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Innovative potato production technology and its influence on quality of tubers

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Abstract: The objective of the paper was to compare the technologies, techniques of reproduction and their use in seed production of potatoes. The paper describes the use of the most important achievements of biotechnology, advanced breeding methods and emerging technologies for solving practical problems in potato cultivation and increasing their resistance to diseases and improving their quality. The most important, safe techniques for the propagation of potato propagating material is in vitro micro-propagation. Among alternatives to conventional propagated potatoes, the Micropropagation, through the aeroponic system (soilless cultivation in the air) is a prospective method of potato cultivation in terms of food safety and sustainability, as the cultivation of plants happens in the air, without any substrate. The nutrient solution is injected into the root zone at short intervals. The biggest advantages are higher yield with optimal quality, reduced consumption of water and nutrients, operation in a closed system and safety for the environment. Thus, an effective method of cooling the root zone and improving plant growth at higher temperatures under glass, signifies advantages making it widely be used in agricultural practice and in the micro-tubers production, offering a high reproductive rate as the tuber harvesting is possible for several times during the growing season and pathogen-free propagation material. The emerging technology enabled methods enable the production of seed potatoes in areas unsuitable for agriculture, unfavourable climatic conditions, or tropics, and allows for considerable water savings.

Keywords: Aeroponics, Agriculture, Hydroponics, Innovative technologies, Micro-propagation, Propagation material

Introduction

The potato (*Solanum tuberosum* L.) is a significant cultivation as farm production in everywhere globally. This species is developed in 180 countries around the world. As per the FAO data (FAO 2019), potatoes are harvested predominantly in Asia, followed by Europe, and America. The prime potato producers in Europe are Ukraine, followed by Poland, Germany, Belarus, Netherlands, Romania, and France. Potatoes are a good source of fiber, which assists in weight loss, prevents heart disease, keeps cholesterol and blood sugar levels in check, and is full of antioxidants to protect against diseases and vitamins that help our body function properly (Sawicka & Diallo, 1997; Sawicka, 2004; Badoni & Chauhan, 2010, Sekrecka & Michałowska, 2013). The potato is the world's most important non-grain edible crop, preceded only by rice, wheat and corn (FAO 2019). It belongs to the family *Solanaceae* and the genus *Solanum*, which includes about 2,000 species, 235 of which are bulbous species. The potato (*Solanum tuberosum* L.), widely cultivated all over the world, is tetraploid and has two subspecies, i.e. ssp. *tuberosum*, adapted

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to long days and ssp. *andigena* adapted to short days. Potato breeding is a burdensome task due to biotic factors, mainly cytoplasmic sterility of the cell nucleus, tetrasomic inheritance and inbreeding depression. In tropical and subtropical countries, the improvement of potato varieties is faced with numerous challenges as European varieties are adapted to long day conditions and their reproduction in tropical conditions leads to rapid degeneration and progressive accumulation of viral diseases, resulting in a decline in yields. In addition to this, limitations on tuber storage and use in hot and humid Indian conditions were other bottlenecks. Over the past seventy years, ICAR-CPRI (India) has developed and introduced to cultivation over 70 improved varieties and one TPS population, meeting the needs of farmers in subtropical and tropical countries. First of all, the immune requirements to various biotic and abiotic stresses. In order to shorten the development time of a potato variety, knowledge of new generation breeding is needed (Luthra, Gupta, Tiwari, Kumar, Bhardwaj, Sood, Dalamu, Kaur, Raj Kumar, Vanishree, Mhatre & Chakrabarti. 2020).

Potato Market across the globe is segmented by Geographies and is projected to record a CAGR of 1.0% forecasted over 2021-2026. Even in traditionally non-potato-consuming countries, they are popular due to their long shelf-life, further the processed food industry, have a bulk demand for potato consumption, which has skyrocketed globally. The consumption has shifted from fresh potatoes to value-added, processed food products, including frozen potatoes for French fries and dehydrated potato flakes mashed as ingredients in the snacks, and distributed food aid. Potatoes have been one of the best inexpensive foods even during the pandemic (Mordor, 2020). Demand for potato has been rising during the pandemic as it can be stored longer than other vegetables (Sutanuka, 2020). Large producers get high profits as they are able to take potatoes to the large markets in urban areas where there is more demand for potatoes and could sell at high prices. The price is influenced at the farm level depending on the demand, urban consumers consume the crop in the form of chips and crisps. The potato market can be classified as seed potato, edible potatoes, starch potatoes and for food processing (for French fries, crisps, frozen, dried products and many more) (Godfrey, Mwajkaje & Agnes, 2012).

The potato is one of the few cultivated species considered to be "life support" for space travel. Advanced scientific research indicates that, as needed, the potato can provide food and oxygen to people living on other planets (Wheeler 2006, Gupta 2017). Potato tubers are also used for vegetative reproduction. They are a special seed material that is much less durable than the seeds. However, vegetatively propagated plants are susceptible to diseases caused by viruses, viroid’s, bacteria, fungi, and nematodes. All these pathogens accumulate in the soil and in subsequent generations of plants, and therefore tubers can transmit and accumulate soil-borne diseases (Struik and Wiersema, 1999, Hajare, Chauhan, and Kassa, 2021). The high quality of the seed material plays an essential role in the potato production and supply chain. Controlled reproduction of tubers in the breeding- and seed potatoes farms as well as the application of national and EU legislation and international standards characterizing the formal system favor the production of certified seed potatoes (Striuk, Wiersema 1999; Hirpa, Meuwissen, Tesfaye, Lommen, Lansink, Tsegaye and Struik, 2010, Sekrecka & Michałowska 2014). However, their cost for end users is one of the main economic problems in the formal systems of many countries around the world. Such seed potato material may constitute from 30 to 70% of the total cost of commercial production (Mateus-Rodriguez, Haan de, Andrade Piedra, Maldonado, Hareau, Barker, Chuquillanqui, Otazu, Frisancho, Bastos, Pereira, Medeiros, Montesdeoca & Benitez, 2013).

Owing to the advanced adaptation of the viral diseases through the propagation material, the access to better quality seed potatoes is the main limitation in potato growing. In addition to the higher expenses incurred on seed potatoes, propagation is very low paced in reproduction, theoretically 10 times, and practically only 4-6 times (Roca, Espinoza, Roca, & Bryan 1978; Sekrecka & Michałowska, 2014; King, 2019, Hajare et al., 2021). The shortage of good quality propagating material was considered to be the most important reason for restraining production of potatoes, especially in countries which are economically emerging. The potato, however, was an early beneficiary of advances in seed production, both in conventional and modern biotechnology, which resulted in the use of biotechnology and advanced breeding methods to solve practical problems in growing and increasing their disease resistance and quality improvement. Meristem cultures were biotechnologically carried out initially to eradicate infection of viruses on a continuous basis from the clones of potatoes. Later, this method was joined along with micro-propagation to obtain uninfected seed potatoes. Quick propagation of uninfected clones through micro-propagation in combination with traditional propagation means has already developed as an essential part of seed generation in many places such as Europe, Asia, and America (Hussey & Stacey 1981; Danielle & Colleman, 2001; Donnelly, Coleman, Coleman, 2003; Coleman, Hajare et al., 2021).

The orthodox approach to potato multiplication contains replantation of it from the earlier harvest (Fairbanks, 2014, Sekrecka & Michałowska 2014, Mohapatra & Batra, 2017; Michałowska, Przewodowska, Piskorz & Olejnik 2019). The constant tuber salvaging controls promptly the diseases that are tuber-borne and a low multiplication rate. It requires replanting the seed tubers in many cycles before getting enough, in a large area of land specifically allotted to cultivate potatoes. These bottlenecks are overcome by speedy multiplication methods such as Micropropagation, Hydroponics and Aeroponics (), Shimeli & Melis 2013). The potato is the best crop, globally carrying on the to tackle food security, revenue generation and poverty reduction. Hence, the aim of this review was to present the latest technologies and techniques for potato multiplication in order to be able to provide better food security in the world, especially in developing countries (Gupta 2017). This paper uses standard deviation approach to analyze the volatility of returns of BIMB within the periods of 2010 till 2016. The main reason to evaluate the performance of BIMB is because BIMB is the first Islamic bank established in Malaysia. Besides that, BIMB is the first full-fledged Islamic banking system used a sharia contract such as *mudhrabah*, *musharakah*, *ijarah* and etc. (Luthra et al., 2020).

