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GERMINATION AND SEEDLING ESTABLISHMENT IN AN AUTOMATED SOLAR-BASED HYDROPONIC SYSTEM

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ABSTRACT
The Solar based Greenhouse system is one of the most significant greenhouse systems, including a source of renewable energy and monitoring and control of the inside greenhouse environment via an automation unit. In this experiment we studied seed germination, germination rate, plant height, number of leaves formed, survival rate and growth of seedling of 4 different plant species (Butter head lettuce, Baby Spinach, Red rose lettuce and Romaine Maximums Lettuce). Among the 4-plant species grown under the same environmental condition, higher rate of seed germination was observed for maximums lettuce, and baby spinach compared to other species. In our experiment, we observed high germination rate for maximums lettuce i.e., 83.7% with MGT of days, compared to other plant species. Survival rate was also maximum for maximums lettuce compared to other species. In our research, we also observed that not all the seeds grow at the same rate, we found red rose lettuce and butter head lettuce germinated within 6-7 days and was ready for NFT transfer, while Baby spinach and maximums lettuce took 8-12 days for germination and root formation.

KEYWORD: Horticulture, Hydroponic, Solar, vertical farming, Germination, NFT.

INTRODUCTION
Hydroponics is a horticulture technique involving soil-less farming, using nutrient-enriched water solution (Mason, 1990). The nutrients used in hydroponic systems may be organic or inorganic. Modern soilless agriculture involves growing various plants in substrate cultures with their roots totally submerged in nutritious water possibly in inert media such as Peat moss, rock wool, coco coir, or coco husk chips (Maharana and Koul, 2011). The majority of hydroponically grown veggies is utilized in salads and is a significant source of vitamins. Customers use vegetables as meals every day because they are more affordable energy sources (Viriyakul, 2013). Sowing times affect crop production. The best crop production and efficient use of the land is ensured by timely seeding by ensuring appropriate plant development and growth (Viriyakul, 2013). Hydroponic systems, with the application of artificial substrate and nutrients, have become one of the fastest crop production techniques in agriculture (Bhattarai et al., 2008). Hydroponic systems implanted within the greenhouse have the capacity to reuse water and nutrients and provide easy management of environmental variability such as temperature and humidity control and control of disease and pests (Chow et al., 2017). Around the world, there is widespread fear about a potential food and water crises as a result of the urban population growth and the consequences of climate change. As a result, cities of the future will be increasingly inhabited, demanding more food and better water management (Yamaguchi et al., 2018). Hydroponic seeding is more successful since it produces an increased yield of crops, improving their productivity over traditional methods (Beltrano et al., 2015). Various crops and vegetables are grown using a hydroponic system, such as tomatoes, spinach, lettuce, radishes, and cucumber. Uttarakhand has diverse agro-climatic regions like hill, tarai, and plain areas (Krishna et al., 2024). Studies say that more than 75-85 percent of the population in the state depends on agriculture for their livelihood. It has been observed that commercial agriculture is practiced primarily on the plain areas of the state. In the agriculture production process, electricity and water are key inputs, and in the last few decades, it has been noticed that electricity tube well-driven groundwater irrigations have been one of the prime drivers towards increased agricultural productivity in India. (De Silva, S 2017) The world population is also expected to grow by over a third, or 2.3 billion people, between 2009 and 2050; consequently, market demand for food supplies will continue to grow. With an

expanding population and changing dynamics in global food markets, it is essential to find solutions for more resilient food production methods closer to urban environments. In this regard, Greenhouse farming and hydroponic techniques, which are indoor soil-less farming in a closed and controlled environment, can provide a better solution as they protect plants from extreme weather, insects, and pests (Ragaveena et al., 2021). Solar-based hydroponics offers a comprehensive and innovative approach to agriculture, utilizing advanced automation technology, water-efficient farming methods, and renewable energy sources. It is becoming increasingly important to embrace cutting-edge solutions like solar-powered hydroponics as the globe faces climate change, resource scarcity, and food poverty to create a sustainable future (Gorjain et al., 2022). Due to closed system, there are no leakages of nutrients and the amount of water used is significantly limited compared to conventional farming. There is little data available on the environmental footprint of this type of farming techniques especially in the context of India. Water-Energy-Food Nexus is a new approach towards food security and sustainable agricultural practices. The Nexus approach helps us in better understanding and systematic analysis of use and management of our resources in a better way. The objective of research work was to study the practicability of growing different agricultural crops using automated solar based hydroponic system and to compare the growth and seed germination rate of plant grown under the same environmental condition.

