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AGRI-TRANSFORMATION TO VERTICAL FARMING SYSTEM TO REDUCE DEPENDENCY ON NATURAL HABITATS, TO CONSERVE ENDANGERED SPECIES AND TO ENHANCE ECONOMICAL PLANTS TO OVERCOME THEIR GROWING MARKET DEMAND

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Abstract

The increasing urbanization has led to the reduction of crops and productivity of other economical plants. To overcome this issue, the country needs an alternative strategy to fulfil the growing market demand. Vertical Hydroponic Farming Systems (VHFS), which involves cultivating plants in controlled indoor environment offer a potential solution to this burning issue. These systems provide numerous advantages over traditional agriculture by enabling precise control over environmental conditions. Vertical farming is recognized as a transformative approach for agri-food systems, particularly in urban or peri-urban contexts. VFS represent advanced indoor cultivation methodologies that facilitate the maximum productivity. The controlled regulation of environmental parameters within these systems enhances the stability and consistency of plant yields, allowing for uniform quality and quantity throughout the year bypassing seasonal variations. In this context, PCSIR Labs., complex, Peshawar took initiative to optimize growing [4]conditions for various plants through VFS. A successful response has been observed by cultivating high-valued and economical plants in the best interest of the public and for industrial use. Medicinal Botanic Centre (MBC), PCSIR has successfully optimized culture conditions for Strawberry, Stevia, Corn mint, Peppermint, Lavender-mint, Spearmint, Tulsi (jangli), Tulsi (holy basil), Sweet basil, Yarrow, Sweet violet, Lemon balm and Musk geranium. These plants were successfully propagated in larger quantities. These plants are being provided for R&D and supplied to industries. The industries are now interested in these plants as compared to the local market-driven plants because these plants are authentic, free from pesticide, weedicide and adulteration. Therefore, it has been practically proven that VFS is the best strategy to enhance the production of multiple plants throughout the year.

Key words: Hydroponics, Vertical farming systems, cost-effective method, organic production, contamination free production, avoid seasonal variation, zero adulteration

Introduction

Hydroponic vertical farming is a cutting-edge agricultural technique that allows for the cultivation of plants without soil, using nutrient-rich water solutions (Smith & Walker, 2024). This innovative system is particularly advantageous in urban environments where land is limited, making it an essential solution for enhancing food security and meeting the rising demand for various plant types, including medicinal plants,

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economically valuable crops, and plants in high industrial demand (Al-Khouri et al., 2021). By integrating hydroponics with vertical farming, growers can optimize space, improve yield, and minimize resource use, offering a sustainable alternative to traditional farming methods (Zhang et al., 2022).

The hydroponic vertical farming system employs controlled environment agriculture techniques, which significantly boost plant growth and quality (Al-Khouri et al., 2021). This is particularly crucial for medicinal plants, where consistent quality and potency are essential (Lee et al., 2023). Research has shown that hydroponically grown medicinal plants, such as basil and mint, can have enhanced phytochemical content, offering greater therapeutic benefits compared to their soil-grown counterparts (Kumar et al., 2019). For example, a study indicated that hydroponically cultivated basil had up to 30% more essential oils than traditionally grown plants, thereby improving its market value (Rahman et al., 2020).

In addition to medicinal applications, hydroponic vertical farming is well-suited for economically important crops, including herbs, leafy greens, and fruits. The increasing demand for organic production in urban areas makes this method particularly attractive. Vertical farming can lead to substantial increases in yield per square meter, significantly enhancing economic viability for urban farmers (Saha et al., 2020). For instance, lettuce grown in vertical hydroponic systems has been shown to produce yields 5-10 times greater than conventional farming, allowing farmers to capitalize on high market prices (Yin et al., 2023). Some of the recent realistic examples of plants grown in hydroponics are shown in table 1.1.

Moreover, hydroponic systems can also support the cultivation of industrially demanded plants, such as those used in biofuels, pharmaceuticals, and cosmetics. Plants like *Aloe vera* and stevia, which are experiencing growing market demands due to their diverse applications, can be efficiently produced in hydroponic systems. The ability to grow these plants year-round, independent of seasonal fluctuations, ensures a reliable supply chain critical for industries that depend on consistent raw materials (Jones et al., 2021). A recent report highlighted that the hydroponic production of stevia has increased by over 60% in the past five years, reflecting its rising importance in the food and beverage industry (Smith & Walker, 2024).

