ISSN No:-2456-2165

A Review on Sustainable Method for Vegetables Cultivation without Soil - Hydroponics

Prajapati Dharmendra H[1], Patel Mahenk D[1], Patel Prachi P[1], Shukla Krishna H[1], Raval Devarshi A[1], Prajapati Ansh B[1],Soni Bhavin R[1], Patani Anil V[1*]
[1]Department of Biotechnology, Smt. S.S. Patel Nootan Science and Commerce College,
Sankalchand Patel University, Visnagar, Gujarat, India

[2]Department of Biotechnology,
Faculty of Basic and Applied Science, Madhav University, Sirohi, Rajasthan, India

Corresponding author: Dr. Anil V. Patani

Abstract:- Open field/soil-based agriculture has faced significant difficulties since the dawn of civilization, chief among which is the decline in the amount of land available per person, per capita land was 0.5 ha in 1960 when there were 3 billion people on the planet. Today, there are 6 billion people, but that number will drop to 0.25 ha by 2050. Arable area under cultivation will continue to shrink as a result of increased urbanisation, industrialization, and iceberg melting. Once more, soil fertility has reached a saturation point, and more fertiliser application does not result in an improvement in productivity. The production of food using traditional soil-based agriculture is also threatened by factors such as low soil fertility in some cultivable areas, reduced chances of natural soil fertility build-up by microbes due to continuous cultivation, frequent drought conditions, unpredictable climate and weather patterns, rise in temperature, river pollution, poor water management and waste of enormous amounts of water, decline in ground water level, etc. Different hydroponic structures, including wick, ebb and flow, drip and nutrient film technique (NFT) systems, have also been covered. This method has several advantages over conventional farming, including shorter crop growth cycles, year-round output, low disease and pest incidence, and the elimination of tasks like weeding, spraying, and watering. Commercial hydroponic technology must be successfully implemented, thus it's critical to develop low-cost methods that are simple to use and maintain, need less labour overall, and have lower setup and maintenance costs. The global hydroponics market is expected to increase from US $ 226.45 million in 2016 to US $ 724.87 million by 2025 as a result of technological developments within the sector and a number of economic variables.

Keywords:- *Soil less medium, Techniques of hydroponic systems, Pest control, water conservation, nutrient management, Hydroponic market.*

I. INTRODUCTION

By 2050, the population of the world is anticipated to reach 9.7 billion. Meanwhile, it has been predicted that 50% of the world's arable land won't be suitable for agricultural. In order to fulfil the huge demand, food production will need to be boosted by 110%. The demand and necessity for many products, particularly food products, increase together with the growth of the global population. A food crisis is anticipated in the upcoming years as a result of this rising demand [15]. Consumers today are more proactive and aware when it comes to taking care of their health and avoiding disorders linked to diet. The prevention of these lifestyle disorders is an appealing sector to get into for both the food and pharmaceutical industries because many of these diseases are approaching epidemic levels [23,51]. The management of natural resources is an issue since the production of food will be hampered by the unusability of millions of hectares due to soil degradation and other problems. Pesticides in runoff water and ground issue such soil-borne diseases, non-arable soil, and poor soil physical qualities are other environmental challenges with old agricultural techniques. Because of its capacity for holding moisture and nutrients, as well as its capacity to act as a buffer in the event of a sudden change in soil pH, soil is by far the main medium supporting crop growth. It also offers support, vital nutrients, water, aeration, and other elements required for plant growth. But soil has some biotic (disease, pests) and abiotic (drought, salinity, nutrient shortage, soil pollution, low water quality, etc.) limits that hinder crop productivity [22].

Plants are one of the few species that can use the energy from the sun to synthesis all the necessary metabolites from inorganic ions, water, and CO_2. This fact is utilised by hydroponics, a method of growing plants, which provides all of the nutrients in their inorganic form, in a liquid solution with or without solid substrate. Scientists have made considerable use of hydroponic systems to investigate the nutrient needs of different plant species, as well as the toxicity of certain components [25,2,10]. The terms "hydro" (which means water) and "ponos," which implies labour, are the roots of the name "hydroponics." A technique called hydroponics uses fertiliser solutions instead of dirt to produce plants. It is possible for these nutrient solutions to move beyond the roots either passively by gravity or actively with an electromechanical pump [42 1]. It is optional to use an artificial medium that offers mechanical support, such as sand, gravel, vermiculite, rockwool, perlite, or peat moss. Open and closed hydroponic systems are other categories [14].

The art and science of soilless crop cultivation is known as hydroponics. In hydroponics, plants are grown in water instead of soil, receiving the same nutrients that they would normally get from the soil in conventional farming. The basic goal of hydroponics is to provide the best nutritional environment for the best plant performance, which is further enhanced by regulating the climate. In traditional farming, soil serves as more than just a reservoir for nutrients; it also serves as a natural habitat for plant roots and a foundation for the construction of plants [15,20]. The adaptable soilless plant growth method known as hydroponics is well-suited for more effective resource usage and independent food production in regulated situations [11]. Produce cultivated hydroponically seems to have a lot of advantages. This includes year-round food production, reduced pesticide use, effective water use, and increased yields [15].