1. MATERIAL AND METHODS

1.1 Study location and plant material

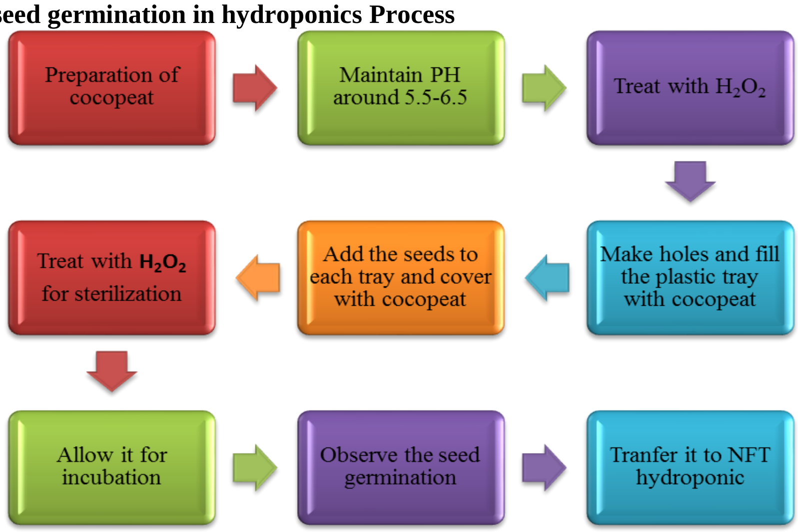
The experiment focused on evaluating the number of seeds germinated, the rate of seed germination, seedling height, and growth of four types of lettuce: Butter head lettuce, Baby Spinach, Red rose lettuce, and Romaine Maximums Lettuce. (Uttarakhand State Council for Science and Technology), UCOST located at coordinates 30.3379° N, 77.9206° E in Dehradun, conducted an experiment on soilless crop farming from May to July 2023.

2.2 METHODOLOGY

2.2.1 Method steps for seed germination in hydroponics Process

- Prior to usage, immerse the coco peat in water for several hours.
- After soaking, allow the coco peat to air dry for a few minutes and monitor its pH and EC levels.
- Maintain the pH within the range of 5.5-6.5 and ensure the EC content remains below 0.8.
- Sterilize the coco peat by treating it with a solution of H_2O_2 (1ml/l).
- Pre-drill holes in plastic trays or containers to facilitate proper aeration for the plants.
- Fill the plastic trays or containers with sterilized coco peat medium.
- Place the seeds in the medium, ensuring they are adequately covered with coco peat.
- Submerge the plastic trays containing the seeds in water for hydration, followed by another round of H_2O_2 sterilization.
- Position the plastic trays in an automated greenhouse with controlled temperature, humidity, and lighting for incubation.
- Regularly monitor the seeds to observe germination progress.
- Keep the coco peat moist by hydrating it daily.
- Once the plants have reached a suitable size, transfer them to the automated NFT hydroponic chamber for continued growth. (Nocentini et al., 2021)

2.2.2 Flow chart for seed germination in hydroponics Process



2.3 Cultural condition

Seedling from different plant species were grown for 5-6 weeks in NFT hydroponic channel with continuous water supply. During the incubation of plants, PH of the nutrient solutions varied from 6 to 6.9, temperature of the greenhouse was maintained as 24-28°c and EC varied from 0.4-1.5 dS/m. The mixing Unit automatically adjusted the EC and pH when adding additional solution.