Methodology

Database. The following databases were used: AGRICOLA (EBSCO), CAB Abstracts, CAB eBooks; CSIRO Publishing Journals; Current Contents Connect (ISI), FSTA - Food Science and Technology Abstracts (EBSCO), GeoRef (ProQuest), GreenFILE (EBSCO) have been searched using key terms such as: 'aeroponic technologies', 'hydroponic technologies' 'food safety', "innovative technologies", "micro-propagation", "propagation material", "micro-propagation techniques", "plant health".

Admission Criteria. Scientific research (in vitro and in vivo) with the use of field and laboratory tests has shown that innovative technologies have been analysed in the potato cultivation technique, which have an impact on the health of plants and their resistance to abiotic and biotic factors. Works not only in English but also in other languages were taken into account in order not to limit the scope of the work. In addition, a manual database search was performed to locate previous articles based on references to already published systematic review articles.

Exclusion criteria. Studies involving species other than potato were excluded. Moreover, presentations, letters to the editor, unpublished materials and theses were excluded. Search results were limited to original scientific articles published between 1962 and 2021. Duplicate articles from different databases were searched and only one was kept.

Result and discussion

Micropropagation

Milestones in the development of plant breeding and biotechnology

Lack of knowledge about the optimal properties of certified material, the use of improved technologies and practices make it difficult to apply new technologies in the production of seed potatoes (Islam & Chowdhury 1998; Kaguongo, Gildemacher, Demo, Wagoire, Kinyae, Andrade, Forbes, Fuglie and Thiele, 2008, Hirpa et al., 2010, Gudeva, Mitrev, Fidanka and Mite 2012, King et. al., 2019). However, research is continuing to improve the various steps in the formal system for the production of healthy seed.

The most important milestones in breeding and biotechnology:

- In 1778 in England, mass occurrence of diseases on potato plants was recorded. In the same year, the Manchester Agricultural Society announced a competition to investigate the causes of potato diseases and provide methods of combating them. Demonstrating that the cause of potato degeneration is the spread of viral diseases was not easy and has been the subject of many scientific papers.
- 1878 Marshall portrayed degeneration as the aging process of vegetatively reproduced varieties. The theory linked degeneration with the influence of environmental conditions and persisted for quite a long time, until the present century.
- 1918 – Quanjer in the Netherlands proved the viral nature of potato degeneration.
- 1938 – Maguro used the in vitro micropropagation technique to study the tuberization process of potatoes.

- 1940 – Ball – obtaining the differentiating cells in the tissues and then the first whole plant from a fragment of a shoot; Skoog and Tsui – the role of auxins and cytokinin's in the differentiation of plant tissues and organs.
- 1949 – Limasset and Cornuet showed that the young organs of a potato contain very little or no virus. However, they were unable to demonstrate or challenge the presence of these viruses in meristems by local damage method. This discovery allowed the possibility of freeing potato plants from viruses by micropropagation.
- 1950 – practical significance. Obtaining a virus-free plant and mastering the plant cloning technique by meristem cultures; Whole plant regeneration from cell; somatic embryos in suspension and callus cultures (Steward and Reinert) (Wang & Hu, 1982).
- 1955 – Morel and Martin demonstrated the possibility of regeneration of potato clones (*Solanum tuberosum* L.) attacked by viral diseases by in vitro micro-propagation.
- 1960 – development of the principles of micro-propagation; development of a universal MS medium (Murashige & Skoog, 1962).
- 1970 – Power et al. – Protoplast fusion; Carlsson - in vitro selection of tobacco biochemical mutants; Nagata, Takebe – Regeneration of tobacco plants from protoplasts; Carlson – the first interspecies fusion; Seibert - Induction of daughter shoots from cryopreserved growth tips.
- 1980 – Flores – establishment of the hair root culture; Neuehaus - Automation of mass production of plants with the use of embryo and organogenesis (Roca et al., 1978, Hussey & Stacey, 1981).
- 1990 – successful cryopreservation of cell cultures (Smith & Drew, 1990; Warren 1991; Gupta, 2017).

The next stage, important for the release of potato plants from viruses, was the combination of thermotherapy with the in vitro method and the size of initiation of growth meristems (Gudeva et al., 2012; Sekrecka & Michałowska, 2014; Michałowska et al., 2019). The achievements of biotechnology allow increasing the amount of high-quality material produced from disease-free seedlings in vitro, shortens the production pattern in the seed, which in the case of potatoes is one of the longest among arable crops (Banadysev, 2012; King et al. 2019). The aim of this biotechnology work is to improve the vigor and quality of seed potatoes. This, in turn, improves production efficiency and increases yields. The innovative production of seed potatoes uses modern biotechnological techniques and usually consists of three stages:

The first stage, i.e., micro-propagation, is based on the method of single-node shoots, which mainly uses stimulation for the development of side buds (Michałowska et al. 2019). In the second stage, minitubers are produced from in vitro seedlings obtained in sterile laboratory conditions or from microtubers. After the dormancy period follow the third stage, which consists in their reproduction of minitubers in the field for three generations to produce a sufficiently large amount of base material, which is the basis for the production of certified seed potatoes, sold to farmers for use in the commercial production (Mbiyu, Muthoni, Kabira, Elmar, Muchira, Pwaipwai, Ngaruiya, Otieno & Onditi, 2012; Kabira, Elmar, Muchira, Pwaipwai, Ngaruiya, Otieno & Onditi, 2012; Michałowska et al., 2019, King et al., 2019). The main goal, for biotechnologists, is conducting sprout cultures and nodal segment cultures as primary explants in the selected potato cultivars. The growth of explants, the individual stages of organogenesis of explants on various hormonal media, and the possibility of microtubers are important in this process (Gudeva et al. 2012, King et al. 2019).

Generalizing the achievements of biotechnology, they allow to increase the amount of high-quality material produced from disease-free seedlings in vitro. Thanks to this, it is possible to shorten the production pattern of seed material, which in the case of potatoes is one of the longest among arable crops (Banadysev, 2012; Gupta, 2017, Michałowska et al., 2019).

In *vitro* technology

The most economically efficient tissue culture technique is substituted to the traditional method of vegetative dissemination in plants, called micro-propagation. The advantage of micropropagation over traditional approaches, in a relatively short time, produces more plants from one single plant, probably in all seasons (Mohapatra & Batra 2017, Michałowska et al. 2019). This method of reproduction is necessary in the case of potato, which is a vastly heterozygous class, in order to obtain homogeneous plants (Roca et al. 1978). Potatoes are swiftly multiplied large scale through meristem, apical cultures, angular shoots grown from nodal cuttings grown *in vitro* (Lutaladio et al.

2009, Kakuhenzire, Tibanyendera, Night Kashaija, Lemaga, Kimoone, Kesiime, Otazu, Ortiz and Barker 2017, Lakhiar et al. 2018), and by producing adventitious shoots straight on the explants or secondarily through the callus phase. These developments are projected during the second start of agriculture process which is probably towards productivity development, profit generations, and eco-friendly safe (Roca et al., 1978; Xuan, Debasis, Eun & Kee, 2003; Bandysev 2012; Mohaatra & Batra, 2017; Michałowska et al., 2019).

The process of potato tuberization is composite, and facilitated in vitro, by their reduced size and weight. The microtube's possess enormous gains through storage, transport, and cultivation practices. They are sown in the soil and can be grown in bulk all the year. They are classified by features such as morphological and biochemical, compared with other tuber producers, as the potato micro tubers have revolutionized the world potato production (Bandysev, 2012; Mohaatra & Batra, 2017, Michałowska et al. 2019). Various growth regulators have been used to induce potato microtubers in vitro (Donnelly et al., 2003, Hossain, 2005, Farran & Mingo-Castel 2006, El-Sawy, Bekheet and Aly, 2007, Hirpa et al., 2010; Rykaczewska, 2016; Michałowska et al., 2019). Physiological Research showed that in vitro tuberization is a precise approach with many factors such as: hormone blend, photoperiod, nutrient composition, and many more (Kanwal, Amina & Shoaib, 2007; King, 2019).` *In vitro* technology has been used in many countries for production of propagating material free from potato diseases (Lutaladio et al. 2009, Mbiyu et al., 2012). Currently, the microtubers potato mass multiplication protocol is automated using a bioreactor system (Xuan et al., 2003; Michałowska et al., 2019). Tissue culture methods produce viral-free sample microtubers as seed potatoes, that are sown in safe production ecosystems for the minitubers (basic seed) cultivation. Basic or sample seeds pass into production phase to link the chain for certified seed intended for direct sale to farmers. An important goal for seed production is to standardize the nutrients for the growth of potato plants and the induction of microtubers.

