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Use of Aeroponics Technique for Potato (Solanum Tuberosum) Mini Tubers Production in India: A Review

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Abstract- Potato, also known as Solanum tuberosum L., ranks as the third most vital food crop worldwide and is essential for food security, especially in developing countries. Potatoes grow from tubers instead of seeds like cereals, making them susceptible to seed-borne diseases that lower seed quality and decrease yields in the long run. India, a leading potato-producing nation, is facing a major challenge due to a significant lack of high-quality seed tubers, as only 20-25% of the required amount is being met by state and central agencies. Identified as promising solutions to address this problem are advanced methods of multiplication such as micropropagation, hydroponics, and aeroponics. These technologies make the production of disease-free Mini tubers faster and more efficient. Aeroponics, a method of growing plants without soil using mist, has demonstrated significant potential for producing seed potatoes on a large scale. Derived from research conducted in the early 1900s, aeroponics has advanced to increase crop yields, reduce disease risks, and improve production efficiency. Small tubers created using this method, varying from 5 to 25 mm in size, are grown in controlled settings such as greenhouses and growth chambers. Aeroponics provides several benefits, including enhanced water usage, quicker growth, increased harvest, and decreased reliance on pesticides and herbicides. Nevertheless, it also poses difficulties such as expensive initial costs, the requirement for specific expertise, and accurate management of nutrients. By making advances in temperature, nutrition, and light management, aeroponics presents a hopeful remedy for the lack of seed potatoes and a means to enhance worldwide potato yield.

Index Terms- Aeroponics, potato tuber, water, nutrients, production

I. INTRODUCTION

Potato (Solanum tuberosum L.) plays a significant role in worldwide agriculture, being the third most crucial food crop following rice and wheat. The significance of potatoes in ensuring global food security is emphasized by their efficient productivity and diverse uses as a food staple. Potatoes are extensively grown and eaten globally, especially in developing countries, where they are a primary food source for millions of individuals.

Unlike rice and wheat, which are spread through seeds, potatoes are spread through tubers. This means new plants grow from existing plants' tubers instead of seeds. This way of spreading has some drawbacks, with the main one being the vulnerability to diseases carried by seeds. Over time, these illnesses build up, leading to a decline in the quality of seeds as each new generation passes (Buckseth et al. 2016, Singh et al. 2016). When the seed quality deteriorates, the potential crop yield of potatoes diminishes, which poses a challenge for farmers in obtaining high yields from aged or diseased tubers.
In India, known as one of the leading potato producers worldwide, farmers face a major hurdle in accessing top-notch seed tubers. In many areas, the low potato yields are a result of using seeds of inferior quality. This issue is aggravated by multiple factors such as inadequate seed storage, high disease rates, and subpar propagation methods. At present, the combined seed agencies at state and central levels are only able to fulfill 20-25% of the total need for top-grade seed potatoes, indicating a significant unmet demand. The lack of high-quality seed is a significant hindrance in the potato production process.

In order to fill this significant void, specialists have recognized the necessity for widespread implementation of fast multiplication methods. Methods such as micropropagation, hydroponics, and aeroponics have great opportunities for commercial use as they allow for quick multiplication of disease-free plants in a controlled environment without soil. These advanced technologies are capable of assisting in:

Generate healthy seed potatoes in a more effective manner.
Reduce the time needed to produce large amounts of disease-free plant material.

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Using controlled laboratory conditions enables the mass production of disease-free plantlets through micropropagation, which can later be moved to hydroponic or aeroponic systems for continued development. These methods of cultivating without soil have the benefit of lowering the chance of soil-borne diseases and pests. Plants in these systems get their nutrients from water (hydroponics) or nutrient-rich mist (aeroponics), leading to quicker growth and increased yields of mini tubers - small seed tubers for the next crop.

New methods have been developed to create small seed potatoes from healthy, lab-grown plantlets, enabling the increase of seed potato production to meet the increasing need for top-quality seeds (Buckseth et al. 2016). With the increasing adoption of these methods, they present a hopeful answer to the issue of seed scarcity, enhancing the efficiency and financial success of potato cultivation in India and other regions.