2.4 Data Collection

An analysis of the effects of various parameters on the quality, production, and growth of seedling was done. The seeds grown in hydroponic system were observed and data was recorded for further observation. The seedling of red rose lettuce, Butter head lettuces, baby spinach and maximums romaine lettuce were planted on same day i.e., 25th May and number of seeds germination of each plant species was counted. After 3, 4 days of seed sown, germination started followed by true leaf formation. The height of each plant species was measured from the medium surface to its highest growth points above ground, using a measuring scale, both before and after NFT transfer and growth of the plants were observed.

Fig. 1: Internal structure of automated solar based hydroponic & Coco peat after H_2O_2 treatment.

Fig. 2: 2.1 Seeds sown in plastic tray. 2.2 Germination of seedling.

Fig. 3: Red rose lettuce, Butter head lettuce, Baby Spinach, Maximums lettuce after germination.

Fig. 4: Red rose lettuce, Butter head lettuce, Baby Spinach, Maximums lettuce after NFT transfer.

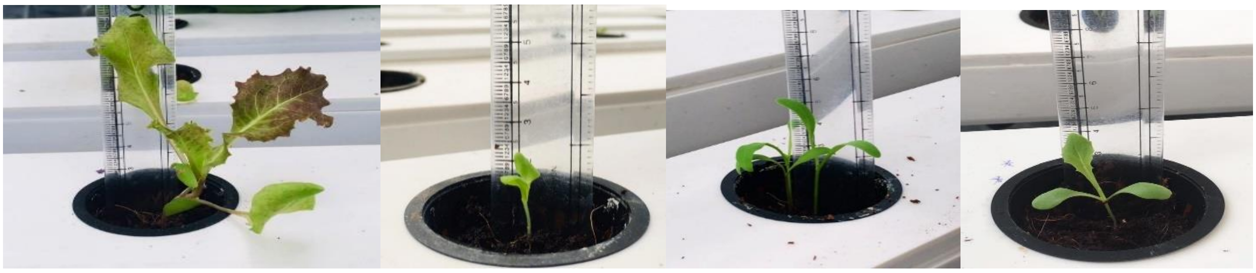


Fig. 5: Seedling growth measurement after 1 week of NFT transfer.

RESULTS AND DISCUSSION

The evaluation of performance demonstrated that in the experimental setup for each of the four plant species (Butter head lettuce, Baby Spinach, Red rose lettuce, and Romaine Maximums Lettuce), seeds were sown in plastic trays containing sterilized coco-peat pretreated with H2O2, as described by (Nocentini et al., 2021). These trays were then placed inside an automated solar-based hydroponic chamber. Following several days, germination occurred, evidenced by the emergence of the plumule from the seedling. Data collection took place daily for up to one month from the time of seed sowing. Consistent watering was provided to the seeds, and two weeks post-germination, the seedlings were transferred to the NFT hydroponic chamber to grow under controlled environmental conditions, as outlined by (Kim et al., 2018). The germination percentage (GP) and mean germination time (MGT) were computed for each plant species using specific formulas. In this study, we analyzed the mean germination times (MGT) and subsequent development of various plant species alongside their germination rates. According to the findings, Romaine Maximums Lettuce exhibited the highest germination rate of 83.7% with an MGT of 0.35. Baby Spinach followed closely with a germination rate of 75.49% and an MGT of 0.318. Similarly, Red Rose Lettuce displayed a germination rate of 73.37% with an MGT of 0.145. Conversely, Butter head Lettuce showed the lowest germination rate of 71.42% with an MGT of 0.595 (Table 2). After germination, the mean height of the plants was measured during the first and second weeks before their transfer to the NFT hydroponic chamber. Among the plant species, Red Rose Lettuce exhibited the maximum height of 71mm after two weeks, surpassing the other species (Table 2). Upon transfer to the NFT hydroponic chamber, the plants experienced a significant increase in height and leaf count. After two weeks in the NFT chamber, the mean height was observed as 82.2mm for Red Rose Lettuce, 38.57mm for Butter head Lettuce, 80.33mm for Baby Spinach, and 32.66mm for Romaine Maximums Lettuce. The mean height was calculated by averaging the heights of 15 plants for each species. Similarly, the mean leaf count was determined by calculating the average leaf number of 15 plants for each species. Maximum leaf number was observed for Butter head lettuce i.e., 8-9 compared to other plant species after 4 weeks of seed germination. Plant survival rate was also measured in our research. Survival rate was calculated using the formula:

$$Survival \% = \left(\frac{\text{Number of plants remaining in NFT chamber}}{\text{Number of plants originally transferred to NFT}} \right) \times 100$$