II. DIFFERENT SOIL-LESS MEDIUMS OF HYDROPONICS

Different solid materials are essential in a hydroponic system since they can substitute soil and give plants mechanical support for growth. In contrast to dirt, substrate promotes root growth that is both faster and more robust. Different materials can be utilised for different growing methods. Numerous mediums have been used in hydroponics as a medium since the beginning. Vermiculite, sawdust, peat moss, and sand are a few examples, but more and more recently, rock wool, perlite, and clay pebbles are being used [3,17].

A. *Inorganic growing media*

a) Perlite

The most common type of medium in a hydroponic system is perlite [4]. It is a volcanic substrate made of a grey-white silicate. It has a pH of zero and expands at very high temperatures [42,48]. The interaction of water and perlite is what causes this expansion. Tiny cavities cover the perlite's exterior surface, adding to the material's enormous surface area. Perlite is utilised as a supplement in soil and soil-free mixtures because of its superior oxygen retention as a result. The biggest disadvantage is that it is readily washed away due of its small weight. Each regular bag of perlite grow bags comprises three or four long and tall plants that are mostly established on a drip feed system [42].

b) Rock wool

Melting rock produces rockwool, which is spun into thin fibres and typically bonded into blocks and slabs [8]. The slabs are used to make perlite grow bags, while the cubes are needed for plant propagation. On the rockwool slab, a plant is placed and nurtured. 3–4 big plants may typically be grown on rockwool slabs. It has the capacity to store water and keep enough air inside to promote healthy root growth. Additionally, it is extremely light, completely inert, and pathogen-free. Due to a unique property, rockwool has a high germination rate and a low insect invasion rate [26].

c) Grorox / Hydroton

Grorox known as enlarged clay aggregates (LECA). It is comprised of clay pebbles that have been enlarged. Because of its surface area and porosity, it conserves water [42]. The clay pebbles are non-nutritive, sterile, PH-neutral, renewable, and inert. Generally speaking, these pebbles are too expensive for commercial endeavours [16].

d) Vermiculite

A hydrated magnesium aluminium silicate mineral, vermiculite expands significantly when heated. It is not dense. Additionally, it has a strong capacity to hold nutrients in addition to having an outstanding capacity to hold water. Additionally, it has exchange and buffering abilities. Contrarily, it costs money and uses energy [15].

e) Sand

The most traditional and ancient hydroponic media is sand. Sand is inexpensive and readily available. In order to provide weight and enhance drainage, it is typically combined with other substrate, such as vermiculite, Perlite, and coconut coir. Sand must be disinfected in between usage despite the fact that it is heavy and ineffective at retaining water. It supports healthy plant growth, has good porosity, and is economically viable. Sand has many good qualities, but it also has several drawbacks, such as high density, poor water retention, and susceptibility to salt build-up [42].

B. *Organic growing media*

a) Coco peat

Coconut coir is another name for coco peat. It is the residue left over after the fibres have been removed from the coconut's external shell. Due to its great water holding capacity, it may provide a buffer in conditions of extreme temperature and high crop load requirement without affecting air supply, making it suitable for seeds whose germination requires steady and high moisture. The drawbacks of coco peat include its high salt content and energy-intensive transportation. The ideal substrate and defence against fungus and root diseases are provided by sterile coco peat [42].

b) Rice husk (Rice hull)

The tough outer layer that protects rice grains is called a hull. Despite being made of organic material, they degrade much more slowly than coco coir. It is better to use parboiled rice hulls (PRH) rather than fresh rice hulls. After the PRH have been milled into rice, they are finished by drying them. This renders the product sterile and destroys the germs. Additionally, it permits drainage [16].

c) Peat moss
Peat moss is the dead, lifeless, and fibrous component of sphagnum moss and other organic components that decay in peat bogs, which are wet, cold, acidic, and devoid of air. This procedure goes on for so long. Despite being disinfected, organic substrates prevent peat from being free of contamination. Because of its capacity to hold large amounts of water and guard against nutrient leaching, it is an excellent substrate for hydroponic planting. The main issue with this growing medium is that it has expensive environmental consequences like the loss of soil organic carbon [26].

III. TYPES OF SYSTEMS

It also goes by the name "Liquid hydroponics. "According to the methods used, modern hydroponics systems of agriculture can be divided into different categories. Roots of plants produced in solution culture are suspended directly in nutrient solutions using a technique known as hydroponics. A hydroponic system should be designed to meet the unique needs of plants using the most dependable and effective nutrient delivery techniques [42].

A growth operation can be optimally customised using a variety of techniques. These farming techniques are ideal for everyone, whether they plan to build a sizable industrial farm or just do some backyard gardening. The best part is that we can select any or all of these strategies simultaneously [18]. There are many soil-less culture techniques available, however before choosing one, the following aspects should be taken into account [44].

A. Wick system

One of the most fundamental and straightforward types of hydroponics is the wick system. As there are no moving parts needed, it is the sole example of passive hydroponics [19]. It costs less than alternative systems. This is the simplest setup because it doesn't require a pump or aerators, or electricity. In order to pull nutrient solutions from a reservoir to the plant roots through capillary action, plants are placed in an absorbent medium with a wick made of nylon, polyester, or rayon [13]. The wick has one side that is submerged in nutrient water and the other end that covers the plants. It is important to ruffle the ends of the wick and leave 10 cm of it inside the pot for optimal nutrient solution circulation. It works best for smaller plants like herbs and spices that don't require a lot of nutrients or water, but it won't work for plants that need a lot of water [46s].