Table-1.1: Comparison of plants production with active metabolites in hydroponics vs soil.

Plant Species	Comparison with Soil	Conservation Benefits	Metabolites	Short References
Aloe Vera	Year-round production	Sustainable product for cosmetics	Aloin, acemannan	Jones et al., 2021; Smith & Walker, 2024
Apium graveolens	Better texture and flavor in hydroponics	Reduces chemical use	Apigenin, flavonoids	Thompson et al., 2022; Lee et al., 2023
Brassica oleracea var. capitata	Consistent quality and shelf life in hydroponics	Effective space utilization	Glucosinolates	Saha et al., 2020; Zhang et al., 2022

Plant Species	Comparison with Soil	Conservation Benefits	Metabolites	Short References
Brassica oleracea var. sabellica	Higher nutrient density compared to soil-grown kale	Effective use of vertical space	Vitamins K, A; flavonoids	Saha et al., 2020; Zhang et al., 2022
Brassica rapa subsp. chinensis	Higher biomass in hydroponics	Reduces land usage	Glucosinolates	Thompson et al., 2022; Lee et al., 2023
Berries (various species)	Consistent quality and flavor in hydroponics	Reduces transportation impact	Antioxidants	Smith & Walker, 2024; Al-Khouri et al., 2021
Capsicum annuum	Better fruit size and flavor in hydroponics	Sustainable farming practices	Capsaicin	Al-Khouri et al., 2021; Jones et al., 2021
Capsicum spp.	Hydroponics can enhance fruit size and capsaicin levels	High demand for fresh produce	Capsaicin	Al-Khouri et al., 2021; Zhang et al., 2022
Coriandrum sativum	Better flavor profile in hydroponics	Reduces pesticide use	Essential oils (e.g., linalool)	Al-Khouri et al., 2021; Jones et al., 2021
Cucurbita pepo	Larger fruit size and quality in hydroponics	Sustainable farming benefits	Carotenoids	Saha et al., 2020; Zhang et al., 2022
Cucurbita maxima	Higher yield and quality in hydroponics	Effective space utilization	Carotenoids	Smith & Walker, 2024; Al-Khouri et al., 2021
Foeniculum vulgare	Hydroponics improves bulb size and flavor	Reduces pesticide reliance	Anethole, flavonoids	Al-Khouri et al., 2021; Jones et al., 2021
Fragaria × ananassa	Consistent size and sweetness in hydroponics	Reduces carbon footprint	Antioxidants (e.g., ellagic acid)	Al-Khouri et al., 2021; Lee et al., 2023
Lactuca sativa	Yields 5-10 times greater than soil-grown lettuce	Minimal land footprint	Vitamins A, C; flavonoids	Saha et al., 2020; Yin et al., 2023
Mentha spp.	Increased potency in hydroponics	High market demand for fresh mint	Menthol, rosmarinic acid	Kumar et al., 2019; Jones et al., 2021
Microgreens (various species)	High nutrient density in small space	Quick turnaround for profit	Vitamins and antioxidants	Thompson et al., 2022; Lee et al., 2023
Ocimum basilicum	Higher essential oil content in hydroponics (30% more)	Reduces water use by up to 90%	Essential oils (e.g., eugenol)	Kumar et al., 2019; Rahman et al., 2020
Origanum vulgare	Hydroponic growth increases aromatic profile	Sustainable production method	Carvacrol, thymol	Al-Khouri et al., 2021; Jones et al., 2021
Phaseolus vulgaris	Improved yield and quality in hydroponics	Efficient water use	Antioxidants	Thompson et al., 2022; Lee et al., 2023
Petroselinum crispum	Consistent growth quality in hydroponics	Efficient nutrient use	Vitamins C, K; flavonoids	Saha et al., 2020; Zhang et al., 2022
Raphanus sativus	Faster maturity compared to soil	Minimal resource consumption	Glucosinolates	Saha et al., 2020; Zhang et al., 2022