(Brown et al., 2017; Smith et al., 2019; Garcia et al., 2020)

Among the 4 plant species studied, the maximum survival rate was observed for Maximums lettuce i.e., 100%, followed by Butter head lettuce i.e., 99.81%, and Red Rose lettuce i.e., 99.27%, whereas the minimum survival rate was observed for Baby Spinach i.e., 96.71% compared to other species (Table 4). Our study suggests a high likelihood that hydroponics, the fastest-growing sector in agriculture (Butler et al., 2006), will likely dominate future food production. Several factors contribute to the superiority of hydroponics over soil-based cultivation. Firstly, the temperature conditions in greenhouses can be effectively managed, allowing plants to be grown throughout the year. Furthermore, the absence of soil allows for plants to be grown in closer proximity, as their roots do not need to search for nutrients. With readily available and abundant nutrients, plants in hydroponic systems develop larger and yield higher outputs due to the reduced time required for establishing extensive root systems. Additionally, the nutrient solution in hydroponics maintains a consistent nutrient level, whereas soil tends to degrade as nutrients are absorbed. Collectively, these factors contribute to the higher productivity of hydroponic plants compared to those grown in soil (El-Kazzaz et al., 2017).

Table 1: Environmental Condition inside automated solar based greenhouse.

Light Intensity (Lux)	Temperature °C	Relative Humidity (Rh) %	Electrical Conductivity (EC)
8680	21-24	64-68	1.5

Table 2: Seed germination and its height measurement before NFT transfer.

Plant Species	Number Of Seed Sown	Number Of Seed Germinated	Number Of Days Taken For Seed Germination	Plant Mean Height (Mm)	
				Week 1	Week 2
Red rose lettuce	1506	1105	3-4	68	71
Butterhead lettuce	756	540	3-4	21	22
Baby Spinach	1412	1066	5-6	23	54
Maximus Lettuce	1000	837	2-3	10	25

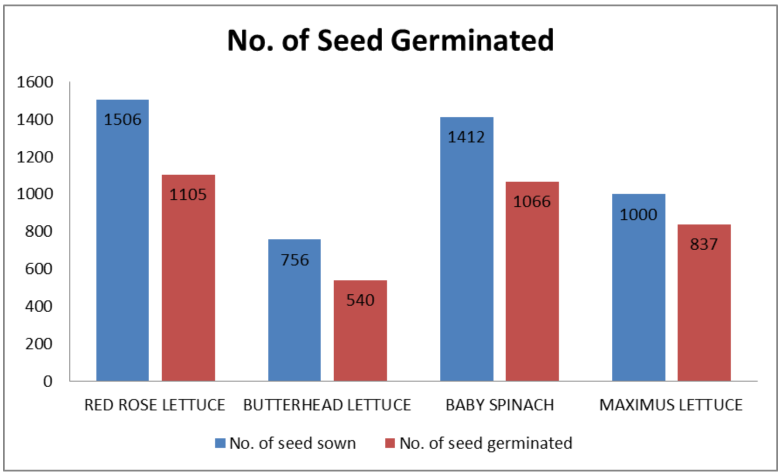


Fig. 6: Graph showing number of seed Germination.

Table 3: No. of days for True leaf formation, leaf count, GP and MGT.

Plant Species	True Leaf Formation	Leaf Count		Germination Percentage (Gp)%	Mean Germination Time (MGT)
		Week 1	Week 2		
Red rose lettuce	4-5 days	2-3	6-7	73.37	0.145
Butterhead lettuce	6-7 days	2-3	4-5	71.42	0.595
Baby Spinach	7-8 days	2	4-5	75.49	0.318
Maximus Lettuce	5-6 days	2	3-4	83.7	0.35

Table 4: Height, leaf and survival rate measurement after NFT transfer.