It is also called tissue culture, where the plant cells from the mother plant are made to grow on an artificial media, enabled by growth media which are solid, liquid, or semi-solid, in disinfected containers or tubes. This is flexible and has a great growth rate. Meristem culture is the most commonly used, where the axillary or apical rising top portions (0.1 to 0.3 mm) is divided and grows into sprouts on simulated in a meticulously conditioned nutrient locations, eliminating viruses in the planting material. The chromosome multiplication and more auxin concentration in the meristematic tissue will obstruct the virus proliferation through intervention by nucleic acid absorption and, there occurs disabling activity pushes the apical region activity to some other position. Tissue culture is not limited by time period, or weather as they can be cultivated on a laboratory scale at all times of the year. Yet, this technology has high operational costs and requires specialized equipment, various nutrients, supporting energy sources, nurturing vitamins, expensive as media formulation requires specific growth regulators, and require specialized skills and knowledge acquired through formal training, and high care or hygiene as inadequacy of equipment sterilization would contaminate leading to complete loss of planting materials (Mbiyu et al., 2012). *In vitro* proliferation approaches using plantlets and seedling knots are consistent in keeping the genetics and veracity of the replicated clones. The first generation potato microtubers tissue culture seeds can address the glitches of resettling seedlings from in vitro to *in vivo*. Due to their lesser sized and lighter microtubers weight, with greater advantages during packing, transport, and cultivation mechanization. Potato seeding's are planted in the soil in a greenhouse, in foil tunnels and produced at any time of the year. They have a common features in morphology and biochemical to old-style potato tubers. The cultivation of microtubers in vitro is key for the production and stowing of valued potato varieties (Michałowska et al., 2019).

The microtubers of Potato acquired in vitro culture from the cutting of single-node are very suitable for storing and replacing fit germplasm. Initial explants with nodal segments, have developed efficiency with respect to the tuber plantlets (Gudeva et al., 2012) the best results were obtained with the composition of MS medium (Marushige & Skoog, 1962) with cytokinin and auxin, particularly MS + 2 mg dm^{-3} BAP + 1 mg / l NAA, in case of the cultivars (Agrija) created 13% more microtubers than the others. More sucrose applications can induce signals that lead to amassing of starch, and to grow the presence of microtubers, the sucrose absorption goes high (Hajare et al., 2021) shows the application of plant tissue growth using side buds as plantlets for in vitro micro-propagation of potato. The shoots they initiated grew two to three times after transplantation on MS medium supplemented with various absorptions of BAP and Kinetin. The greater number of multiple sprouts was gained on MS medium having 2.5 mg dm^{-3} of kinetin. However, the shared action of BAP and Kinetin ensured not show several further positive outcomes on sprout proliferation in these studies. The highest percentage of rooting and the highest number of roots / shoots were established on MS medium supplemented with 1.0 mg dm^{-3} IBA + 0.5 IAA (Figure 1).

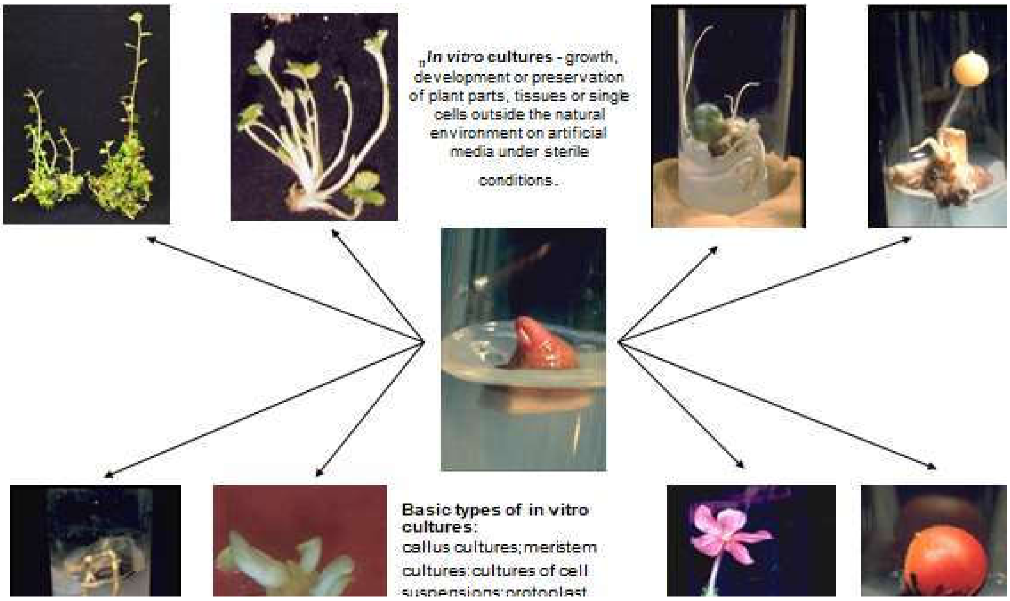

Figure 1: In vitro cultures - growth development, preservation of plant parts and basic types of *in vitro* cultures

Potato micropropagation is understood as a set of methods of vegetative multiplication with the use of in vitro tissue cultures used on a production scale. The task of micro-propagation (*in vitro* cultures) is primarily to improve plant health. In vitro micropropagation and the production of mini-tubers on a larger scale were already dealt with in the world in the 1950s. (Wang & Hu, 1982; Simko, 1993, Khan, Hoque, Sarker & Muhlbach, 2003; Kanwal, Amina & Shoaib, 2006; Badoni & Chauhan, 2009; Sekrecka & Michałowska, 2013; Hajare et al., 2021).

The microtubers are obtained by an in vitro microtuberization process. They are generally very small, their caliber does not exceed 10 mm, and have an average weight of 0.7 g (Diallo 1997; Striuk & Wiersema 1999). For the production of microtubers, single-node in vitro plant fragments are used, which are exposed to chemical and physical factors that induce tuberization. The microtubers multiplication factor is relatively low (Sekrecka & Michałowska, 2014). The main advantage of this method is the production of tubers in a controlled, closed environment, regardless of the season. An additional advantage is the relatively low cost, since microtuberization takes place in complete darkness. Factors important in the microtuberization process include, among others sucrose level and presence of growth regulators in the medium, and incubation temperature and light. The energy source for this process is sucrose. The optimal concentration in the medium is 8%. Both lower and higher sucrose concentration may have a negative effect on the number and size of microtubers obtained (Woznicki, Møllerhagen, Heltoft & Kusnierek, 2021). The inclusion of growth hormones to the substrate may stimulate or inhibit tuberization, but it is not necessary for the formation of tubers in the glass (Struik & Wiersema 1999). The microtubers are produced all year round and then planted under cover in temperate climates. Currently, more and more emphasis are placed on the use of non-hormonal micro-reproduction systems. Until now, little attention has been paid to them, probably due to the relatively slow and ineffective growth of explants. The development of a micro-reproduction system without hormones is advisable as such systems allow production without subsequent hormone disrupted problems and may be commercially viable. Production of mini-tubers under covers (greenhouse, foil, or mesh tent), where it is much easier to ensure proper and accelerated plant growth in order to obtain a relatively large number of tubers suitable for field production (Zaklukiewicz & Sekrecka 1994; Sekrecka & Michałowska, 2014). Tubers from the first generation of in vitro plants or microtubers are called minitubers (Hajare et al., 2021).

The starting material is the tested tuber. In vitro plants are derived from apical meristems or tuber sprout sections. Self-feeding plants have a small accumulation of young dome-shaped cells at the ends of each shoot that can divide, which can be used in tissue production and organ differentiation (shoots, leaves, flowers). The Meristem consists of 3 zones with different activities:

- apical, central zone, inactive for flower induction, called the "waiting" meristem.
- annular zone – precursor of the differentiation organ: initial ring.
- sub-terminal, axial zone, related to the merystem (Zaklukiewicz & Sekrecka, 1994; Michałowska et al., 2019).

Meristem cultures are considered to be fragments of the meristem dome of various sizes, ranging from 0.1 mm to 1 cm in length. Most often, however, the size of the apical meristem is defined as <0.1 mm. Meristems are divided into 3 groups:

- without leaf buds (0.1-0.2 mm).
- with seedlings of 2 primary leaves (0.21-0.4 mm).
- with seedlings of 4 primary leaves (0.41-1 mm) (Zaklukiewicz & Sekrecka, 1994; Michałowska et al., 2019; Hajare et al., 2021).