B. Water culture system

The simplest active hydroponic system is the water culture system. It is an extremely affordable method. The supplies needed for this technology, which works similarly to the wick system, include a reservoir, an aeration system, and a growing tray. Similar to a wick system, there is nothing between the plants and the water. In this approach, air is transferred to the plant roots via an air stone after the roots are first suspended in a nutritional solution. The bucket system is a traditional example of such a technique [13,31]. Net pots protect plants while they are placed in their correct locations. These pots are fixed to a piece of Styrofoam and let to float in the nutrient solution that has been added to the container. Due to the rapid growth of algae and moulds in the reservoir, the amount of oxygen, nutritional content, salinity, and PH should be monitored [6]. Grow trays feature openings for net cups or baskets. The grow trays are then positioned such that plant roots may easily absorb nutrients, which causes plants to grow rapidly. The utilisation of the water culture for larger, water-loving plants that produce fruits and vegetables, particularly cucumber and tomato, is its finest feature [49]. Water culture system and deep water culture (DWC) are slightly dissimilar [8].

C. Ebb and flow system

It is also known as a flood and drain system since it is the first commercial system to operate on the flood and drain principle. It is reasonably easy to install and has a modest installation cost. However, it is rarely utilised in commercial production and is primarily employed by home gardeners [47,54]. Ebb and flow systems have three fundamental parts.

a) Planttray
Flood tray and growth tray are other names for plant trays. It is deep and broad. In small plastic buckets or pots with inert rooting media like perlite, rockwool, or expanded clay pebbles, plants are typically grown. These pots are then positioned in the grow bed such that they emerge fully when the tray is filled with nutrient solution. Grow trays are supplied with nutrients and water from a reservoir using a submerged pump until they reach a particular level, at which point the roots are totally buried in the nutrient solution to give them with necessary moisture and nutrients. Excessive solution eventually drains back into the reservoir. Before nutrients flood the tray again, this outflow of nutrient solution from the grow tray allows the roots to dry and be oxygenated [49,32].

b) Reservoir
Reservoir is installed directly below the flood tray. Two tubes a fill tube and a drain tube connect it to the flood tray. While the drain tube is connected between the grow tray and the reservoir, the fill tube is attached to the immersible pump [8].

c) Submersible pump
The grow dish was regularly submerged in nutrients by a pump. The pumps are activated by a timer so that the nutrient solution can reach the grow tray. The solution refills the reservoir once the timer switches off the pump. The type and size of the plants, as well as the temperature, humidity, and types of growing medium, all have a role in timer setting. The added benefit of the ebb and flow system is that it is computer automatable. Additionally, it is evident to cultivate various crops, but the complications of root rot, algae, and mould are frequent. The primary problem with the ebb and flow method is that, in the event of a malfunction, the pump controller will prevent functioning until the pump is replaced [16].

D. Drip system

The trickling irrigation system, often known as a drip system, is undoubtedly the way that both household and commercial farmers most commonly use [43]. Drip irrigation is used to deliver the nutritional solution to the plants. It is possible for this system to be more effective than other methods, depending on how well it is designed, deployed, and used. This uses much less water than flooding the grow tray with nutrient-rich solution since it slowly feeds the nourishing solution to the base of each plant. Growing media like coco coir and peat moss that have a high water retention rate are effective. Additionally, as organic material blocks lines much more quickly than synthetic nutrients do for these systems, synthetic nutrients are a preferable option [53,28]. Plants are often planted in a growing medium with an intermediate absorbtion capacity when using a drip system [49]. A nutrient solution-filled pump with a timer is installed in the. Schedule for watering is managed by a timer. The pump is essential for transferring the right amount of solution to the grow tray. Either the reservoir can receive the extra solution or it can be emptied from the system. Pipe has a variety of drip emitters that slowly trickle fertiliser solution to the roots of each plant. There are two types of drip systems [8].

a) Recovery system
It is a method for recycling nourishing fluid. The majority of the time, it is utilised in vertical gardens, where the residual solution drains back into the tank as the solution moves from the top to the bottom. It is feasible to preserve solution because of this drainage, but it's crucial to constantly monitor the PH and TDS of the solution. A less expensive timer can be used during the recycling process because the precise control of the watering cycle in the recovery system is not so important [53].

b) Non- recovery system
This approach eliminates the nourishing solution from the system rather than reusing it. In comparison to the recovery procedure, it is resource-efficient. For this system, the cycle time and irrigation time must be precise. In order to save as much nutrient solution as possible, drip emitters deliver precisely the right amount of solution to plants. It is not necessary to maintain control over the solution's PH and TDS. It requires a time since the watering cycle needs to be changed to provide enough solution. This system is appropriate for the cultivation of fruit crops such as tomato, sweet pepper, cucumber, watermelon, and strawberry [49,29].