Plant Species	Comparison with Soil	Conservation Benefits	Metabolites	Short References
Solanum lycopersicum	Consistent quality and disease resistance in hydroponics	Reduces land use and waste	Lycopene, vitamins C and K	Thompson et al., 2022; Lee et al., 2023
Stevia rebaudiana	Hydroponically grown stevia shows 60% yield increase	Supports healthy sweetener options	Steviol glycosides	Smith & Walker, 2024; Yin et al., 2023
Thymus vulgaris	Higher oil concentration in hydroponics	Conserves water and nutrients	Thymol, carvacrol	Kumar et al., 2019; Rahman et al., 2020

The environmental benefits of hydroponic vertical farming are significant. This method can reduce water usage by upto 90% compared to traditional agriculture, thanks to recirculation and efficient nutrient delivery systems (Thompson et al., 2022). This reduction is critical in regions facing water scarcity, where traditional farming can exacerbate resource depletion. Furthermore, vertical farms can be established in urban areas, minimizing transportation emissions and ensuring fresh produce reaches consumers quickly. Integrating renewable energy sources, such as solar power, further enhances the sustainability of these systems, allowing them to operate with lower carbon footprints (Lee et al., 2023).

Pakistan is a net food exporter, except in occasional years when its harvest is adversely affected by droughts. Following the poor harvest in nineties, the government has been introducing agriculture assistance policies, including increased support prices for many agricultural commodities, and expanded availability of agricultural credit. Agricultural reforms play a central role in the government economic reform package. Unfortunately, outdated irrigation practices have led to inefficient water usage in Pakistan. Almost, 25% of water withdrawn for use in the agricultural sector is lost through leakages, and line losses in the canals. Only a limited amount of the remaining water is actually absorbed and used by the crops due to poor soil texture, and unleveled fields.

Vertical farming includes the method of growing crops in stacked layers. It incorporates controlled-environment agriculture, optimizes plant growth, and utilizes soilless farming techniques like hydroponics, aquaponics, or aeroponics. Hydroponic farming is growing soil free plants that use mineral nutrient solutions in water to regulate the plant growth in the available atmosphere. Herein, the installation of vertical hydroponics growing system was carried out to increase the yield of medicinal herbs that are resistant to severe environmental conditions of Pakistan. In line with this, the herbal extracts of the grown plants will be subjected to analytical techniques, process development and phytochemical standardization to exploit the plants for use in food, therapeutic herbal and cosmaceutical products.

In developed countries many people are switching towards alternative therapies, resulting in manifold increase in the demand of medicinal plants and their products. As majority of these plants are unsustainably collected from their natural habitat, leading the existence of these plants towards extinction. To conserve the natural flora and for sustainable & uninterrupted supply of raw material, and by using advanced farming techniques including hydroponic farming, domestic cultivation of medicinal

plants is the best option to overcome these threats. Hydroponic vertical farming systems represent a revolutionary approach to agriculture, particularly for the cultivation of medicinal, economically valuable, and industrially demanded plants. As urban populations grow and environmental challenges mount, innovative agricultural solutions will be increasingly critical. By leveraging the advantages of hydroponics and vertical farming, stakeholders can effectively meet market demands while promoting sustainable practices. The overall objective of the current project was to strengthen agriculture sector by introducing new technologies in the country, saving water as compared to conventional farming, R&D activities for better utilization of the natural resources i.e. fruits, vegetables and medicinal herbs available in the country and to save land and to enhance an efficient, and low cost crop production via recyclable protocol.

Materials and Methods

The current project is ongoing under the supervision of Dr. Hina Fazal (SSO) at the Medicinal Botanic Centre (MBC), PCSIR Labs Complex Peshawar. The execution of this project needs important parameters to obtain enhanced productivity.

Selection and preparation of land

The land for hydroponic vertical farming was provided at feasible location without harming the biodiversity (flora and fauna) and infrastructure. An isolated and suitable land was selected upon mutual consensus of various personals involved in this project (Figure 1.1).



Figure-1.1: Selection of suitable land, preparation of land, leveling, water channel, and installation of VHFS for feasible productivity

Net-house Installation:

During installation, a proper set-up was designed for the usage of net/green-house to protect plants from vectors carrying pathogens (Figure 1.2) and to induce uniform productivity throughout the year.



Figure-1.2: Pictorial presentation of net-house installation for VHFS

Drip irrigation system and drainage system

There are several types of vertical hydroponic systems, such as a nutrient film technique (NFT), drip irrigation system, or deep water culture (DWC) system. Each system has its own advantages and disadvantages, and we choose the drip irrigation system that is suitable and working properly as compared to others (Figure 1.3). A proper setup was designed for water circulation and drainage depends on the requirements.