The size of the growth meristems has a great influence on the possibilities of obtaining plants in vitro. The easiest method is to plant the sprouts after disinfecting the dome with leaf buds into nutrient tubes. We call this method "Stem Cutting". The second option of obtaining plants in vitro is more complicated, but gives a sense of security (Figure 2). It requires additional stages of harvesting growth meristems (Badoni & Chauhan, 2009; Cambourios, Zebarth, Ziadi & Perron, 2014).

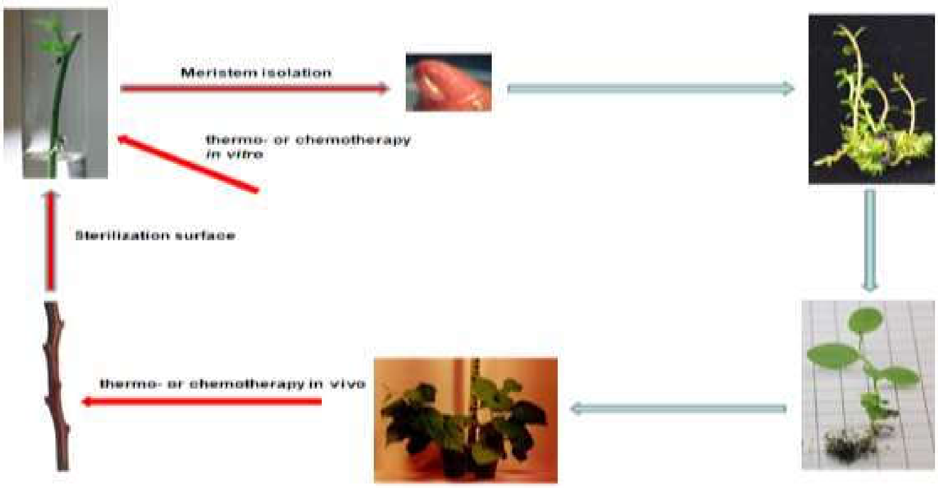

Figure 2: Scheme of realizing plants from endogenous microorganisms

Factors influencing the isolation of growth meristems

The success of obtaining plants from apical meristems in vitro depends on whether or not meristem domes without leaf buds or domes with seedlings of 1-2 pairs of primary leaves are isolated. It is easier to obtain plants from meristems having more leaflets, but harder to obtain virus-free plants from them. Precise cutting of the explants is of great importance - the cut must be on a drop of water and should be quickly placed on the nutrient medium so that the cut surface adheres to the nutrient medium. In the case of too much tearing of the tissue and placing it on the medium too late, oxidation processes take place faster, which leads to the death of the explants. It is very difficult to grow meristem cultures smaller than 0.1 mm (Simko, 1993; Sekrecka & Michałowska, 2014). In vitro plants can be derived from meristems (apical bud) or angular buds. Meristem cultures are carried out when there is no healthy starting material, and it is necessary to free the plants from pathogens. Most often, thermo- or chemotherapy is included in parallel. Using a healthy starting material, whole buds can be isolated by removing only the outermost buds (Badoni & Chauhan, 2010, Sekrecka & Michałowska, 2013; Michałowska et al., 2019).

Factors Affecting Plant Tissue Culture

Growth Media includes minerals, development factors, carbon basis, and hormones. The ecological factors are light, heat, light exposure period, sterility, and the substrate. The explant sources the younger, less differentiated the plantlets for better tissue culture (Badoni & Chauhan 2010, Sekrecka & Michałowska 2013). Genetics differentiate the species in responsiveness to tissue culture. However, in many cases, the diverse genotypes in a species have flexible reactions to tissue culture; somatic embryogenesis relocated between melon cultivars over sexual hybridization (Srivasta et al., 2012, Sekrecka & Michałowska, 2014).

Steps of micropropagation and tissue culture applications micropropagation

There are 4 phases of micro-multiplication:

- Stage 0 – Collection, disinfection of the plant tissue & provisioning of the mother plant.
- Stage I – Beginning of culture – plantlet positioned into growth substrate
- Stage II – Growth – plantlet relocated to shoot media; and constantly divided.
- Stage III – Rooting – plantlet shifted to root substrate.
- Stage IV – Relocation to soil –plantlet into soil; hardened off (Simko 1993, Gudeva et al. 2012).

Ways of preserving the germplasm preservation:

- Soma clonal distinction & mutation range.
- Embryonic culturing.
- Haploid & Diploid Production.
- In vitro hybridization – Protoplast Fusion
- Industrial Cell Culture Products (Al-Gaadi, 2016).

Features of Micropropagation and Potential Uses for Micropropagation in Plant Breeding

Micropropagation in Plant proliferation eradicates virus from sick vegetal assortment. Moreover, via meristem culture otherwise every now and then through thermal actions of cultured matter (or grouping). Preserve a heterozygous plant collection for marker expansion. Through multiple clones, every genotype of a clone be given in to numerous assessments. Crop inbred vegetation for fusion seed invention wherever inherited seed generation is inadequate for conservation of male sterile lines (Al-Gaadi, et al., 2016). Clonal reproduction is a good way of preserving the heterozygosity. Development phase can be recycled for numerous occasions to crop an infinite number of clones: Normally used for economic gains are many ornamental types, in which some are vegetatively proliferated yields. Easy part of this activity is to use construction cycles which are flexible to all field farming periods, and ecological impacts. Disease-free plants can be produced: has been used to eliminate viruses from donor plants (Al-Gaadi et al., 2016; Wasilewska-Nascimento et al., 2019).

Germplasm Preservation, Cryoprotection, Cryopreservation Requirements

They are two methods of germplasm preservation: Slow development method, wherein the temperatures drop, sunlit, and substrate increases the osmotic retarders, growth decelerators, tissue dehydration, medium-term protection for 1 to 4 years; Cryopreservation includes ultra low temperatures, tops cell separation & metabolic methods, on an enduring basis (Wasilewska-Nascimento et al., 2019). Pre-Culturing. Regularly, a speedy development phase generates cells with minor vacuoles and small water mixture with Glycerol, DMSO, PEG, etc., to shelter contrary to ice destruction and modify the arrangement of ice crystals (Gudeva et al., 2012; Mbiyu et al., 2012).

Freezing. The record crucial phase here; includes two types, wherein the slow freezing permitting for cytoplasmic dehydration, while the rapid freezing consequently leads to quick intracellular freezing with little dehydration (Wasilewska-Nascimento et al., 2019).

Cryoprotection requirements are following:

- Stocked frequently in aqueous nitrogen (-196°C) to evade all variations during crystallization of ice crystals that happens more than -100°C.
- Thawing - regularly happened due to rapid warming to escape away from the disturbances in ice crystal growth.
- Recovery (Al-Gaadi et al. 2016).

Thawed cells must be essentially cleaned of from the cryoprotectants then fostered to its usual development. Must be devoid of lump generation to preserve inherited constancy (Warren, 1991; Wasilewska-Nascimento et al., 2019).

Stages of micro-reproduction

Stages of micro-reproduction:

1. Plant micropropagation at the laboratory stage: plant in vitro > plant in vitro (glass).
2. Micro-propagation in the greenhouse – production of mini-tubers: in vitro plant> mini-tubers (soil).
3. Micro propagation in the field: mini-tubers > seed potatoes (soil).

First, healthy plants taken from the in vitro gene bank are passaged several times until the planned number of plants is obtained. Plants are run in test tubes on Murashige-Skoog medium (Marushoge & Skoog 1962, El-Sawy et al. 2007). Transferring in vitro cultures into the field takes place in two ways; by rooting the plantlets. After 2-3 weeks from the last passage, well-rooted plants (in tubes) with 2-3 leaves can be planted under covers, by creating microtubers in the glass (test tubes). They have a diameter of 3-8 mm and a mass of 0.05-0.15 g. Their physiological state is homogeneous (Sekrecka & Michałowska, 2014; Michałowska et al., 2019, Hajare et al., 2021). The rate of in vitro plant preparation is largely dependent on the cultivar multiplication ratio (i.e., the specificity of plant growth in test tubes). This coefficient ranges from 5-15 internodes (stem section with 1 leaf). The substrate for the cultivation of mini-tubers is a mixture of compost soil, peat, and sand. It is more advantageous to plant the plants in vitro to a permanent location. The optimal density is the number of plants · m^2, as this density gives the highest proportion of tubers with a diameter of 1.5 cm. Intensive protection against aphids is carried out throughout the growing season, and in the second cycle, additionally against potato blight. Randomly selected plants are re-checked for viruses and PSTV (tuber spindle) by electrophoresis or c-DNA, and for other viruses by bioassay or ELISA (enzyme immunoassay) or other more sensitive test. This test makes it possible to test very young plants (2-3 weeks old). High sensitivity 1000 times higher than traditional methods and thus better detectability by testing tubers or sprouts. After harvesting, tuber samples are tested for Corynebacterium sepedonicum and viruses (Sekrecka & Michałowska, 2014; Hajare et al., 2021).