IV. NUTRIENT FILM TECHNOLOGY (NFT)

In Australia and Brazil in Latin America, NFT is the most used hydroponic technique [7]. The characteristics of NFT are comparable to those of the ebb and flow system, but they have a different configuration. The only notable distinction between them is that NFT continuously flows nourishing solution, whereas ebb and flow approach follows flood and drain process. In the nutrient film technology, dense mats rather than net pots filled with growing media are typically utilised to produce plants. According to Dubey and Nain (2020) and Patel et al. (2010), plant roots penetrate the mat in the channel [8,30]. The majority of growers have discovered that flat bottomed channels give more surface area for root development and oxygen uptake, even though round pipes have been acknowledged in NFT production [47]. The roots receive water even when they are not wholly submerged in the provided solution. Reservoir is positioned just beneath the grow tray. Pump continually transfers the fluid from the reservoir to the grow tray where the plants reside by way of the channels. It's interesting that timer and pump are not connected. The thin film of solution passing by keeps the plant roots moist. In ideal circumstances, the roots should have their bottoms exposed to the nutrient solution and their tops kept moist but not soggy. The grow tray has a little incline for drainage [53]. Because of this nutritional solution's shallow flow, roots can immediately access atmospheric oxygen. Because nutrients are constantly flowing through roots, they are also susceptible to fungal infection. On the other hand, the roots may quickly dry out if the flow of solution is interrupted. To prevent dehydration, the enclosed room is set to 100% humidity [42]. For ideal dissolved oxygen levels and stagnation, air stones are used. NFT is ideal for short-stemmed plants since it uses less water per plant and is easier to stack, clean, and customise for a given growing area. This technique makes it easier to raise light-weight, short-rooted plants with short roots like strawberries as well as leafy vegetables like lettuce. Spinach could be produced year-round with NFT in a greenhouse with the right cultivators and solution temperature [16].

V. FACTORS AFFECTING ON GROWTH OF PLANTS IN HYDROPONICS

In soilless culture gardens, soil-free growing mediums are mostly utilised for seeding and cutting germination. A system is simpler and less expensive to run the less media it needs. A ideal medium can contain an almost equal amount of air and water. Nutrient solution, temperature, air, supporting materials, water, mineral nutrients, light, and most important growing media like sawdust, bark, chips, straw, gravel, rockwool, perlite, sand, and vermiculite are the fundamental requirements of hydroponics [37].

A. Water:

Reverse osmosis (RO) water with little total dissolved salts (TDS) is used for hydroponics so that salts can be added based on the crop and stage of the plant [16].

B. Nutrients:

To provide the plant all it requires in terms of nutrients is one of the fundamental tenets of growing vegetables, both in soil and in hydroponic systems. Plant development and production require a number of chemical components. Without the use of soil, plants are grown in highly oxygenated, nutrient rich water. The key to a good hydroponic system is fertiliser solution control [16,39,35].

The hydroponic fertiliser solution is necessary to provide soluble forms of the vital mineral components, water, and oxygen to the plant roots. Organic matter in the soil is broken down into basic nutrients via biological decomposition, providing food for plants. These nutrients are subsequently dissolved in water and taken up by the roots. Everything in the soil needs to be in great condition in order to give plants a diet that is well-balanced. Plants need seventeen different components in order to grow properly. For growth of plants, nine of these are Carbon (C). Hydrogen (H), Oxygen (O_2). Sulfur (S), Phosphorus (P), Calcium (Ca), Magnesium (Mg). Potassium (K) and Nitrogen (N) are required in large amounts and hence are called as macro nutrients. The remaining eight elements which are known as macronutrients such as Iron (Fe), Zinc (Zn), Copper (Cu), Manganese (Mn), Boron (B), Chlorine (CI), Cobalt (Co) and Molybdenum (Mo) are needed in small amounts [16,24]. Depending on the grade utilised, there can be a considerable difference in the price, purity, and solubility of the chemicals that make up a nutritional solution.

Smaller businesses frequently purchase pre-mixed nutrient formulations, to which water is the only ingredient needed to create nutritional solutions. Larger facilities create their own solutions using standardised or little changed formulas. Nutrient components are combined in all hydroponic systems in the precise solutions, dosages, and ratios that different plants need. The plant roots are directly exposed to the solvent [16,31,5]. The quality and production of vegetables and fruits are significantly influenced by nutrients. As a result, the quality of the product is greatly influenced by the balanced application of nutrients. The range of nutrient concentrations in soil and soilless crops is shown in Table I. A higher concentration of nutrients are often needed for soil less media than soil media (Table 2) [16,34].

Nutrients	**Soil (mM)**	**Hydroponics (mM)**
N - NO_3^-	0.5-10	5-20
N – NH_z^+	0.02-0.05	0.5-2
P ($H_2PO_4^-$)	0.0005-0.05	0.5-2
K^+	0.2-2	5-10
Ca^{2+}	0.5-4	3-6
Mg^{2+}	0.2-2	1-2
S (So^{2-})	0.1-2	1.5-4

Table 1: Comparative concentration ranges of macronutrients (mM) in soil and soilless crops

Elements lonicform Concentration		
range mg / l or Ppm		
N	NO_3^-, NH_4^+	100-200
P	H_2PO_4	30-15
K	K^+	100-200
Ca	Ca^{2+}	200-300
Mg	Mg^{2+}	30-80
S	SO_4	70-150
Micronutrients		
B	BO_3^-	0.03
Cu	Cu^{2+}	0.01-0.10
Fe	Fe^{2+}, Fe^{3+}	2-12
Mn	Mn^{2+}	0.5-2.0
Mo	Mo^{2-}	0.5
Zn	Zn^{2+}	0.5-0.50

Table 2: Major elements and micronutrients needed also their concentration range in most nutrient solutions

C. Electrical conductivity (EC):

The different media used in soilless cultivation may have varying EC values depending on the admixtures and source from which they are obtained. Organic substrates always have greater EC values than inorganic substrates do. The greatest EC value among the organic substrates was found in peat, which was then followed by peat moss [15].