Figure-1.3: Drip-irrigation system, auto-shading and ground cover at VHFS

Stacking of containers, Construction of storage tank & Installation of Reverse Osmosis (RO) water plant and gallons for fertilizers

Containers designed for vertical farm have an excellent potential for water retention capacity or nutrients, power supply for operation (helps to measure density of nutrients in water as water has no EC as it contains no nutrients and best range for EC is 1.6 - 1.8 for better performance) and water sources were managed for the RO plant. Storage tanks were selected on basis of capacity to provide proper water and nutrients during the operation of RO plant. For gravity-based water flow, the tanks were slightly installed at elevated position with valves for inlet/outlet connections (Figure 1.4). The reverse osmosis system was installed near the storage tanks. The RO system was regularly monitored to check its efficacy, pressure, and water circulation through the

VFS and tanks. Periodic maintenance of the irrigation system, water flow, leakage, nutrient levels and filter performance was properly investigated in the current project



Figure-1.4: Construction of water storage tank, RO plant un-packing, RO plant installation and isolated room for RO with proper power supply, water inlet/outlet and tanks when needed for fertilizers during VHFS installation.

Nutrient Formulation for Coco-peat Based Substrate

Nutrient solution acts as butter and bread and NPK is regarded as special sauce for VHFS with Part (A) containing Calcium Nitrate, Potassium Nitrate and Iron Chelate, while the Part (B) comprising Mono Potassium Phosphate, Magnesium Sulphate, Manganese Chelate, Zinc Chelate, Borax, Copper Chelate, Sodium molybdate that play a key role in plant architecture, major functions, vegetative and reproductive productivity. Coco-peat is used as a substrate for nutrients attachment and retention, and as a support for the rooting plants (Figure 1.5).



Figure-1.5: Coco-peat filling in strawberries containers in VHFS

Cocopeat based hydroponics system having no nutrients. Additional nutrients are required for the plants. Nutrients were added through drip irrigation system from the already prepared stock solution in two separated tank (tank A & tank B). Equal quantity

of stock solution from tank A & tank B were added to another tank C and adjust the final volume of tank C according to the crop requirement. EC & pH can be adjusted at vegetative and reproductive stages accordingly. RO water was chemically analyzed for pH, EC, TDS and minerals. The pH of the nutrients was maintained (6 to 6.5) for maximum productivity.

Seedlings development from seeds

Stevia seeds were sown in a raised seed bed which was composed of Sand, Silt and Clay. Seeds were emerged in 8-10 days and seedlings were transplanted to the vertical hydroponics system after a month (Figure 1.6).

Seedling development through cutting

Stevia is perennial plant and can easily propagated through cuttings. The young shoots were cut and planted in plastic bags and peat moss trays. The seedlings were well established in 2-3 weeks and were than transplanted to vertical hydroponic system (Figure 1.6).

Optimization of physical condition, Timing & Duration

Physical condition of the vertical hydroponics system was maintained through different techniques like auto shading during excessive light hours.

Weed Managements

Weeds can be a common problem in hydroponic systems, especially if the system is outdoors or if the growing media contains weed seeds. Weeds were controlled in the system manually on regular basis.



Figure-1.6: Plantlets growth and development for VHFS includes seed-derived plants and stem cutting.

Data Collection

Data were collected on routine basis for mortality rate, healthy plants, crop growth rate, number of leaves and plant height.

Harvesting

Stevia was harvested for final product development and grinded in the lab.

Results

The current results suggested that VHFS is preferred over other conventional cultivation techniques due to year-round crop production, better use of space, more sustainable than soil farming, less resource waste, reduced-transportation costs, lower labour cost and overall considered as a cost-effective technology

Vertical farming is not weather dependent and therefore, consistent year-round crop production without the impact of adverse weather conditions may be achieved. It is safe growing technique that is allowed repeatable and programmable crop production in climate-controlled environment. This technology allows automation to reduce harvest times, and improve yield without compromising on flavor or quality.