One plant in vitro yields 5-24 mini-tubers depending on the planting date, the fertility of the prepared soil, plant density per 1 m2 and, finally, the variety itself (Muthon et al. 2013). Calibration of minitubers: the produced mini-tubers are sorted into 3 groups: diameter> 3 cm, 3-2 cm, <2 cm. All tubers> 2 cm in diameter are transferred to conservation breeding and planted in the field (fig. 3) (El-Sawy et al. 2007, Sekrecka & Michałowska 2014, Michałowska et al. 2019, Wasilewska-Nascimento, Jankowska, Boguszewska-Mańkowska, 2019).

Figure 3: The size of the mini-tubers of 'Owacja' cv. compared to the seed potato

After planting microtubers, e.g., in a greenhouse or a tunnel with an area of gross of 200 m2 is harvested, depending on the variety, from 45 to 90 thousand. mini-tubers, which can then be planted on 0.7-1.3 ha. In the production of one planted microtubers, depending on the variety and planting density, 6 to 12 minitubers are obtained, which are planted in the field as pre-basic material for PB II. The pattern of reproduction is shown in Figure 3 and photos on the third cover page. Each stage of reproduction is subject to health checks, as shown in Figure 3. Microtubers are produced throughout the year and then planted under covers. Conservative breeding of all varieties is currently carried out using this method. At the current level of production, the harvest from the second year of field propagation from an area of about 1 ha is a commercial material (basic and qualified materials depending on the order) (Burski, 2006; Sekrecka & Michałowska, 2014, Al-Gaadi et al., 2016). Microtubers and micro-seedlings are planted under covers and minitubers are obtained from them (Srivastava, Kumar, Joseph, Sharma, Bag and Singh, 2012), which are planted in the field as pre-basic material (PBII). This method has both advantages and disadvantages.

Advantages of micro-reproduction:
Elimination of viral diseases transmitted from tubers.
- Obtaining an increased yield.
- Achieving a higher multiplication factor.
- Reduction of the dependence on the physiological state of the mother tuber.
- Reduction of the number of tests and reduction of the labor intensity of health assessment.
- In vitro plants are a convenient form for the exchange and transport of materials internationally
- flexible response to market needs (Srivastava et al. 2012).
- the possibility of obtaining many plants in a short time. Depending on the rate of plant development, which varies from one variety to another, from one starting plant after 6 consecutive cuts, 730-1,000,000 plants can be obtained.
- independence from the season of the year because all works at the stage of in vitro cultures are carried out in laboratory conditions, and the development of cultures takes place in strictly defined conditions, artificial, imitating natural ones.
- the possibility of creating a healthy collection and maintaining it for a long period of time without the risks that occur in the field.
- in vitro starting material with an appropriate health certificate does not require re-testing.
- after organizing an in vitro collection (plant bank), plants can be reached at any time and propagated regardless of the season (Srivastava et al., 2012; Sekrecka & Michałowska, 2014).

The achievements of biotechnology have therefore allowed to increase the amount of high-quality material produced from disease-free seedlings in vitro, making it possible to shortening the production pattern of seed material, which in potatoes is one of the longest among plants cultivated (Banadysev 2012).

Disadvantages of micro-propagation:
- quite expensive method, requiring the organization of a specialized laboratory in septic conditions,
- in the case of contamination of materials in vitro with fungi and bacteria, the losses are very serious,
- The produced diasporas are small, weak and have a long growing season and a very slow initial growth, there is a risk of spontaneous mutations (Srivastava et al., 2012; Sekrecka & Michałowska, 2014, Michałowska et al., 2019).

The size and quality of the crop is influenced by many factors. First of all, these are: genotype, planting date and density, soil fertility, as well as care and protection measures. In addition to ensuring the appropriate phytosanitary conditions (disinfection of greenhouses, tents, substrate replacement, keeping the premises free of pests (aphids, spider mites and thrips), protection against potato blight, etc.), the production of mini-tubers plays an important role, similarly to field cultivation, the composition of the substrate, its structure, appropriate pH, and richness in nutrients (macro- and microelements). One of the most important factors determining the seed value of minitubers (apart from health) is their size. Numerous studies indicate lower usefulness of the smallest tubers (less than 1 cm in diameter), hence the conditions that ensure the maximum share of larger fractions in the yield, i.e., those with a diameter of more than 1 cm, play a key role in the production. The size of minitubers is significantly influenced by: planting density per area unit and the physiological and chronological age of planted in vitro plants and microtubers. The optimal age for plants planted under covers is approx. 4 weeks; the yield of minitubers is about 50% higher compared to the yield of 2-week-old plants (Diallo, 1997; Burski, 2006; Sekrecka & Michałowska, 2014; Wasilewska-Nascimento et al., 2019).

The use of minitubers in breeding practice

Micro-propagation allows for a great improvement in conservative breeding, e.g., allows you to resign from clone propagation or reduce the scope of tests for health assessment. Minitubers obtained in own laboratories of tissue cultures of breeding units are the starting material for conservative cultivation of potato cultivars (Siewierska, 2011). This healthy propagating material is used primarily for conservative breeding, the aim of which is to maintain genetically fixed traits of a given potato variety (Diallo, 1997). The end product of this reproduction in a 2-3-year cycle are seed potatoes referred to as mother material. By using micro-rotation techniques, it is possible, apart from the guarantee of high healthiness of the material, to quickly, within 2 years, adjust the supply of seed potatoes of a given variety to the changing demand. Prior to planting the minitubers in the field, it is essential to prepare them in advance, i.e., to store them, thoroughly fractionate them and germinate them properly. The influence of the temperature during the storage period on the seed value of minitubers is similar to that in the traditional production of seed potatoes. Higher temperatures accelerate the aging process of minitubers by lowering their development potential. In order to maintain their good seed value, it is necessary to maintain constant, low temperatures. It is especially important when storing tubers from spring harvest for almost 10 months. Mechanized techniques for planting minitubers have already been developed. Regardless of the reproduction scheme, each of the selected fractions of tubers should be planted in a separate "block". In this way, in addition to better leveling of the field, it is possible to carry out additional care and protection treatments for individual batches of material during the vascularization (Sekrecka & Michałowska, 2013, 2014; Gupta 2017; Kamrani, Chegeni & Hosseinniya, 2019).

Hydroponic system

All known technologies for the production of mini-tubers fall into two categories: with and without a substrate. The classic method is the production of mini-tubers in greenhouses, foil or mesh tents on natural soils or soil substrates in vases (Banadyse 2012, Sekrecka & Michałowska 2013). Such a standard method of reproduction in the formal system, carried out in vivo, is a long-term, even more than 10-year, laborious process. When using this method, the multiplication factor is relatively low (Striuk, Wiersema 1999, Hajare et al. 2021), which makes it difficult to meet the demand for high-quality seed potatoes. Otherwise, this method requires sterilization of the substrate, which increases production costs (Hossain, 2005; Otazu, 2010; Mbiyu et al., 2012; Hajare et al., 2021). Due to climate change, Schafleitner, Ramirez, Jarvis, Evers, Gutierrez, De Scurrah, Ramirez, Jarvis, Evers, Gutierrez and De Scurrah (2011) predicted that the greatest losses in land suitability for potato cultivation would occur in southern Africa and the tropical highlands. In addition, India, the second largest potato producer in the world (FAO, 2019), is projected to lose 11% by 2080 (Kumar, Govindakrishnan, Swarooparani, Nitin, Surabhi and Aggarwal, 2014). Therefore, alternative production systems that allow for an increase in global food security in future climate scenarios should be explored by expanding the area under potato cultivation, using areas with inadequate or degraded soils. Hydroponics is soilless a cultivation method in which plants are grown using nutrients. This cultivation system removes dependence on agricultural land and soil, reduces the presence of diseases and can mitigate the negative effects of extreme weather events by using precise dosing of nutrients (fertigation).