D. PH:

In addition to the media's physical characteristics, chemical characteristics like PH and electrical conductivity are crucial factors in determining how well soilless crops thrive. Depending on the crop type, different pH ranges are advised for soilless media [26]. The pH of growth medium is influenced by irrigation and fertilisation techniques, media component ratios, and the chemical makeup of the media particles. The availability and absorption of nutrients are greatly influenced by PH. The medium's PH was within the acceptable range of 5.5 and 6.5. By adding coco-coir, the EC of the media containing the kenaf stem core was significantly lowered. The PH of the coir growing media varies greatly, with readings between 4.8 and 6.9. The P content of coir is typically low. Micronutrients are also present in coir in substantial concentrations, and they can also vary greatly. Deals with CEC are expensive and akin to peat [16].

E. Media:

A good culture medium should be able to provide the plant with the most water availability (have a good water retention capacity) while also ensuring that the roots receive enough aeration. In other words, the ratio of macro to micro porosity (which are the pores that may still hold water at the conclusion of drainage after full saturation) should be balanced (porosity free, provided by all the pores that do not retain water and that are filled with air). The majority of media and mixtures have an air-filled porosity of between 10% and 30%. For bedding plants cultivated in shallow trays or plugs, lower air filled porosity is necessary. It's crucial to take into account that most root systems have a propensity to grow under the effect of gravity and produce a dense layer at the bottom of all types of media and containers [38].

F. Light:

The impact of light on photosynthesis, photorespiration, and photoperiodism on a plant's growth is significant. For the majority of greenhouse vegetable crops, light intensities between 50000 and 70000 lux are ideal. For plants to flourish light is necessary. The amount of nutrients, water, CO_2, light, and temperature that are available affects how quickly photosynthesis proceeds. Reducing the carbon from its coupled state with oxygen in CO_2 gas to the state it occupies in carbohydrates requires a significant amount of energy. As a result, the light energy is captured and used by the carbohydrate. Reduced light intensity causes photosynthesis to slow down, which has an impact on growth. Even if higher optimum intensities are offered, the damage to the chloroplasts causes the growth to slow down once more. In photoperiodism, a plant's reaction to the cycle of day and night, light plays a second role.

The length of the light's wavelength is crucial. According to Khan et al. (2020), PSI and PSII absorb energy most effectively at 700 tm and 680 nm, respectively. As a result, light with a higher concentration of energy at these wavelengths will result in a higher rate of photosynthesis [16].

G. Temperature:

Although the light dependent reactions of photosynthesis are not affected by changes in tempera true, the light independent reactions of photosynthesis are reliant on temperature. They are reactions catalysed by enzymes. As the enzymes near their optimal temperatures the overall rate increases. For every 10°C increase in temperature, it roughly doubles. Above the ideal temperature the rate begins to drop, as enzymes are denatured, until it ceases in this way, temperature plays a major effect on the vegetative and photosynthetic activities of the plants. It affects the plant growth either by raising or lowering the rate of several plant process as photosynthesis, respiration, and transpiration. The highest activity is attained between 21-27 ^{0}C day temperatures under greenhouse for most of the veggies. The rate of photosynthesis typically increases unless it is constrained by another factor. Carbon dioxide enhances the rate at which carbon is integrated into carbohydrates in the light-independent reaction. Increasing carbon dioxide concentration produces a rapid increase in the rate of photosynthesis, which finally reaches a plateau when the maximum rate of fixation is attained because it is typically present in the atmosphere at relatively low concentrations (approximately 0.04%). Thus one can claim that CO_2 concentration is directly proportional to the rate of photosynthesis [16].

H. Relative humidity:

The regulation of relative humidity inside the green house is of most essential as it affects the quality of plant. Most of the crop typically has a relative humidity index (RHI) between 60 and 75 percent. A few hours after sunrise is when closed greenhouses experience their most dangerous high humidity levels because solar radiation that is conveyed into the interior speeds up plant transpiration. Rise in air humidity encourages development and photosynthesis and high humidity levels resulted in an enhanced photosynthetic rate [15].

VI. APPLICATIONS OF HYDROPONICS

Today's globe is dominated by soilless farming, which has many advantages over conventional farming methods. It offers ideal environment to plants and produce a year round production with minimum expenditure of water and fertilisers compared to conventional agriculture. Numerous studies on the subject have demonstrated that soilless faming has potential to yield better output than soil based farming [45]. The managed system of soilless farming also decreases biotic and abiotic stressors hence sustain crop growth. One of the significant benefits of soilless farming is resource preservation and ecological sustainability. It is spreading over the globe to sustain the growing population, and related techniques present numerous prospects for producers and clients to generate excellent vegetables enhanced with bioactive components by replacing traditional farming [41]. It is feasible to cultivate diverse vegetables in places with less space and decreased water availability; therefore hydroponics can make a big contribution in such situations. Additionally, it can spark and boost a nation's economic development by encouraging creative enterprise. Furthermore, as it is a controlled system, it allows a year - round production. In order to improve industrial soilless farming with lower investment and operational expenses, low-cost soilless and other high-tech innovations must be developed. Future research on the topic might focus on the application of particular soilless farm methodologies [22]. In hydroponics, the effects of the soil and external variables on the plant are minimal. The atmosphere can be adjusted for temperature, humidity, and lightning frequency [37]. Water used for irrigation can be recycled or reused. using enough water. By utilising various medium, water holding capacity may be readily maintained. Nutrient loss from run-off in the culture media is nonexistent [21].