Traditional farms need fertile arable land. On the other hand, vertical farms can be designed and built in any climate or location, regardless of weather conditions or extreme temperature. Vertical growing allows to the farmers to achieve higher productivity in a relatively small space. Depending on the crops grown, one acre of a vertical farm could grow the equivalent of 10 to 20 soil-based acres.

Indoor farming can be more environmentally friendly since it reduces the amount of fossil fuels needed for farming equipment. Secondly, solar light can help mitigate these costs to the environment. Vertical farming helps improve biodiversity because it does not cause a land surface disturbance, which helps the natural animal population that lives in, and around farms to thrive.

If managed correctly and with the proper methods, growing crops in a vertical farm offer the opportunity to eliminate the need for pesticides. Pests cannot easily enter a controlled environment to cause infestations, and fungal diseases cannot survive as humidity levels are managed. Vertical farms, especially those that use hydroponics, use far less water than traditional farms as well. The water is recycled, and there is virtually no water wasted.

Growing crops closer to where customers live is a massive vertical farming benefit. It reduces transportation costs, CO_2 emissions, and reduces the need for refrigerated storage, that makes the farmers to produce fresher and more profitable crops.

Fully automated indoor growing systems and greenhouses do not need huge amounts of manual labor to achieve successful year-round production. Obviously, supporting staff is needed to conduct crop registration, and ensure equipment is working properly. Thus far less manpower is needed to manage the growing environment.

Similarly, hydroponics includes technique of growing plants without soil, by using mineral nutrient solutions in an aqueous solvent. The main purpose of hydroponics is to demonstrate many advantages, notably a decrease in water usage in agriculture.

The current project aims to grow the following herbs and/or fruits plants with detailed applications/uses via hydroponic vertical protocol.

Medicinal and economical plants grown in VFS at PCSIR-Peshawar.

1. *Fragaria× ananas* (Strawberry)

Fragaria× ananassa originated in Europe in the 18th century, currently many countries have developed their own varieties during the 19th century, and those are suitable for the climate, day length, altitude, or type of production required in a particular region. Strawberries are produced commercially both for immediate consumption and for processing as frozen, canned, or preserved berries or as juice. Given the perishable nature of the berries and the unlikelihood of mechanical picking, the fruit is generally grown near centers of consumption or processing and where sufficient labour is available. To overcome all these issues strawberries will be produced by hydroponic farming. In this project, more than 3000 strawberries were propagated from seedlings with highest survival rate (90%) in vertical farming (Figure-1.7).



Figure-1.7: Cultivation of *Fragaria× ananassa at vertical farming system with quality flowering, fruiting and harvesting.*

2. *Mentha spp.*

Genus Mentha, with more than 30 reported species, grows across the world. Some of the common species of Mentha such as *M. aquatica, M. arvensis, M. citrata, M. longifolia, M.piperita, M. pulegium, M. rotuntifolia*, and *M. spicata* are commonly grown for the production of essential oils (EOs) or utilized as food flavoring and medicinal agents. Mentha species are widely used as a flavoring agent in raw and processed foods such as soups, salads, herbal teas, cheese, and breads. Likewise, the EOs and extracts from Mentha plants are now gaining popularity as natural ingredients in herbal cosmetics and pharmaceutical preparations. High yielding menthol varieties including

Mentha piperata, *M. citrata* and *M. spicata* were grown hydroponically. These Mentha species displayed 78% survival in the current VFS at PCSIR-Peshawar (Figure-1.8).



Figure-1.8: Cultivation and potential applications of Mentha spp. Grown at VHFS.

3. *Stevia rebaudiana*

Stevia rebaudiana is a small perennial shrub that has been used for centuries as a bio-sweetener and for other medicinal purposes. Its chemical compounds including steviosides and rebaudiosides are 200-300 times sweeter than table sugar. It can be used for diabetic and obese persons. *S. rebaudiana* showed antibacterial, antiseptic, anti-inflammatory, anti-fertility, hypotensive, diuretic and cardiotonic properties.

In this project, the strawberries and Stevia displayed the highest survival (88%) and production at vertical farming system. The local demand for stevia powder for diabetes and obesity are too much higher. The only way to overcome the higher demand is to propagate stevia through vertical farming (hydroponics). Some of the pictures of stevia growth was shown in figure-1.9.



Figure-1.9: Nursery development for stevia plants, transferring to hydroponics (VHFS), growth studies, harvesting and packaging for market demand.

