Chorchorus olitorius L.*, *Coriandrum sativum L.*, *Mentha arvensis L.*, *Cicer arietinum L.*, and *Spinacia oleracea L.*, grown in a hydroponic system and soil for comparative analysis. Standardized seeds were purchased from local markets and sown in December and May as per seasonal availability in local markets. Growth responses, including seed initiation time (SIT) and seed viability ratio (SVR), were systematically analyzed (Chauhan *et al.*, 2014; Vandam *et al.*, 2017; Prabhas *et al.*, 2017).

2.2 Hydroponic system: design and setup establishment: The Ebb and Flow flood and drain systems are popular among home hydroponic growers due to their ease of construction, cost-effectiveness, and adaptability. These systems flood plant root systems with nutritional solutions, using a timer to pump water through tubing from a reservoir. The overflow tube sets water levels and prevents spillage. The system can be built using various household materials and can be modified based on plant size, temperature, humidity, and medium (Lee *et al.*, 2019; Mamatha *et al.*, 2023). The system involves flooding a growing tray with nutrient solution and draining it back into the reservoir using a submerged pump with a timer. The frequency of the timer's use depends on plant type, size, temperature, humidity, and growing medium. The Ebb and Flow System

modifies its nutritional solution according to plant size, temperature, humidity, and medium by momentarily flooding a grow tray with it using a submersible pump and then draining it back into the reservoir (Harsha *et al.*, 2018; Jan *et al.*, 2020; Jangilwad *et al.*, 2020).

2.3 Nutrient medium: Plant growth relies on sunlight and water, with nutrient solutions providing major and micro elements. Macronutrients include potassium, phosphorus, nitrogen, calcium, magnesium, and sulfur, while micronutrients include iron, chlorine, manganese, boron, copper, nickel, and molybdenum (HwiAhn *et al.*, 2023). Supplements like cobalt, selenium, silicon, iodine, sodium, and vanadium may also be beneficial. Careful selection of optimum concentrations of micro- and macro-elements is crucial for optimal plant growth and metabolic activities. A broad-spectrum nutrient medium is beneficial (Choi *et al.*, 2005; Ferguson *et al.*, 2014; Currey *et al.*, 2019; Gillespie *et al.*, 2021).

Table 1: Showing broad range nutrient solution (Jones, 2014)

Major Elements			Micronutrient		
Element	Ionic form	Concentration Range mg/L, ppm	Element	Ionic form	Concentration Range mg/L, ppm
Nitrogen (N)	NO ₃ ⁻ , NH ₄ ⁺	100 – 200	Boron (B)	BO ₃ ³⁻	0.03
Phosphorus (P)	HPO ₄ ²⁻ , H ₂ PO ₄ ⁻	15 - 30	Chlorine (Cl)	Cl ⁻	-
Potassium (K)	K ⁺	100 – 200	Copper (Cu)	Cu ²⁺	0.01 – 0.10
Calcium (Ca)	Ca ²⁺	200 – 300	Iron (Fe)	Fe ²⁺ , Fe ³⁺	2 – 12
Magnesium (Mg)	Mg ²⁺	30 – 80	Manganese (Mn)	Mn ²⁺	0.5 – 2.0
Sulfur (S)	SO ₄ ²⁻	70 - 150	Molybdenum (Mo)	MoO ₄ ⁻	0.05
			Zinc (Zn)	Zn ²⁺	0.05 – 0.50

2.4 Control over climatic factors: Climate change impacts temperature, light intensity, and relative humidity, which are crucial for plant survival and growth. The most beneficial light spectrum for plant growth is red (600–800 nm) and blue (380–480 nm). Temperature and rainfall are also important factors for agricultural productivity. Optimal temperature ranges from 10°C to 35°C for most plant species, enhancing physiological and biochemical changes (Ferreira *et al.*, 2018; Diwan *et al.*, 2021; Tadevosyan *et al.*, 2023).

2.5 Measurement and analysis of various growth parameters in soil-based cultivars and hydroponics.

2.5.1 Time period of seedling initiation: After sowing seed in the soil, seed germination occurs through rupturing of the seed coat, and the first visual appearance of the seedling coming out of the soil was noted and counted manually in 3 different quadrates to maintain replicas for each species. Hence, a total of 21 plus quadrates were established and maintained throughout the study for each leafy vegetable plant species in both soil and hydroponic systems (Dube *et al.*, 2021). Simultaneously, seeds were also sown in a hydroponic system. Time was recorded for seed initiation based on physical observation of sown seeds at a particular time interval. Important characteristics that are important for the observation of seed initiation time are listed below:

1. Rupturing of seed coat.
2. Appearance of foliage.
3. Different plant species may show different seed initiation times. Hence, regular monitoring at a particular time interval is required.