The medium is evenly distributed with fertiliser. There is reduced chance of excessive use of fertiliser. PH is simple to maintain. Crop production is stable and is influenced by the media types used. As opposed to soil-based agriculture, soil-less culture offers a number of benefits to plant cultivation [37]. Hydroponics is a widely utilised method for biological research and instruction in addition to being beneficial economically [27].

VII. FUTUREPROSPECTS

Agriculture's fastest-growing industry, hydroponics, may eventually control how food is produced. As population increases and arable land declines due to poor land management, people will turn to new technologies like hydroponics create additional channels of crop production .Hydroponics technique presents a “new” door of science helping more crop production for food, fodder and ornamental use as well as produce improved yield quality. In overpopulated locations, hydroponics can generate high yields of native crops like green vegetables or flowers. Any plant or crop might be grown anywhere in the world if the hydroponics method could be modernised.

Hydroponics can feed millions in parts of Asia and Africa, where water, land and crops are scarce. Therefore, hydroponics offers a glimmer of hope for managing crop and food production. To be honest, the hydroponics approach can be useful in both high-tech space stations and rural or urban settings. When growing food in harsh environments like hilly areas, deserts, or polar towns, hydroponics can be an effective technique. In both wealthy and developing nations, there is currently a greater need for hydroponic farming. The hydroponics techniques create a yield 1,000 times larger than the same sized area of soil could produce annually. Robots employing an assembly line-style system, such those seen in manufacturing facilities, can control this system. The shipping containers are subsequently driven across the nation. NASA has elaborate plans for doing hydroponics research in space, which will help with both current and long-term space exploration.

VIII. CONCLUSION

In hydroponics, plants are grown in water rather than soil and are provided with the same nutrients as they would in regular farming. The fundamental purpose of hydroponics is to create the optimum nutritional conditions for the best plant performance, which is further improved by controlling the climate. Traditional farming uses soil not only as a storehouse for nutrients but also as a natural home for plant roots and a building block for plants. In controlled environments, the adaptive hydroponics technology of soilless plant growing is ideal for more efficient resource use and autonomous food production. Due to rising urbanization, industrialization, and glacier melting, the amount of arable land that is currently being farmed will keep decreasing. Traditional soil-based agriculture's ability to produce food is also endangered by factors like low soil fertility in some cultivable areas, decreased opportunities for natural soil fertility build-up by microbes as a result of continuous cultivation, frequent drought conditions, unpredictable climate and weather patterns, rise in temperature, river pollution, inadequate water management and waste of enormous amounts of water, decline in ground water level, etc. There are many advantages to hydroponic farming over conventional farming, including shorter crop growth cycles, year-round output, low disease and pest incidence, and the elimination of chores like weeding, spraying, and watering. Different hydroponic structures, including wick, ebb and flow, drip, and nutrient film technique systems, also have these advantages. The effective implementation of commercial hydroponic technology necessitates the development of low-cost procedures that are easy to use and maintain, require less labor overall, and have lower setup and maintenance expenses.

REFERENCES

[1.] Aghajanzadeh, T.A, Prajapati, D.H, Burow, M. (2020b) Copper toxicity affects indolic glucosinolates and gene expression of key enzymes for their biosynthesis in Chinese cabbage. *Archives of Agronomy and Soil Science* 66(9): 1288-1301

[2.] Aghajanzadeh, T.A., Prajapati, D.H., Burow, M. (2020a) Differential partitioning of thiols and glucosinolates between shoot and root in Chinese cabbage upon excess zinc exposure. *Journal of plant physiology* 244: 153088

[3.] Barman, N. C., Hasan, M. M., Islam, M. R., Banu, N. A. (2016). A review on present status and future prospective of hydroponics technique. *Plant Environment Development*, *5*(2), 1-7.

[4.] Boodley, J.W.,Sheldrakejr, R. (1977). "Cornell peatlitemixes for commercial plant growing."

[5.] De Kok, L.J., Neves, M.I., Prajapati, D.H., Shahbaz, M., Aghajanzadeh, T., Stuiver, C.E.E. (2016). The significance of sulfur nutrition and metabolism in the detoxification of excessive levels of copper, zinc and molybdenum in plants. *Berichte aus dem JuliusKühn-Institut* (184): 4

[6.] Domingues, D.S., Takahashi, H.W., Camara , C.A.P and Nixdorf, S.L.(2012). Automated system developed to control pH and concentration of nutrient solution evaluated in hydroponic lettuce production . Computers and Electroponics in Agriculture, 84 : 53 –61.

[7.] Donnan, R. (1998). Hydroponics around the world. Pract. Hydrop. Greenh. 41:18-25.

[8.] Dubey, N., Nain, V. (2020). Hydroponic- The Future of Farming. International journal of Environment , Agriculture and Biotechnology, 5(4), 857- 864.

[9.] George, P., George, N. (2016). Hydroponics-(Soilless Cultivation Of Plants) For Biodiversity Conservation. *International Journal of Modern Trends in Engineering and Science*, *3*(6), 97-104.