II. HISTORY OF AEROPONICS USE

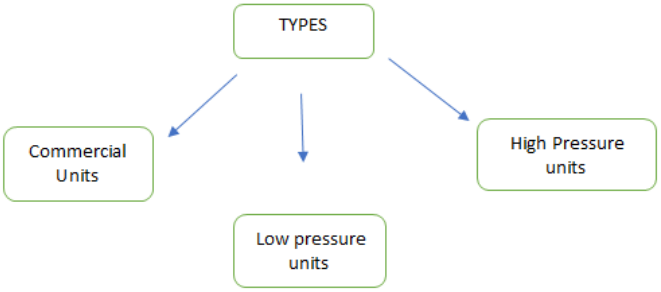
In the 1920s, scientists in the field of botany were the first to develop techniques for cultivating plants without soil, experimenting with primitive versions of aeroponics to study the root systems of plants. These first tests laid the groundwork for upcoming research on root physiology and plant development (Barker, 1922). In the early 1940s, the main use of air culture technology was for research purposes instead of being a practical approach for growing crops. Carter (1942) was among the pioneers in researching this technology, outlining a technique for cultivating plants in water vapor to make root observation easier. In 1957, fifteen years after, Went officially introduced the term "aeroponics" to describe the air-growing method used in spray culture, further improving the technique. Aeroponics started becoming popular in commercial settings in the 1990s.

In Korea, Kang et al. (1996) and Kim et al. (1999) made significant advancements in using the aeroponic system to produce potato seed tubers. Ritter et al. (2001) showed that aeroponic cultivation can greatly improve mini tuber yields in potato production in temperate conditions. In 2006, Farran and Mingo made additional progress by obtaining 800 tubers per square meter with 60 plants per square meter, through weekly harvests over five months.

This led to a ratio of 1:13 being achieved. Additionally, it was discovered that tubers grown using aeroponics exhibited field performance similar to those cultivated in conventional pots. At the CIP in Peru, Otazu (2010) stated that aeroponic systems yielded more than 100 tuber lets per plant. Aeroponics technology is presently being assessed in multiple African nations as a potential answer for growing potatoes (Lung'aho et al., 2010).

III. PRINCIPAL OF AEROPONICS

Aeroponics involves growing plants without soil or any other growing medium, using only an air or mist environment. In essence, the whole plant, roots included, is hanging in the air. The word "aeroponics" comes from two Latin words: "aero," which means air, and "ponos," which means work. In aeroponic cultivation, plants are suspended in a closed or partially enclosed space, with their roots and lower stems being sprayed with a nutrient-rich solution. Plant upper extremities, like leaves and crowns (also known as canopies), extend vertically, while structural components provide support for plant roots. Compressed closed-cell foam is commonly inserted around the lower stem and into the aeroponic chamber opening to decrease labor and expenses. Trellises are utilized to provide support for the weight of the foliage and fruit in taller plants. In an ideal scenario, plants can thrive faster and healthier in an environment free from pests and diseases, in comparison to those grown in soil or other mediums. Nevertheless, the majority of aeroponic systems are not completely isolated from external elements, so pests and diseases remain a potential threat. A regulated setting enhances plant growth, health, flowering, and fruiting in different species and types. Because the root system is fragile, aeroponics is frequently combined with traditional hydroponics as a safety net, offering water and nutrient assistance in case of system malfunction. High-pressure aeroponics involves supplying nutrients to plant roots through a fine mist, usually between 20-50 microns, at a high pressure of around 80 psi (550 kPa).



Process

IV. AEROPONICS SYSTEM FOR POTATO MINITUBER PRODUCTION

1. The Polyhouse Facility

In aeroponics, it is essential to maximize the height of the screenhouse as both the root system and foliage tend to grow longer than when plants are grown in pots (Otazu, 2010). In KARI's aeroponics unit in Tigoni, potato plants have grown to heights ranging from 110 to 140 cm. Smaller greenhouses have a tendency to experience higher temperatures. Asbestos sheets are used to cover the screenhouse to prevent dust and fungal spores, while a shading net is installed on the roof to

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lower the internal temperature. To avoid insects from getting inside, the roof and doors have good seals, while fine netting is used on the sides to keep insects away.

