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भाकृअनुप
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Foreword

Providing quality nutritive food to more than 1.64 billion people by the Year 2050 would be a major challenge for the country. Increasing population, decreasing land and water holding, urbanization, industrialization, global warming are some of the major impediments related to agriculture. Various biotic and abiotic stress factors are threatening the open field agricultural production systems throughout the world in varying degrees. The soil fertility status has attained almost the saturation level in most parts of the country and productivity is not rising *pro rata* with the amount of inputs. More than 6 million ha area has been affected by salinity and alkalinity apart from other factors continually degrading the soil health. Under these circumstances, it would become increasingly difficult to provide quality nutritive food for the burgeoning population in the near future. The demand for fresh and green horticultural produce, mainly vegetables, fruits and flowers, is rising sharply particularly in peri-urban and urban areas. Under such scenario, Smart Urban Farming system is emerging as potentially alternate technology for growing quality vegetables and flowers through Hydroponics, Soil less, Aeroponic, Vertical Farming technology under limited space with integration of smart sensors and automation throughout the year. Although the technology is in fledgling stage in the country it is high time that initiatives are taken for timely technological adoption and its agro-ecological refinement *vis-a-vis* our crops and climate, so that the pace of development is in tune with the needs of the nation, economic viability of production systems, health and safety of the consumers. The Government of India has been providing technical and financial support to the commercial initiatives related to Smart Urban Farming through National Horticultural Board (NHB) and National Horticultural Mission (NHM). Our institute is mandated to spearhead modern smart technological innovations including Protected, Vertical and Urban farming in agricultural production system besides their outreach to all the stakeholders. I am happy that the team of scientists from CPCT, IARI have taken a lead in developing a popular literature on "Smart Urban Farming Technology" for its wide spread not only for technological but also its commercial adoption at large. I congratulate the authors for their efforts in developing this technological bulletin, which I am sure would be helpful in adoption of Smart Urban Farming technology among farmers, growers and urban citizen of our country.

(Ashok Kumar Singh)

New Delhi
Date: 05.03.2022

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Preface

Smart Urban Farming is being actively practised by many farmers, entrepreneurs, professionals and common citizens mainly in peri-urban and urban areas for growing green vegetables, flowers, seedlings and herbs in many parts of the world. It has become one of the most popular agricultural technologies related to precision farming and protected cultivation. The major advantage of Smart Urban Farming is round the year availability of green, healthy and safe horticultural produce. Its technological advantages are encouraging growers and professionals to start the cultivation with their own initiatives, innovations and investment in kitchen garden, rooftop, balcony and farms. Lately it is fast catching up with not only among progressive growers but also urban and peri-urban households. Lack of technical knowhow, systematic protocols and procedures, input management and plant protection are some of the major impediments in the expansion and popularization of Smart Urban Farming. The major problems being faced by the growers are non-availability of indigenous Smart Urban Farming models and fertigation scheduling charts in the form of user friendly packages. ICAR-IARI has been actively promoting Smart Urban Farming, protected cultivation and precision farming technology through its dedicated Centre for Protected Cultivation Technology. The Centre has been actively working on different aspects of protected cultivation, Vertical farming and Smart Urban Farming. The Centre has standardized various indigenous Smart Urban Farming models like soilless, hydroponics, Aeroponic, vertical farming with water and nutrient budgeting and fertigation scheduling. User friendly models and related fertigation scheduling charts have been developed to prepare indigenous fertigation solutions with local and commonly available water soluble fertilizers in the most economical way. The bulletin deals with the suitable designs of structures, production and protection technologies, fertigation scheduling, GAP & IPM, Government initiatives and addresses of fabricators and suppliers, related to Smart Urban Farming. This Technical bulletin cum manuscript has been developed under the DST-IGSTC funded project “Development and evaluation of automated sensors for a highly efficient nutrition management system in indoor vertical farming (SENSVERT)”. The authors acknowledge the funding grant under the project and technological details developed and incorporated.