[10.] Gupta G., Paul S., Singh S., Pietramellara G., Pathan SI., Danish S., Jha PN. (2022) Exploring Functional Diversity and Community Structure of Diazotrophic Endophytic Bacteria Associated with *Pennisetum glaucum* Growing under Field in a Semi-Arid Region. Land 11(7): 991

[11.] Halbert-Howard, A., Häfner, F., Karlowsky, S., Schwarz, D., Krause, A. (2021). Evaluating recycling fertilizers for tomato cultivation in hydroponics, and their impact on greenhouse gas emissions. *Environmental Science and Pollution Research*, *28*(42), 59284-59303.

[12.] Informational Bulletin 43. New York State College of Agriculture and Life Sciences.

[13.] Jan, S., Rashid, Z., Ahngar, T. A., Iqbal, S., Naikoo, M. A., Majeed, S., Nazir, I. (2020). Hydroponics—A review. *International Journal of Current Microbiology and Applied Sciences*, *9*(8), 1779-1787.

[14.] Jensen, M. H. (1997). Hydroponics worldwide. In *International Symposium on Growing Media and Hydroponics 481* (pp. 719-730).

[15.] Khan, S., Guo, L., Maimaiti, Y., Mijit, M., Qiu, D. (2012). Entomopathogenic fungi as microbial biocontrol agent. *Molecular Plant Breeding*, *3*(7).

[16.] Khan, S., Purohit, A., Vadsaria, N. (2020). Hydroponics: Current and future state of the art in farming. *Journal of Plant Nutrition*, *44*(10), 1515-1538.

[17.] Kohli A., Ahmad T., Singh S. (2022) *Aegle marmelos* (Bael) and *Annona squamosa* (Sugar Apple). In Herbs, Shrubs, and Trees of Potential *Medicinal Benefits* (pp. 339-364). CRC Press

[18.] Maboko, M.M., Plooy, C.P., Bertling, I., 2011. Comparative performance of tomato cultivars cultivated in two hydroponic profuction systems.SouthAfrican journal of Plant and Soil , 28(2). 97- 102.

[19.] Maiti, M., Saha, T.(2020). Understanding Hydroponica and Its Scope in India. Just Agric, 1, 281 – 288.

[20.] Mano Bala J., Jannet Vennila J., Ganesh S., Sing S. (2011) Analysis of active components in *Acanthus ilicifolius* leaves for their potential chemo protective activity against hepatocellular carcinoma: *An in silico approach. J Pharm Res* 4: 1809-1812

[21.] Midmore, D., Deng-Lin, W. (1999). Work that water! Hydroponics made easy. *waterlines*, *17*(4), 28-30.

[22.] Mir, Y. H., Mir, S., Ganie, M. A., Shah, A. M., Majeed, U., Chesti, M. H., Wani, F. J. (2022). Soilless farming: An innovative sustainable approach in agriculture.

[23.] Moreno, D. A., López-Berenguer, C., MartínezBallesta, M. C., Carvajal, M., GarcíaViguera, C. (2008). Basis for the new challenges of growing broccoli for health in hydroponics. *Journal of the Science of Food and Agriculture*, *88*(8), 1472-1481.

[24.] Neves MI., Prajapati DH., Parmar S., Aghajanzadeh TA., Hawkesford MJ., Kok LJ. (2017) Manganese toxicity hardly affects sulfur metabolism in *Brassica rapa*. In Sulfur Metabolism in Higher Plants-Fundamental, *Environmental and Agricultural Aspects* (pp. 155-162). Springer, Cham

[25.] Nguyen, N. T., McInturf, S. A., & Mendoza-Cózatl, D. G. (2016). Hydroponics: A versatile system to study nutrient allocation and plant responses to nutrient availability and exposure to toxic elements. *JoVE (Journal of Visualized Experiments)*, (113), e54317.

[26.] Othman, Y., Bataineh, K., Al-Ajlouni, M., Alsmairat, N., Ayad, J., Shiyab, S., St Hilaire, R. (2019). Soilless culture: Management of growing substrate, water, nutrient, salinity, microorganism and product quality. *Fresenius Environmental Bulletin*, *28*(4), 3249-3260.

[27.] Pandey, R., Jain, V., Singh, K. P. (2009). Hydroponics Agriculture: Its status, scope and limitations. *Division of Plant PHysiology, Indian Agricultural Research Institute, New Delhi*, *20*.

[28.] Patani, A.V., Patel, R.R., Prajapati, D.H., Patel, M.S., Patel, A.D. (2020). Evaluation of Plant Growth Promoting Rhizobacteria to Improve Tomato (*Lycopersicon esculentum* Mill.) Productivity and Resilience under Salinity Stress. *Journal of Cell and Tissue Research* 20(2): 6953-6964

[29.] Patel, A.D., Lalcheta, K., Gill, S.S., Tuteja, N. (2013) Salinity tolerance of *Avicennia officinalis* L. (Acanthaceae) from Gujarat coasts of India. *Climate change and plant abiotic stress tolerance* 189-208

[30.] Patel, A.D., Panchal, N.S., Pandey, I.B., Pandey, A.N. (2010). Growth, water status and nutrient accumulation of seedlings of *Jatropha curcas* L.(Euphorbiaceae) in response to soil salinity. In *Anales de biología* (Vol. 32, No. 1, pp. 59-71). Facultad de Biología, Universidad de Murcia

[31.] Patel, D.J., Patani, A.V., Prajapati, D.H., Patel, C.A. (2020). Design and Synthesis of Fluorochemosensors and their Cation Recognition Study. *International Journal of Research in Engineering, Science and Management* 3(6): 279-285

[32.] Patel, P. P., Patel, P. A., Chiplonkar, S. A., Khadilkar, A. V., Patel, A. D. (2016). Effect of mid-day meal on nutritional status of adolescents: A cross-sectional study from Gujarat. *Indian Journal of Child Health*, 3(3), 203-207.