2.5.2 Seed viability ratio in both soil and hydroponic systems per unit time: A total of 100 seeds are used per square foot (quadrat) for both systems. A total of nine quadrates were established for cultivating each leafy plant species to maintain replicas. (Lee *et al.*, 2021).

$$\text{Seed Viability Ratio} = \frac{\text{Total number of seeds sown in all quadrates}}{\text{Total number of seedlings appeared after time interval}}$$

3. RESULT AND DISCUSSION

3.1 Seed Initiation Time (SIT): Seed initiation was examined through the clear appearance of rupturing of the seed coat, recorded in the time required (in the number of days) for rupturing of the seed coat (Kader, 2005; Bhadra *et al.*, 2024). This was visible to the naked eye. In soil-based seed sown, the first appearance of seed initiation was recorded earliest in *C. arietinum* (3 days), followed by *A. viridis L.* (6 days), *C. olitorious L.* (7 days), *T. foenum- graecum L.*, *S. oleracea L.* (9 days), *C. sativum L.* (11 days), and *M. arvensis L.* (15 days). *M. arvensis L.* has taken the longest time period of 15 days to show the first appearance of seed initiation. *M. arvensis L.* required a large amount of water per day (Table 2 and Figure 1).

On the other hand, the first appearance of seed initiation in hydroponics was recorded earliest in *C. arietinum L.* (2 days), similar to the soilless technique. Secondly, *A. viridis L.* was observed for seed initiation 5 days after the seed was sown. *C. olitorious L.* and *S. oleracea L.* took 6 days, followed by both *T. foenum- graecum L.* and *C. sativum L.* (9 days). Lastly, seed initiation was recorded in *M. arvensis L.* (11 days) in hydroponics, comparable to soil-based cultivation. In this experiment, the seed initiation sequence in both soil-based cultivation and hydroponic systems was almost similar. Although, the hydroponic system showed more positive support for *A. viridis L.*,

C. olitorius L., *C. sativum L.*, *M. arvensis L.*, and *S. oleracea L.* (Tables 2 and Figure 1).

The results showed that seed initiation time varies among plant species and is influenced by factors such as seed coat thickness, nutrient absorption, and soil moisture availability. Water softens the seed coat, allowing embryos to rupture easily. Temperature variations can delay seed coat rupturing. Hydroponics provides consistent water supply and moisture support, while a humid environment outside the indoor system may reduce seed initiation time (Yadav *et al.*, 2023).

Table 2: Assessment of seed initiation in seven different plant species in soil and hydroponic system per unit time.

S. No.	Name of the plant	Common Name	Total no. of seed sown in soil and hydroponics (Number of seed per 1 ft ² area) x Average of 9 quadrates	Average no. of days for seed initiation in Soil (No. of Days) ± SD	Average no. of days for seed initiation In Hydroponics (No. of Days) ± SD	
1	<i>A. viridis L.</i>	Chaulai bhaji	100 x 9 = 900	6 ± 0.50	5 ± 0.60	
2	<i>T. f. graceum L.</i>	Methi bhaji		9 ± 0.78	9 ± 0.92	
3	<i>C. olitorius L.</i>	Chech bhaji		7 ± 0.70	6 ± 0.70	
4	<i>C. sativum L.</i>	Dhaniya		11 ± 0.60	9 ± 0.50	
5	<i>M. arvensis L.</i>	Mint / Pudina		19 ± 0.86	12 ± 0.70	
6	<i>C. arietinum L.</i>	Chana bhaji		2 ± 0.70	2 ± 0.00	
7	<i>S. oleracea L.</i>	Palak bhaji		9 ± 0.50	6 ± 0.92	
Mean ± average SD				9.14 ± 0.66	7.00 ± 0.62	
SD and Standard Error				5.04 and 1.90	3.26 and 1.23	