4. *Melissa officinalis* (Lemon balm)

Melissa officinalis is a medicinal plant that has long been used in different ethno-medical systems for the treatment of several diseases. It is also widely used as a vegetable and to add flavor to dishes. Phytochemical investigations revealed that this plant contains volatile compounds, triterpenoids, phenolic acids and flavonoids. Crude extracts and pure compounds isolated from *M. officinalis* exhibited numerous pharmacological effects including anxiolytic, antiviral and antispasmodic activities of this plant. Moreover, its effects on mood, cognition and memory have been shown in clinical trials. In VHFS the lemon balm displayed 70% survival (Figure 1.10). Interestingly, it has been observed that these plants exhibited friendly growth in VHFS as compared to soil with vigorous and lush-green appearance for limited period and finally represent 70 % survival.



Figure-1.10: Growth stages of *Melissa officinalis* in hydroponics (VHFS).

5. *Rosmarinus officinalis* (Rosemary)

Rosemary has therapeutic properties and has been used in the folk medicine, pharmaceutical, and cosmetics industries, mainly for its antioxidant and anti-inflammatory properties. Other uses studied, includes wound healing and skin cancer and mycoses treatments. Moreover, rosemary has potential applications in cosmetic formulations and in the treatment of pathological and non-pathological conditions, such as cellulite, alopecia, ultraviolet damage, and aging. Rosemary has also shown better response to VHFS. Now, we have shown more 1000 plants for studies various growth stages and overall production.

6. *Origanum vulgare* (Origano):

Genus Origanum is important medicinally as it has antimicrobial, antioxidant, antifungal, antibacterial, antimutagenic, antithrombin, antiparasitic, angiogenic, and antihyperglycaemic activities. Phytochemical investigations of the species of this genus have resulted in the extraction of a number of important bioactive compounds. Origano is used as seasoning in different dishes, soup and salads.

The origano was found VF friendly plant in the current project. An estimated production of the origano is more efficient than soil plantation with 85 % survival which was comparatively higher than growing in natural repositories. VF-based production, harvesting and its proper packaging (Figure 1.11) was formulated for market-based demand.



Figure-1.11: Packaging of origano after growing in hydroponics (VFS at PCSIR-PESH)

7. *Ocimum basilicum* and *Ocimum sanctum*

The genus with multiple species that were grown in hydroponics at large numbers. The quality and taste of the VFS-based plantlets were too much favorable than field grown plants. These species perform the best survival in hydroponics ranges from 95 to 97 % and we are further increasing their quantities as most of the industries demanded it. These are highly medicinal species with their Anti-inflammatory, Immuno-modulatory, Antioxidant, Antibacterial, Antispasmodic, Aromatic-health promoting agents, body parts specific-Tonic, and Carminative properties with potential to cure Digestive problems and commonly used in herbal teas and various commercial products for health benefits.

Here, a special packaging material was designed for powdered (*Osimum* species) to avoid humidity and adulteration and to attract maximum customers (Figure 1.12).



Figure-1.12: The most effective species grown in VHFS **(a)** *Ocimum basilicum* **(b)** *Ocimum sanctum* **(c)** the most sale out dengue drop obtained from VHFS-grown plants

8. *Achillea millefolium* and *Geranium macrorrhizum*

The highly medicinal and aromatic species with huge biological properties. *Achillea millefolium* is considered the most important medicinal plant of Pakistan while the alien/exotic *Geranium macrorrhizum* essential is commonly used for treating multiple ailments. One of the interesting aspects of the specie is “Musk perfumes” that is obtained from the leaves of *Geranium macrorrhizum* and famous throughout the world. Other properties of these medicinal species depend on its use either additive,

nutritional supplements, and possessed antiseptic, antispasmodic, astringent, carminative, diaphoretic, digestive, vasodilator, aromatherapy, soothing effect, immuno-stimulatory and perfumery industries. Some of pictures of VFS-based products of species were shown in figure-1.13.



Figure-1.13: Growing medicinal species at VHFS **(a)** 30-days old *Geranium macrorrhizum* **(b)** mature *Geranium macrorrhizum* **(c)** *Geranium macrorrhizum*-based marketable product and **(d)** *Achillea millefolium*-based products from various industries with different names.