Lakhiar et al. (2018) described a type of hydroponic production as a useful system to produce a variety of crops, including potatoes. Hydroponic potato production has also been studied at NASA (2006), Tibbits, Cao, and Wheeler, (1994). Potato in soilless cultivation requires an advanced production setup, which may limit the widespread adoption of this technology. Woznicki et al. (2021) investigated the hydroponic production of potato minitubers on a substrate of: perlite, soil, a combination of perlite and vermiculite; perlite and moss of peat; soil and perlite; perlite-soil-composted cattle manure, and finally perlite-soil-vermicompost. These studies showed that the yield of minitubers was higher on substrates without soil (Kamrani et al., 2019). Rolot and Seutine (1999) concluded that soilless cultivated minitubers produce minitubers of higher caliber and higher average weight compared to soil cultivated minitubers. Hydroponic systems for ware potato production were also considered (Lommen et al. 2007, Woznicki et al.. 2021). New technological solutions introduced in recent years, the so-called soilless, replace conventional soil production, rely on water solutions of minerals (hydroponics). Examples of hydroponics include the NFT & DFT, which are nutrient film technique and deep flow technique respectively. In NFT systems, roots grow directly in a shallow (2-3 mm), continuously flowing layer of nutrient solution. DFT systems use large tanks, filled with nutrient solution, on which floating plates hold the plants upright while their roots hang directly in the nutrient solution. As the roots are suffering from insufficient oxygen when immersed in the aqueous solution, another modification of hydroponic cultivation has emerged. Chang, Park, Kim and Le (2012) designed the first aerohydroponics device as an alternative to NFT, in which the lower part of the roots is submerged in the nutrient medium and the upper part a portion is exposed to a spray medium.

Plantlets when moved in to a hydroponic arrangement can facilitate quick creation of sterile high quality mini-tuber seeds for marketable use. Hydroponic arrangement is culturing in a nutrient liquid that has a well-adjusted quantity of the vital facilitators that are compulsory for the vegetal development. The NFT arrangement comprises of a succession of PVC or asbestos upwardly racked slope, in which a slimmer film of 1 cm thick nutrient aqueous solution streams over the roots of the vegetation. Using a submersible pump, solution flowing down the slope is collected and pumped back to the top, permitting continuous movement of the nutrient aqueous solution. The DFT arrangement has a tank where the plants, placed on a platform have their roots submerged in 5-20 cm deep nutrient solution, here the nutrient recirculation is through a pump. These hydroponic methods provide adequate supply of nutrients to the plant for multiple harvests and with the yield increase (Mbiyu et al. 2012, Thiago, Factor, Jünior and De Araüjo, 2012). The diagram of the hydroponic system is shown in Figure 4.

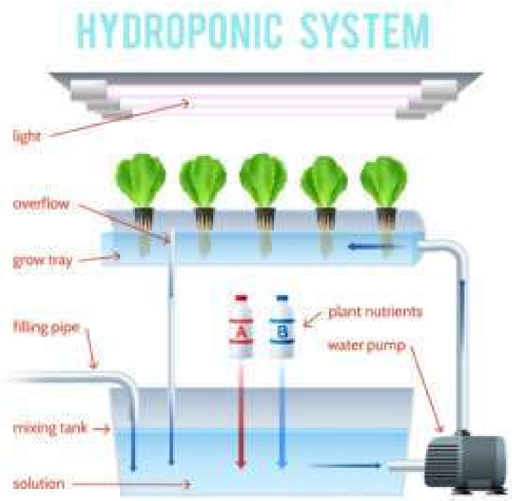

Figure 4: Schema of Hydroponic system

Benefits of Hydroponic Growing:

- the possibility of establishing crops in areas unsuitable for soil cultivation, e.g., in dry areas,
- no restrictions in the field of plant rotation - any plants can be grown one after the other, also in monoculture, because there is no soil fatigue phenomenon,
- higher yields due to denser sowing and faster plant growth and development,
- lower contamination of products due to non-application of pesticides and no heavy metal uptake from soil,
- possibility of postponing flowering and fruiting beyond the normal season,
- elimination of some heavy manual work (soil replacement, digging, hoeing, etc.),
- saving water (Thiago, 2012, Woznicki et al. 2021).

In humid settings of Brazil, Central and South African countries, depending on the elevation, potatoes can be planted and cropped month on month every year, which promotes the occurrence of pests and diseases, especially viral diseases. One of the main strategies for increasing the healthy rate of seed potato propagation and creation is to practice hydroponic arrangements, with or without media, in channels, boxes and pots. In hydroponic arrangements without media, the aeroponic arrangement is effective as it produces a high multiplication factor, with an average of 47 tubers per plant, equated to NFT / DFT of 35 / 37 tubers per plant, correspondingly. When using substrates, better results are obtained in pots with 12 tubers in plant^{-1}, tracked through capillary irrigation and box systems with 8 - 7 tubers in plant^{-1}, correspondingly. In general, hydroponic systems have a significantly high impact on the production of seed potatoes. Among hydroponic systems with pot substrate, they proved to be the best option.

However, higher yields of seed-fraction tubers were gained in the hydroponic arrangements without media, or in the aeroponic arrangement, which gave the best results (Thiago et al., 2012).

The use of hydroponics in the production of ware and seed potatoes can mitigate crop losses in very sensitive regions (e.g., the tropics). Wozniacki et al. (2021) conducted preliminary studies to test the prospects of hydroponic ware potato production on wood fiber by associating various fiber categories and fertigation approaches. Hydroponic potato production on wood fiber gave a 200% more yield than that which happened through usual cultivation in the field. However, the tuber quality to some extent decreased (dry matter low in content). The cultivation method and fertigation strategy influenced the productivity of ware potatoes. The cultivation of potatoes on wood fiber is conceivable and may in the imminent supplement traditional production structures and even develop as a significant alternative in those regions of the world where field cultivation is impossible for climatic reasons. However, the influence of the fiber wood characteristics and the various fertigation strategies used on the yield possibilities and quality of tuber needs further investigation. Optimizing these features will be crucial for a hydroponic system.

Aeroponic system

This is quite expensive involving the plant growth in a mist setting, deprived of the use of soil or aggregates. The suspended roots are in misted nutrient medium, and more successful than any other technique, consumes less time labor dependence, as they conserve water and energy. The recirculation requires less water and easy to monitor the nutrients and pH, and reduced fertilizer requirement. This minimizes the risk of fertilizer overload as residues into the water table. They are minimum space efficient, and plants can grow at higher density with a constant power supply throughout the growth period. The cost of installation and operational costs are high and can produce disease-free potato seed tubers. However, around which are risks of soma clonal differences that are brought in through tissue culture, which needs to be taken care of Langemeier & Shock (2019), Mohanty &, Baruah (2019).

Classification of aeroponic crops Aeroponic culture or aeroponic system is classified as soilless culture. It is included in the group of hydroponics, along with stagnant hydroponics and NFT (nutrient film technique) which use no media. If, however, it is defined that "the substrate is the root growth environment", it can be considered that the substrate in aeroponic cultivation is air (Langemeier & Shock, 2019).

Aeroponics - what is an aeroponic system?

Growing a plant in the air or in fog short of the normal practice of soil or another dense substrate is called aeroponics. The aeroponic system does not require soil and the roots are suspended in the air to receive oxygen and nutrients. The nutrient solution containing all macro- and microelements is injected into the root environment in the form of a mist. Aeroponic systems generally use less water compared to other types of hydroponic methods. It is one of the most effective, low-emission types of farming methods. In an aeroponic arrangement, vegetation is generally introduced into the stand openings at the top of the tank placed in a closed container. Due to the lack of substrate for the root zone of plants, a collar supporting the stems must be prepared. These sleeves essentially be stiff adequate to hold the vegetation upright, but supple enough to permit space for root growth (Farran and Mingo-Castel 2006, Gopinath, Vethamoni & Gomathi, 2017; Kakuhenzire et al., 2017, Mohanty & Baruah, 2019).

What is an aeroponic system and how does it work?