*Area = 1 feet²

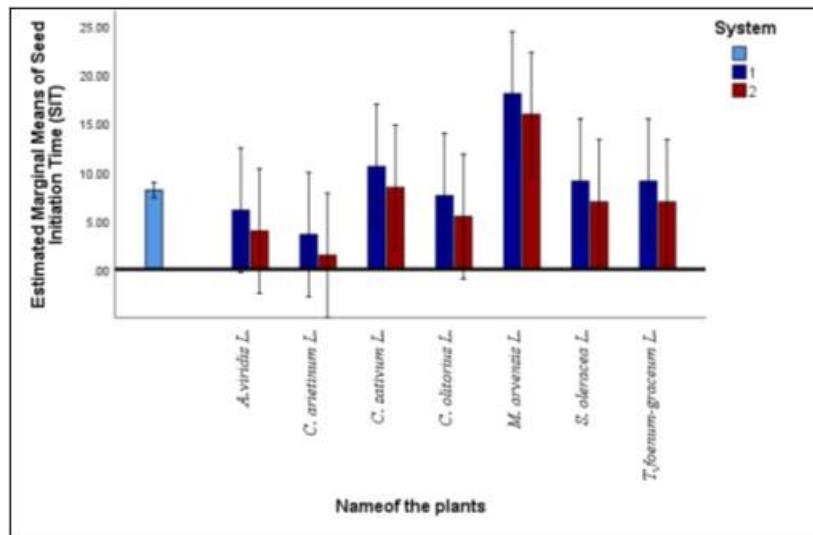


Figure 1: Showing seed initiation time after seed sown in soil (SSS) and hydroponics (SSH) of selected leafy vegetables.

3.2 Seed Viability Ratio (SVR): A total of 900 seeds were sown in nine quadrates, both in soil and hydroponics. Viability was observed through the clear appearance of rupturing of the seed coat and the appearance of seedlings coming out of the seed coat (Fantinatti and Usberti, 2007; Kanmege *et al.*, 2016). Percent viability was recorded between seed sown in soil (SSS) and seed sown in hydroponics (SSH). Percent viability in *A. viridis* L. (37% in SSS and 66% in SSH), *T.F. graceum* L. (45% in SSS and 73% in SSH), *C. olitorious* L. (56% in SSS and 81% in SSH), *C. sativum* L. (75% in SSS and 92% in SSH), *M. arvensis* L. (41% in SSS and 83% in SSH), *C. arietinum* L. (77% in SSS and 80% in SSH), and *S. oleracea* L. (81% in SSS and 87% in SSH). The seed viability percent ratio was higher in hydroponics for all leafy vegetables. A significant difference was recorded between seed sown in soil and seed sown in hydroponics. *M. arvensis* showed a significant difference between SSS and SSH; the viability rate was almost double in hydroponics (Tables 2 and 3). Numerous other factors support the efficacy and appropriateness of hydroponic farming for the cultivation of tiny leafy vegetables. In a hydroponic system, seed viability was unquestionably higher than in a soil-based growth method. More protection for seeds is offered by indoor facilities against insects and animals that feed on seeds (Yadav *et al.*, 2023). Furthermore, variations in common environmental parameters such as temperature, moisture content, and soil texture can impact the rate of seed viability in all plant species (Tables 3 and Figure 2).

Table 3: Assessment of seed viability analysis for seven different plant species in soil and hydroponics per unit area.

Name of the plants	Mean values for sample's reading in 9 quadrates	
	Soil	Hydroponics
<i>A. Viridis L.</i>	37 ± 3.10	66 ± 2.73
<i>T. foenum-grecum</i>	45 ± 2.51	73 ± 0.78
<i>C. olitorius L.</i>	55 ± 1.51	81 ± 1.24
<i>C. sativum L.</i>	75 ± 2.57	92 ± 1.44
<i>M. arvensis L.</i>	40 ± 2.21	83 ± 2.08
<i>C. arietinum L.</i>	77 ± 3.02	80 ± 1.36
<i>S. oleracea L.</i>	81 ± 1.60	87 ± 1.73

*Area = 1 feet² (Size of one quadrat)