The above mentioned fruits and medicinal herbs including others like Viola, Achillea and Geranium will be cultivated at large scale for R&D demand by following the vertical hydroponics farming. The selection of plants is based on the suitability of environmental factors needed for the efficient crop production. Some of the pictorial presentation of plants grown at VHFS was given below (Figure-1.14) from recently installed system at PCSIR-Peshawar with huge potential for nearest industries and other stakeholders.



Figure-1.14: Potential products of medicinal/economical species currently growing/available at PCSIR-Peshawar and further formulations are in progress for developing, cosmaceutical & medicinal products including dry skin\Moisturizer, sensitive skin, acne\hyper pigmentation, anti-ageing, scrub, shampoo for hair fall\ dandruff, Soap, Sun Screen lotion.

Discussion

The hydroponics and specially the VHFS was found to most suitable for the cultivation of various plants. Some of the selected species that were grown in current study represent excellent survival and uniform productivity (Figure-1.15).

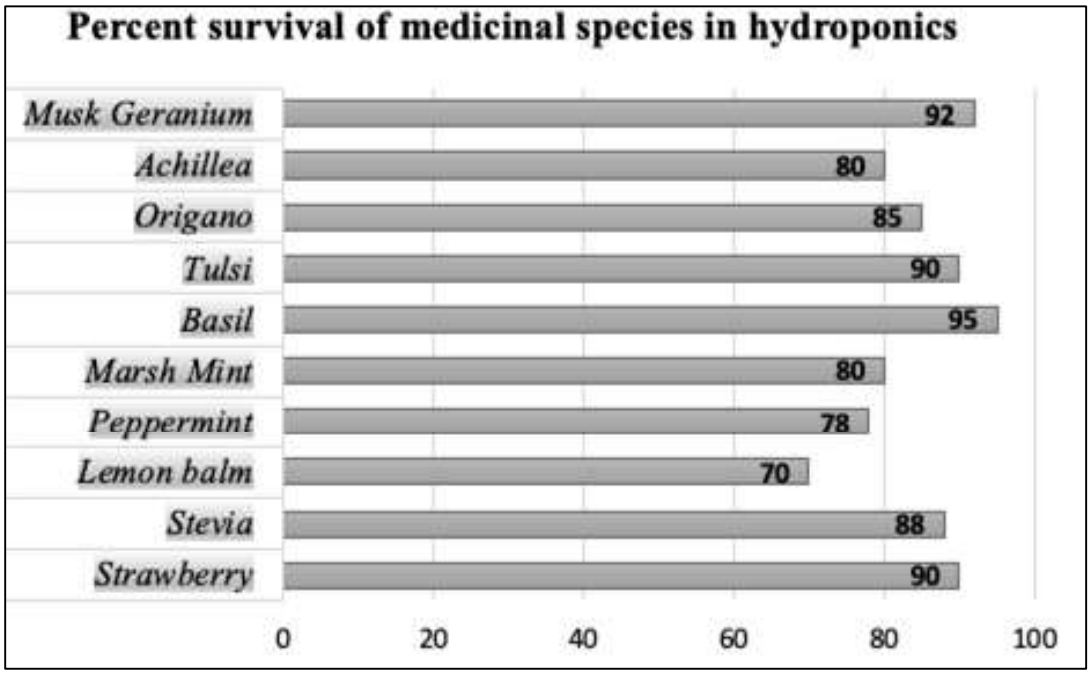


Figure-1.15: Various plants and its survival percentage after growing in hydroponics

Hydroponic farming offers an effective way to reduce agriculture's reliance on soil, enabling more sustainable crop production. By growing plants with their roots immersed in nutrient-rich solutions instead of soil, hydroponics enhances crop yields per unit area and shortens production cycles, resulting in high-quality crops grown more quickly than in traditional farming systems (Mahjoor et al., 2016). This method not only reduces the need for large tracts of land but also minimizes environmental impacts by optimizing nutrient use in the growing solution (dos Santos et al., 2013; Peer and Schippers, 1989; Khalil et al., 2001). Studies indicated that land requirements can be reduced by up to tenfold, and yields per unit area can increase by up to eleven times compared to conventional agriculture (Barbosa et al., 2015). Hydroponic systems also offer a number of benefits, including the absence of soil, which simplifies maintenance and cleaning while making it easier to manage pests and diseases between crop cycles (Mahjoor et al. 2016). The efficient use of resources, such as water and nutrients, reduces waste and improves overall sustainability. Additionally, hydroponic farming generates a lower carbon footprint, particularly when powered by renewable energy, compared to traditional agriculture that heavily relies on fossil fuels (Barbosa et al. 2015). The faster crop production and higher yields per unit area allow for more efficient land use, while reduced shipping costs are possible when hydroponic systems are located near urban areas. Furthermore, hydroponic farms can operate year-round, even in colder climates, by using artificial lighting to supplement or replace natural sunlight. This makes hydroponics a promising solution for sustainable, high-efficiency food production.