In this system cultivate suspended plants in a closed or semi-closed environment by spraying overhanging roots and the lower stem of the plant. The leaves and crown, often referred to as a canopy, protrude above. A pump and sprinkler system creates steam (hydro-atomized with a blend of water, growth associated hormones and nutrients) from a nutrient-rich aqueous solution and atomize a mist into the tank to irrigate the overhanging plant roots. The atomized shower delivers the required quantity of nutrient that excites the plant's development and permits it to grow comfortably (Figure 5) (Gopinath et al., 2017; Kakuhenzire et al., 2017; Mohanty &, Baruah, 2019; Langemeier & Shock, 2019).

Figure 5: Aeroponic system in potato cultivation

Aeroponic plant cultivation is used in vegetable production in tropical and subtropical countries. This method enables the cooling of plant root systems (Lee 1993). The research conducted by Him, and Lee (1998) showed that cooling the root zone increased photosynthetic activity and increased plant productivity. Cooling down the root zone of plants of temperate climates and plants adopted for cultivation in tropical climates causes an increase in the ratio of the mass of shoots to roots, as a result of greater transport of assimilates in the plant. High temperature of the root environment causes symptoms of iron deficiency, which is not found in aeroponic cultivation, as a result of cooling down the root systems (He & Lee, 1998; Mohanty & Baruah, 2019). The cooling effect of root systems depends on the volume of the injected medium covering the root systems, which in aeroponic cultivation have both vertical and horizontal distribution (Tan et al., 2002). The temperature of the root environment has a significant impact on the development of root systems (Menzel, Turner, Doogan & Simpson, 1994). Du and Tachibana (1994) showed that the presence of N, P, K, Ca, Mg, Fe, Mn, and B in the leaves decreased when the temperature of the root zone increased from 25°C to 35 and 38°C. Stoltzfus et al. (1998) showed that an increase in the temperature of the root zone above 35°C reduces the content of P, Zn and Mn in the shoots, while the content of P and Zn in the roots increases linearly. Tan et al. (2002) showed that plants grown at the temperature of the root zone of 20°C had longer roots, a greater number of hairs, and a larger root area than plants grown in high thermal conditions, typical for the tropical climate zone. Plants grown at a temperature of 20°C in the root zone had a greater number of fine and delicate roots, which was significantly related to their smaller diameter. The plants having a temperature of 20°C in the root environment had a higher content of N and P in the leaves. The buildup of $N\text{-}NO_3$, K, Ca, Cu, Fe, Mg, Mn and Zn in leaves and roots was more in the root zone temperature of 20°C than in the non-cooled root zone conditions. They emphasize that the temperature of the root environment has a significant impact on the morphology of the root system, the absorption of nutrients by the roots, enzymatic and phytohormone activity, and the ratio of nutrients between the roots and the above-ground part of plants (Tan, He & Lee, 2002; Kakuhenzire et al., 2017; Lakhiar et al., 2018; Rykaczewska, Zarzyńska & Boguszewska-Mańkowska, 2018).

Aeroponic potato mini tuber production arrangement?

The key advance in agricultural research and innovation is the aeroponic arrangement. This modern finding might expose a new world of openings for potato and minitubers harvesters (Lakhiar et al., 2018; Mohanty & Baruah, 2019). The aeroponic system (soilless cultivation in air) is recognized as a prospective method in terms of food safety and sustainability. Commercial production of seed potatoes in this technology is developing, among others in China and India. Modern aeroponic structures for the production of mini-bulbs operate under fully controlled conditions. They consist of an aeroponic chamber, an installation for the administration and collection of nutrients, and a system supporting and securing the fogging devices. Such cultivation ensures a high reproduction rate, multiple harvesting, free from pathogens of propagation material during the growing season. Aeroponics allows for the multiplication of seed potatoes, especially in areas unsuitable for agriculture and in climatic conditions unfavorable to traditional potato cultivation (tropics). It is also tested for use in human-crew space flights, due to the spatial flexibility of aeroponic structures and significant water savings (Kakuhenzire et al., 2017; Wasilewska-Nascimento et al., 2019). The number of test results characterizing minitubers is still insufficient produced in aeroponic systems. From the research of Farran and Mingo-Castel (2006) shows that the yield of such minitubers it may be low and may be related to the small size of the daughter tubers.

Advantages and disadvantages of aeroponic crops

The main advantages of aeroponic farming leads to greater yields, their best quality, improved use of the greenhouse space, increased farming cycles, enhancement of phytosanitary settings, greater level of mechanization, reduction of farming costs, operation in a looped system and extensively deliberated on the applied impact associated with the root cooling methods (Massantini, 1977a; Molitor, 1991; Leoni et al., 1994; Repetto et al., 1994; Kreija & Hoeven, 1996; Lima, 1996; Tan et al., 2002; Mohanty & Baruah, 2019). The possibilities of increasing the cultivation cycles and plant density on the cultivated area were documented (Mohanty & Baruah, 2019). This authors developed the High Density Aeroponic System (HDAS) in greenhouse tomato cultivation. He investigated the density of 20 plants m^2 in the first 2 cultivation cycles and 35 plants m^2 in the third cycle. Plants occupied the cultivated area in the greenhouse for 90-95 days. Moreover, significant savings in the consumption of water and fertilizers constitute an important item in the balance of economic effects. The advantage of aeroponic crops is also that they function in closed systems. Aeroponic production under glass may be the first branch of plant production that does not pollute the natural environment. Extremely important practical importance is the fact that no substrate is used in aeroponic cultivation. This advantage is considered to be the most important, especially in view of the increasing acreage of mineral wool cultivation and the problems associated with its disposal. Plant root systems in aeroponic crops are much better developed than in crops with the use of substrates considered to be the best, such as mineral wool, expanded clay or coconut fiber. The root systems of plants in aeroponic cultivation develop throughout the entire period of plant cultivation at the maximum oxygen content and maximum humidity of the root environment, without encountering substrate resistance. In aeroponic crops, there is no antagonism between the humidity and air conditions of the root environment. This is the first cultivation technology in which these two parameters do not contradict each other (Mbiyu et al., 2012; Pala, Mizenko, Mach & Reed, 2014; Langemeier & Shock, 2019).

The main disadvantage is the high cost of such cultivation (Ritter, Angulo, Riga, Herran, Relloso and Jose, 2001, Komosa 2002, Mateus-Rodriguez, et. al., 2013, Rykaczewska et al., 2018, Langemeier & Shock 2019). Aeroponic cultivation creates further opportunities to increase yields with optimal quality and not polluting the environment. It is the most scientifically and technically advanced method of growing plants. Aeroponic cultivation does not require any substrates, with significantly lower consumption of water and nutrients, and is a future method of cultivating horticultural plants in practice (Mohanty & Baruah, 2019).

New Technology Adoptions to Increase Production

Emerging Technologies application

Precision farming uses information technology to gather and exploit the specific data about fields, for instance mapping of the soil, yield, robotic directed arrangements, drones, satellite imagery, and various production practices for positive relation to farm size. Precision agricultural technologies improves profitability, and promotes better management controls. However, new adoption of precision agriculture technologies, would consume costs (Michael et al., 2019). Through this technology application the potato crops and seed tuber lots are treated through intervention at the smallest scale and at the right time, optimized with time, dosage, and site of application. Using technologies such as GPS for sensing and dosages create responses which generate right decision control systems affecting the yield of crops, to effectively manage the value chain, by tracing, tracking, and learning for improving the performance. Potato suffers from suboptimal biotic and abiotic environmental conditions as it is more sensitive to drought than the cereals, requiring interventions through decision support systems (DSS) at specific locations depending on the quality of the crop harvested per plant. The soil is evaluated spatially depending on the rooting depth, water holding capacity, pH, organic matter, then ensuring all inputs such as seed tubers, fertilizers, protection agents and water, at every level of the site, offers conditions that are favorable. DSS in potato production for planting times and densities, fertilization, irrigation, control for dealing with losses due to diseases, pests, weeds, and harvest scheduling have a time component, which can be taken care through hardware and equipment to interact for right row spots on the soil map by considering the soil layer whether sandy or thinner depending on the yielding ability and then be suitably spaced (Bisness, 2020; World, 2020). Emerging technology applications in potatoes take care of the sensitivity of yield, quality to crop controls and environmental conditions, competitively using the spatial and temporal variability of soil conditions and crop growth through geospatial IT and manage the differences more precisely, involving soil sampling techniques intensively, watching cautiously the yield, identified through soil and plant sensors for the location, time and intensity of dosage required at specifically in the field (Cambouris, et al., 2014). Precision agricultural techniques offer variable-rate applications of crop inputs that can significantly benefit the crop, the environment and the grower's bottom line, saving on agrochemicals, promoting sustainability by applying fewer chemicals just enough to meet the crop's nutrient needs, across the field, enhancing the plant performance and reduce fertilizer costs. Such applications avoid excessive nutrient levels which shoot up the risk of nutrient losses in the environment, degrade water quality and increase greenhouse gases to the atmosphere.