[33.] Patel, P. P., Patel, P. A., Patel, A. D., Chiplonkar, S. A., Khadilkar, A. V. (2020). Varying Body Composition and Growth in Indian Adolescents from Different Socioeconomic Strata. *Current Nutrition & Food Science*, 16(4), 578-584.

[34.] Prajapati, D.H., Aghajanzadeh, T., De Kok, L.J. (2017). Impact of sulfur nutrition and H_2S exposure on expression and activity of Group 1 sulfate transporters in developing *Brassica pekinensis* seedlings. *Berichte aus dem Julius Kühn-Institut* 191: 40

[35.] Prajapati, D.H., Ausma, T., De Boer, J., Hawkesford, M.J., De Kok, L.J. (2020). Nickel toxicity in *Brassica rapa* seedlings-Impact on sulfur metabolism and mineral nutrient content. *Journal fur Kulturpflanzen-Journal of cultivated plants* 72(9 S): 473-478

[36.] Radha, M. K., and C. Igathinathane. (2000). Greenhouse technology and measurements. BS Publications, sultan Bazar. Hyderabad,India,8178001365.

[37.] Radhakrishnan, G., Upadhyay, T. K., Singh, P., Sharma, S. K. (2019). Impact of hydroponics: present and future perspective for farmer's welfare. *Suresh Gyan Vihar University International Journal of Environment, Science and Technology*, *5*(2), 19-26.

[38.] Raviv, M., Lieth, J. H., Bar-Tal, A. (2008). Soilless culture: Theory and practice Elsevier San Diego.

[39.] Reich M., Shahbaz M., Prajapati DH., Parmar S., Hawkesford MJ., De Kok LJ. (2016) Interactions of sulfate with other nutrients as revealed by H_2S fumigation of Chinese cabbage. *Frontiers in plant science* 7: 541

[40.] Reich M., Shahbaz M., Prajapati DH., Parmar S., Hawkesford MJ., De Kok LJ. (2016) Mineral nutrient composition of *Brassica pekinensis L.* as affected by plant sulfur status

[41.] Resh, H. M. (2022). *Hydroponic food production: a definitive guidebook for the advanced home gardener and the commercial hydroponic grower*. CRC press.

[42.] Roberto, K. (2003). *How-to hydroponics.* Futuregarden, Inc.

[43.] Rodriguez,A.(2012). Advances of Hydroponics in Latin America. Acta Hort.947, 23- 32.

[44.] Sardare, M. D., Admane, S. V. (2013). A review on plant without soil-hydroponics. *International Journal of Research in Engineering and Technology*, *2*(3), 299-304.

[45.] Savvas, D. (2002). *Hydroponic production of vegetables and ornamentals* (p. 463). H. Passam (Ed.). Athens: Embryo publications.

[46.] Sharma, N., Acharya, S., Kumar, K., Singh, N., Chaurasia, O. P. (2018). Hydroponics as an advanced technique for vegetable production: An overview. *Journal of Soil and Water Conservation*, *17*(4), 364-371.

[47.] Sheikh, B.A. (2006). Hydroponics: Key To Sustain Agriculture In Water Stressed And Urban Environment . Pak.J.Agri., Agril. Engg., Vet.Sc.22(2), 53- 57.

[48.] Singh A, Sengar RS, Singh AK, Singh S, Kumar A, Ahmad K (2019) Impact of genetic engineering on agriculture food crops. Biotech Today: *An International Journal of Biological Sciences* 9(1): 17-24

[49.] Swain, A., Chatterjee, S., Vishwanath, M. (2021). Hydroponics in vegetable crops: A review. *The PHarma Innovation Journal*, *10*(6), 629-634.

[50.] Treftz, C., Omaye, S. T. (2016). Hydroponics: Potential for augmenting sustainable food production in non-arable regions. *Nutrition & Food Science*.

[51.] Verma N., Sao P., Srivastava A., Singh S. (2021) Physiological and Molecular Responses to Drought, Submergence and Excessive Watering in Plants. In Harsh Environment and Plant Resilience (pp. 305-321). *Springer, Cham*

[52.] Yang, X., T. H. Short, R. D. Fox, and W. L. Bauerle. (1990). A theoretical model of solar radiation transfer in low crop canopy. Transactions of ASAE 33 (3): 917-24.

[53.] Yuvraj, M., Subramanian , K.S.(2020). Different Types Of Hydroponics System. Biotica Rsearch Today , 2 (8), 835- 837.

[54.] Zuidersma, E.I., Ausma, T., Stuiver, C.E.E., Prajapati, D.H., Hawkesford, .., De Kok, L.J. (2020). Molybdate toxicity in Chinese cabbage is not the direct consequence of changes in sulphur metabolism. *Plant Biology* 22(2): 331-336.