This project aims to introduce versatile hydroponic vertical farming system at PCSIR Laboratories Complex, Peshawar. This research unit is equipped with well reputed Medicinal Botanic Centre, as well as, Food Technology Centre. The project outcomes will be subjected to the already installed scientific technique for essential analytical and biological tests for the suitability as food and medicine. Peshawar is the capital of KP, that

is linked will all provinces of Pakistan through motor ways and high ways etc. Also, the city has its own international airport. Most of the industries surrounding the project area required raw material, standardized extracts, food and herbal products. Therefore, there is remarkable potential for business portfolio of the private sector, large and small scale industries specially including food, herbal and pharmaceutical sector.

Hydroponics is a need of the current agriculture industry and now even more so since water is becoming a scarce resource of our country and the planet. Hydroponics ensures this and saves up to 90% of fresh water to be used in this particular system. We will be using this technology to grow the Best and most Premium, Pesticide free, Herbicide free, Soil free, luscious and fine quality herbs which has no match in the current traditional market. Such fruits, vegetables and herbs can only be found in imported products which fetches a huge price tag from our local venders as well.

Indoor farming can be more environmentally friendly since it reduces the amount of fossil fuels needed for farming equipment. And while energy bills can be high, solar can help mitigate these costs to the environment Vertical farming helps improve biodiversity because it does not cause a land surface disturbance, which helps the natural animal population which lives in and around farms to thrive. If managed correctly and with the proper methods, growing crops in a vertical farm offer the opportunity to eliminate the need for pesticides. Pests cannot easily enter a controlled environment to cause infestations, and fungal diseases can't survive as humidity levels are managed. Vertical farms, especially those that use hydroponics, use far less water than traditional farms. The water is recycled, and there is virtually no water wasted. The proposed idea is better in the sense of growing more product in the limited area without any loss of water and nutrients in a soil free medium. It is therefore believed the project will replace the trivial farming method for the majority of herbaceous plants growth to achieve efficient production at low cost. Vertical hydroponic farming is not dependent on the weather, so consistent year round crop production will be achieved without the impact of adverse weather conditions. Further, growing in a safe, climate-controlled environment will allow for repeatable and programmable crop production. Such technique allows automation to reduce harvest times and improve yield without compromising on flavor or quality. Likewise, the project will help to eliminate the need for pesticides. Pests cannot easily enter a controlled environment to cause infestations, and fungal diseases cannot survive as humidity levels are managed. Briefly, the project straight aims to producing strawberry, and other herbaceous plants. The plants are potential in making food stuff, and medicine to fulfill the basic needs of humankind. The food product will be readily sold out to the market on high definite demand for revenue generation.

Conclusions/ Recommendations:

The proposed idea will help in growing the crops closer to where customers live. It reduces transportation costs, CO_2 emissions, and reduces the need for refrigerated storage, making produce fresher and more profit-able. The production of natural and medicinally sound stuff will fulfills the basic needs of human kind. The food product will be readily sold out to the market on public demand, and the Marketing & Sales Plan will be efficiently applicable at limited processing costs. No advertisement charges will be required, instead the low cost availability will attract the public, and therefore the

sale will be high. To cut short, the proposed idea will help in enhancing the fruits and herbaceous plants production. Furthermore, the current project has definitely opened up new horizons for the researchers of PCSIR, and other organizations, many stake holders are approaching to pursue their research (of choice) in efficiently producing targeted crops.

The beneficiaries/interested parties of the project include Agriculture, Food, Cosmaceutical and Herbal Pharmaceutical industries/ entrepreneurs. Various types of food, cosmetics and herbal products will be developed, as well as uninterrupted raw material supply will lessen the burden on inter-cities transport and international import.

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