Various sensors and technologies for mapping in-field variations determines the better options for creating prescriptions for variable-rate applications on potato fields, using cameras to capture thermal imagery and multispectral imagery, by mounting on drones or field equipment, and mapping weeds, crop health, disease, heat emission from the soil, moisture content through yield monitors and soil moisture sensors. These applications are suitable for different options such as elevation and slope mapping using real time or instantaneous kinematics global positioning system (RTK-GPS) and radars which are enabled by lights called light detection and ranging (LIDAR), creating a digital model for mapping water flow across landscapes for identifying soil erosion and depositions (Carolyn, 2019). The size of the tuber is the vital control point, as such potatoes sized up for 45mm or up to that has more demand in the salad market, therefore use of emerging technology having a joint connection of GPS, satellite and image caught by drone to monitor the growth of potato from its plant stage till the end of burn down, supports to forecast tuber size and exact burn-down time, maximizing yields and profit margin. Observing the activities under the ground aids the result on haulm clearance by characterizing on the yield and distribution size for every cropping, thus deciding the exact date for the crops to be charred, considering the prediction of weather and the development of other crops. Thus, accurate prediction before burning down the crop delivers the customer expectations on the size and quality (Business, 2020). Remote sensing and global positioning system technologies identify the time-based differences in cropping, together with variabilities in yield and its space. Electromagnetic spectrum of visible and near infrared, hold confirmed success in evaluating the type, health, soil moisture, concentration of nitrogen and plant yield.

Progression in remote sensing methods improved the practice of multispectral imageries to control and observe plant settings, concentrations, and yield estimates. Remote sensing provides the three-dimensional and chronological land tropical features, with the ecological influences on the harvest. The vegetation measurements obtained through remote sensing on yield and biomass engage with coarse or simpler resolutions of the images obtained from the satellite, for a wider evidence on the plant cover environments and yield evaluations in measurable indices supporting the decision making of export and import across the region can be assured. Forecasting the yields is classically related with specific agronomical parameters, namely the density, potency, development, and sickness, that can affect the yield. RS also provides a close analysis of vegetal health, with the spectral reflection factor of the vegetation is reliant on the phenology, stage, and health. Normalized difference vegetation index (NDVI) improves the agile smart farming by relating the leaf area index (LAI) and the plants photosynthetic activity, it is also an indirect method to measure primary thruput by its quasi-straight-line model applying the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR). TERRA MODIS pictures can evaluate potato yield, within an error tolerance of 15%, compared to that determined by real data obtained from a sample of 50 farms. Only through the use of decision support tool and return of investment prognosis, the mappings that are projected on the yield can be analyzed with spatial records for the deployment of variable rate technology (VRT) to realize a specific implementation of field-level inputs that can enhance the returns across the entire field (Al-Gaadi et al., 2016).

Emerging technology applications require parameters for controlling. Salient technology linked farming parameters are productivity, yield, income, improvised methods, market expansions, means of support impact and farm prosperity, and activity management. Productivity - Farming productivity is the proportion of farming outputs to agronomic inputs; where the output is generally considered as the economic value of the tradeable output, and discounts all transitional products in its process. Agricultural productivity is a comparative index. Further to the automations and machinery mechanizations that happened in the farming practices, it is now the role of emerging technologies that are influencing the productivity, namely the data on precisely timed climatic changes weather, fog, and rain. Implementation to emerging technologies competitively complement to assist improvements in productivity, and farming production without much emphasize on our environment (Umachandran, 2015). Yield - It is the degree of the desired merchantable production per unit area through novelty, rigorous farming, conception of enhanced agrobusiness tools, pursuing more for amended high-yielding varieties, expansion of irrigation infrastructure modernization of management techniques, distribution of hybridized seeds, synthetic fertilizers, pesticides to farmers, and microbiological facilitations technology. Income - It is the money thus earned from carrying farming operations and the revenues from tributary byproducts of the original crop; subtracting land value, effort impacts that made the vegetation, rental payments made for any utilizations and services.

Improvised methods

This includes mobile network and connectivity bandwidths, which the agricultural marketing can leverage superior access to data and customers, progressively adding to the agriculture market facts and to time the prices, based on perishability of the produces/ products. This real time information interprets into precise capture of the demand projections and a boosted capability to regulate the process of production and accomplish the establishment of right supply chains. Market is visible and voids Monopoly or spurious market practices. Profitably closing the chain of agriculture within the constraint parameters of time, finances, and commerce. Communication channel is strengthened with producers, wholesalers, intermediaries, dealers, and small vendors. Facilitates better peer coordination and community living. Leverages economies of scale and reduces the cost of transportations, hedging with truck providers for aggregating volumes and cubicle spaces utilization, thereby achieving optimization in Logistics & Transport. Market expansions - This includes competition level fields and reaches the market on time and avoids speculative loss on pricing. Customers can budget their expenses as there is a relatively clear band of price for the commodities based quantity, quality, grades, and product presentation, thus an Open Market is evolved. Market demand and consumer trends are affected by the unique Value additions and innovative commercial practices of the sellers. Producers make more informed decisions about the choices of the customer and their needs, thereby obtaining data that focuses for more commercialization. Advantages of mobile phones in marketing, increases the diffusion of mobile networks and gadgets offered more chances to fully utilize the information, which is extensively available, facilitates agronomic markets to function proficiently, and manage the challenges.

The stakeholders can reduce their costs, profitably price the goods, and get market information to improve the value (supply) chain to fluctuating demands. It further strengthens the bond of brotherhood and fosters community living. Livelihood Impact and Rural Prosperity - This affects the investments on livelihood, prosperity for farming growth opportunities and relationships with agronomic investments is the main component of an agricultural expansion strategy. There needs to be an actual request for the commodities produced in the domestic market intended towards endurance of the agrobusiness activity. Adverse Seasons handling or combat such periods through innovative partnerships. The collaborations are enabled and constructed amid assemblages of farm producers, for qualitative straight communication with establishments and dealers, or for the capacity to distribute produces, just-in-time as per quality required. Activity Management - Knowledgeable use of inputs help agriculturalists to progress their business scalability to promote yields over recovered practices of inputs to recognize resourceful startups, get through them more competitively priced products that can be applied at the best required opportunity. Beneficial impact on larger masses happens through enhanced negotiation influence. Agriculturalists can rise their authority to bargain and exchange with dealers, only based on their skill to comprehend pricing in numerous markets, by eliminating business intermediaries, so to directly reach and sell to bulk buyers. To avail the above benefits of big data applications in agriculture the emerging technology implementation is a must, as it has a cost imperative which is an investment paying dividends on a longer run, reduced logistics and transportation costs, more cultured publicity with clear pricing, wider and grounded networks, pioneering cooperation's, conversant with input resources, enhanced farm business controls (Umachandran et al., 2017).

Conclusion

The potato is susceptible to manipulation in tissue culture. Since potato tissue is easily multiplied, it can be used extensively in the production of high-quality seed material. Meristem culture in combination with thermotherapy and / or chemotherapy is now standardly used to obtain healthy, pathogen-free potato plants. Plants in vitro can be propagated into successive plants in vitro or for microtubers production. Microtubers and micro-seedlings are planted under covers, and minitubers are obtained from them and planted in the field as pre-basic material (PBII).

The wide use of micro-propagation in conservation breeding prevents the spread of quarantine pathogens in seed production, and also enables the production of seed potatoes of potato varieties with low resistance to viruses. The aeroponic system (soilless cultivation in the air) is considered a prospective method of growing crops in terms of food safety and sustainability. This system means the cultivation of plants only in the air, without any substrate. The nutrient solution is injected into the root zone at short intervals. The greatest advantages of aeroponic systems are higher yield with optimal quality, reduced consumption of water and nutrients, operation in a closed system and safety for the environment. The aeroponic system is also an effective method of cooling the root zone and improving plant growth at higher temperatures under glass. Due to its significant advantages, the aeroponic system can be widely used in agriculture practice as well as in the production of minitubers.

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