Fig 1: Top view of greenhouse facility

2. Cultivation Chambers

The growth containers are placed within the screenhouse, and their dimensions are based on the screenhouse's limit and the quantity of Mini tubers required. Boxes measuring 60 × 45 × 85 cm deep are utilized at KARI-Tigoni. These growth chambers, also known as boxes, consist of a steel bar frame, with Styrofoam used for the lids, sides, and bottoms. The detachable covers feature holes with a diameter of 2 cm, placed at 10 × 10 cm intervals, for inserting short ½-inch diameter Perspex pipes to support the plants. The boxes' sides can be adjusted to easily monitor and harvest the root system as needed. At the bottom, the compartments have drainage pipes that are slanted to enable the nutrient solution to return to a tank. The tank is positioned below ground level to keep temperatures lower and guarantee a steady flow of nutrients.

Fig 2: Potato plants grown in an aeroponics system (upper compartment)

Fig 3: Lower compartment with roots and fog nozzles

3. Temperature Control

In Otazu's (2010) study, it is emphasized that precise regulation of the temperature within the aeroponic unit is crucial, achieved by using a shade net to cover the roof and manage the internal temperature. The daytime temperature shouldn't go over 30°C or drop below 4°C. The best temperature for tuber formation is between 10 and 15°C at night and around 20°C during the day. Temperatures at KARI-Tigoni are controlled using a shade net, maintaining them at 18-23°C during the day and 14-15°C at night. Temperature: the daytime range should be 18 to 20°C, while at nighttime it should be 14 to 15°C (Otazu, 2010).

Fig 4: Greenhouse control panels

4. Nutrient Regulation

Farran and Mingo (2006) suggest using the nutrient solution with the following concentrations for optimal Mini tuber

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yields: KNO3 (0.4 me/l) , Ca(NO3)2 (3.1 me/l) , NH4NO3 (4.4 me/l), and MgSO4 (1.5 me/l) , maintaining a pH of 5.7.

Table 1: Composition of 500 L nutrient solution for seed potato production

Nutrient	Quantity
KNO3	252g
Ca (NO3)2	118g
KH2PO4	68g
MgSO4	24g
Fe (EDTA) Fe 6%	9g
Micro (fetrilon)	12
pH	5.7

Fig 5: Misters used for nutrient application

5. Plant Growth Management

Following the insertion of the plants into the Perspex pipes, a small piece of slender sponge is wound around the base of the plant to fully close the opening and maintain the plant in an upright position. Next, the sponge is wrapped in black polythene and held in place with masking tape to keep the inside of the boxes dark. The absence of light is necessary for the formation of tubers, as exposure to light will cause stolons to transform into leaves. After six weeks, the bottom foliage is pruned, and the plant is carefully guided down into the container to promote more stolon growth. Sanitation precautions such as using disinfectant on hands, soaking shoes in a footbath, and sterilizing equipment with common disinfectants are important to avoid spreading diseases when caring for the crop.

6. Size Range of Mini Tubers

Mini tuber size can range from 5-25 mm, with bigger mini tubers increasingly prevalent in contemporary setups. This weight range corresponds to a size range of 0.1 to 10 grams or beyond (Struik, 2007). The difference between micro tubers and mini tubers is not just their size, but also how they are produced. Micro tubers are produced in a controlled environment from plants that have been micro propagated, whereas Mini tubers are cultivated in a natural environment from plants that have been micro propagated or from micro tubers in controlled environments such as greenhouses or screen houses (Ahloowalia, 1994). Certain big micro tubers can be as big or even bigger than smaller mini tubers.