Plant Species	Mean height (mm)		Mean Leaf Count		Survival rate (%)
	Week 3	Week 4	Week 3	Week 4	
Red rose lettuce	71	82.2	6-7	6-7	99.27
Butterhead lettuce	22.85	38.57	4-5	8-9	99.81
Baby Spinach	61.2	81.3	4-5	5-6	96,71
Maximus Lettuce	21.3	32.66	3-4	5	100

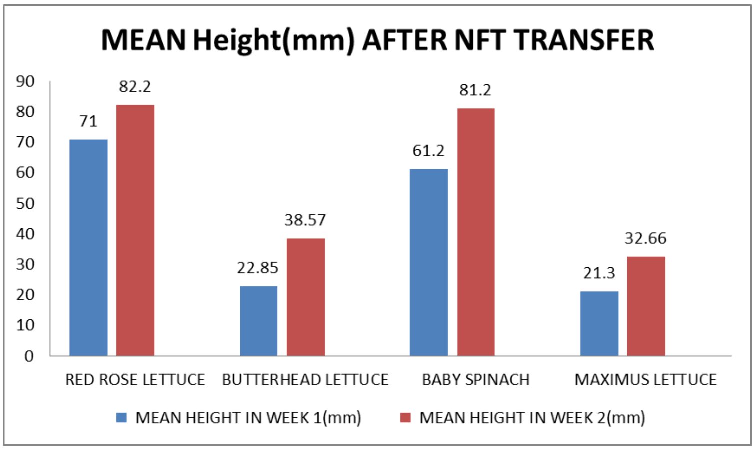


Fig. 8: Mean heights of plants after transfer to NFT hydroponic chamber.

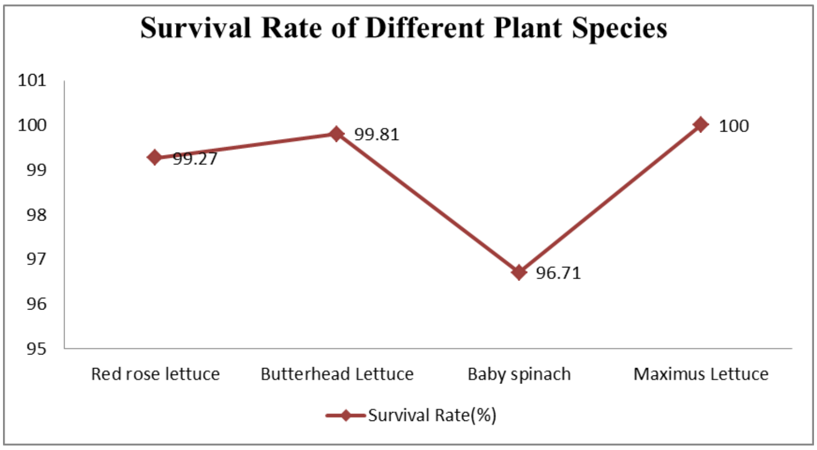


Fig. 9: Survival Rate of Plant in NFT Chamber.

CONCLUSION

Recent research data has substantiated the viability of newly introduced hydroponic systems when employed under controlled conditions for the cultivation of various plant species. Our study specifically aimed to investigate the germination and growth processes of different plants within hydroponic systems. A key highlight of hydroponic systems is their capacity to conserve water and enhance yield per unit area, surpassing traditional farming techniques. As advancements in hydroponic research continue, these systems are poised to play a pivotal role in refining other cultivation methods, ultimately contributing to global food sustainability. Furthermore, our findings underscore the potential benefits of hydroponic farming for rural farmers. The advantages include cost-effectiveness, the absence of soil requirements, year-round cultivation possibilities, and the elimination of the need for herbicides and insecticides. This indicates a promising avenue for improving agricultural practices and addressing food security challenges in rural areas.

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