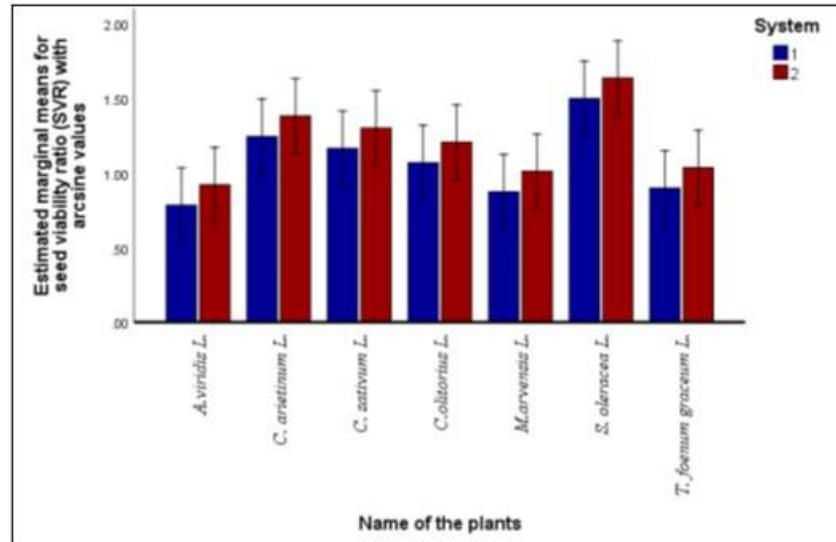


Figure 2: Showing seed viability percentage recorded after seed sown in soil (SSS) and hydroponics (SSH) of selected leafy vegetables.

3.3 Statistical Analysis: Experimental measurements were performed. The obtained data is analyzed and expressed as the average ± standard deviation for the number of plants in a total of nine quadrates (Table 3). The magnitude of the means, standard curve, standard errors, and standard deviations were calculated using SPSS software 24.0. Descriptive analysis of the data obtained for seed viability ratio (SVR) values obtained for soil and hydroponics is shown in tables 4 and 5 separately.

3.3.1 Seed Initiation Time (SIT): In order to compare the data and analyze LAI in two distinct independent production systems (soil and hydroponic), significant values at the 95% confidence

level were tested with a t-test. First, Levi's test and the normalcy assumptions were verified. There was no significant difference in scores for soil ($M = 9.14$, $SD = 5.69$) and hydroponics ($M = 7.0$, $SD = 3.55$); $t (12) = .844$, $p = .561$. As the $p > 0.05$, the null hypothesis is accepted (Table 4).

Table 4: Showing results of t-test of leafy vegetables for seed initiation time (SIT) in Soil and Hydroponics

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
Seed Initiation Time	Equal variances assumed	.358	.561	.844	12	.415	2.14286	2.53948	-3.390	7.67592
	Equal variances not assumed			.844	10.06	.418	2.14286	2.53948	-3.510	7.79643

Table 5: Showing results of t-test of leafy vegetables for Seed Viability Ratio (SVR) in Soil and Hydroponics

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
Seed viability ratio (SVR)	Equal variances assumed	4.502	.055	-.961	12	.355	-.13714	.14267	-.44799	.17370
	Equal variances not assumed			-.961	9.840	.359	-.13714	.14267	-.45573	.18144

3.3.2 Seed Viability Ratio (SVR): In order to compare the data and analyze SVR in two distinct independent production systems (soil and hydroponic), significant values at the 95% confidence level were tested with a t-test. First, Levi's test and the normalcy assumptions were verified. There

is a significant difference in scores for soil ($M = 1.07$, $SD = .32$) and hydroponics ($M = 1.21$, $SD = 0.19$); $t(12) = -.961$, $p = 0.05$. As the p value is equal to 0.05, the null hypothesis is rejected (Table 5).

4. CONCLUSION

A comparative analysis has been conducted between hydroponic systems and soil-based plant cultivation methods. It was found that seed initiation occurs when the seed coat ruptures, causing sprouting. The experiment began with the selection of healthy seed from a stock of seven plant species, including *C. arietinum L.*, *A. viridis L.*, *C. olitorius L.*, *T. foenum-graecum L.*, *S. oleracea L.*, *C. sativum L.*, and *M. arvensis L.* Seeds were sown in soil and a hydroponics system simultaneously. Hydroponics readings showed more support for the preliminary growth parameters, such as seed initiation time. The experimentation was continued for a seed viability ratio check also. This phase of research revealed that hydroponics had a higher percentage of seed viability ratio for leafy vegetables, with *M. arvensis L.* having almost double the viability rate in hydroponics, influenced by indoor facilities and environmental parameters.

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