7. Harvesting and Storage of Mini Tubers

After two weeks of transplantation, early-maturing potato varieties start to develop small tubers. Mini tuber harvesting commences once they have reached a minimum weight of 8 grams, equivalent to approximately 0.5 cm in diameter. It is better to gather crops during the cooler morning time (Otazu, 2010). In the initial harvest, mini tubers over 1.5 cm in diameter are eliminated to promote more tuber formation. Harvesting takes place every 10 to 14 days after the initial harvest, until the plants reach approximately six months of age. Following the harvest, the small potatoes need to be allowed to dry for a period of two weeks before being stored in a cold environment, as they take in a large amount of moisture while growing and could decay if stored right away.

8. Benefits of Aeroponics

Aeroponics is an advanced technology that is very effective for cultivating plants on a large scale, especially beneficial for growing young trees using soil microorganisms like AM fungi to restore damaged land in humid regions. Perfect for areas with poor soil, this indoor gardening technique is highly water-efficient, requiring only 2% of the water used by other systems. It cuts down on fertilizer usage by 60% and completely removes the necessity for pesticides and herbicides (Stoner 1983; NASA 2006). Aeroponics can boost plant yields by 45% to 75% when compared to hydroponic or conventional soil-based methods. Nutrient solutions can be reused, increasing the efficiency of the system. Moreover, aeroponics promotes vertical farming by maximizing space utilization and increasing crop production. The system enables several harvests of perennial crops and speeds up the cultivation process by promoting quicker plant growth and maturation. Fully grown plants can be taken out without

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causing any disturbance to neighboring plants, and the sterile root environment without soil lessens the chance of spreading diseases. Plants thrive with a full supply of carbon dioxide and oxygen, which helps them grow more quickly and develop roots in a shorter amount of time. Aeroponics allows for cultivation throughout the year due to its independence from weather conditions. In general, this technology is eco-friendly, cost-effective, and a hopeful answer for sustainable farming.

Challenges of Aeroponics

Aeroponics may result in high costs when utilized for large-scale production, despite its high efficiency. The grower needs to have a certain level of skill in order to function efficiently, since accurate management of nutrient delivery is essential. Lack of a stable growth substrate to soak up extra nutrients can cause the death of plants with even a slight excess supply. Moreover, the system depends on costly materials and sophisticated equipment, including high-pressure pumps, atomizing nozzles, EC and pH monitors, and sensors for temperature, light, and humidity. Timers are required to guarantee the system functions effectively, which increases both complexity and cost.

Key Elements Affecting Aeroponic Mini Tuber Growth

- **Temperature:** The optimal temperature should be maintained at 18 to 20°C during the day and 14 to 15°C at night (Otazu, 2010).
- **Nutrition:** Calcium is essential for the development of stolon tips and promoting tuber initiation (Balamani et al., 1986). Excess nitrogen supply can lead to excessive vegetative growth and delayed tuberization
- **Mechanical Stress:** aeroponic cultures thrive better when roots grow in air without any mechanical obstructions.
- **Light:** Tuber formation requires absolute darkness with minimal light penetration, as light can cause stolon to develop into new stems.
- **Lowering of Plants:** Hand-pulling the plants down after each harvest is important to enhance the formation of new stolon with tubers
- **Harvesting:** Frequent harvesting boosts overall yield, particularly the number of tubers. This is likely because removing larger dominant tubers encourages the initiation of new tubers.

V. CONCLUSION

Aeroponics provides a highly efficient answer to the issues related to growing potato mini tubers, particularly in regions with low soil quality or limited availability of high-quality seed tubers. This new technology allows for effective and disease-free growing of potato crops, offering several benefits compared to traditional soil-based methods, such as higher yields, quicker growth, and improved use of water and nutrients. Moreover, aeroponics reduces the chance of soil-borne diseases and enhances plant health, resulting in the generation of ample amounts of superior mini tubers crucial for satisfying the growing need for potato seed. Despite the advantages, the widespread use of aeroponics in businesses is hindered by obstacles like expensive starting costs and the need for expertise in managing nutrient solutions and environmental factors. Despite continuous advancements and innovations, aeroponics has the ability to revolutionize potato farming in countries like India, where the lack of quality seed tubers is a major obstacle. Aeroponics can greatly increase potato productivity and improve global food security by quickly producing disease-free mini tubers.

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