The publication shall be very useful for the wide range of stakeholders including farmers, growers, professionals, entrepreneurs, policy makers, extension officials, students and most importantly the common households for actively growing green horticultural crops through Smart Urban Farming. The authors would like to acknowledge the Director IARI, publication unit, all the collaborators and co-workers for co-operation and suggestion.

New Delhi
Date

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Smart Urban Farming Technology:

Smart urban farming deals with growing high value horticultural crops in peri and peri urban areas with the help of modern technologies. High value horticultural crops like vegetables, flowers, herbs and seedlings can be grown round the year or in off season under smart urban farming. It is being practised in open field, protected structures, roof top, balcony, kitchen garden and also inside closed room. It can be adopted with or without artificial light. Smart urban farming involves lots of modern technologies mainly for efficient control and management of costly inputs like energy, water, seed, fertilizer and other chemicals. Value chain based efficient marketing system is the important component of Smart Urban Farming. These two important components of Smart Urban Farming are attracting youths and common citizens to adopt it on mass scale mainly in the big cities. Simultaneously this type of farming helps in growing safe food with one's own involvement in relatively small space sometimes within home itself. It also helps in pollution control and facilitates supply of abundant oxygen and control of many harmful gases by growing specialized plants. This is the main reason for massive adoption of Smart Urban Farming technology in the post covid era. Smart Urban Farming gives the opportunity to grow safe and high value horticultural crops for our own family and for the society. Many start ups related to different aspects of Smart Urban Farming are now flourishing in big cities.

Following Modern technologies are important components of Smart Urban Farming.

- Protected Cultivation Technology
- Drip Irrigation and Fertigation
- Soilless Cultivation Technology
- Hydroponics, Aeroponics and Aquaponics
- Automation, Sensors, Controller and IoT
- Artificial Light

Major advantages of Smart Urban Farming are as following.

- Round the year possibility of growing high value horticultural crops
- Off season availability of growing high value horticultural crops
- Efficient control and management of inputs
- Safe and chemical free production of high value horticultural crops
- Leads to healthy and environmental friendly atmosphere
- Personal involvement in growing high value horticultural crops
- Smart Urban Farming under Protected Cultivation Technology:

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The main purpose of protected cultivation is to create a favourable environment for the sustained growth of crop so as to realize its maximum potential even in adverse climatic conditions. Protected cultivation technology offers several advantages to produce vegetables, flowers, hybrid seeds of high quality with minimum risks due to uncertainty of weather and also ensuring efficient and other resources. This becomes relevant to farmers, growers and citizens having small land holding who would be benefitted by a technology, which helps them to produce more crops each year from their land, particularly during off season when prices are higher. This kind of Smart Urban Farming crop production system could be adopted as a profitable agro-enterprise, especially in big cities and peri-urban areas. Protected cultivation technology is based on greenhouse effect. Greenhouse effect refers to the absorption of infrared energy by the atmosphere and the earth, which maintains the optimum temperature range on the earth that is suitable for life. The earth would be a frozen planet without the greenhouse effect with an average temperature of about $-18^{o}C$. Greenhouse gases like carbon dioxide, water vapour, nitrous oxide, methane etc allow incoming short wavelength (0.3-2.3 μm) solar radiation to reach the earth surface but restrict the outward flow of long wavelength (>2.3μm). They absorb as well as reradiate the outgoing radiation after storing some heat in the atmosphere, which results in the warming of the earth surface through greenhouse effect. Greenhouse is an inflated structure made with G.I or steel pipes covered with plastics and nets, which can be used for crop production under controlled environment conditions. Micro climate inside greenhouse is created and maintained for high quality crop production mainly of vegetables and flowers for round the year.

Protected cultivation based smart urban farming offers several advantages to produce horticultural crops and their planting material of high quality and yields, through efficient land and resource utilization. Fruits, vegetable and flower crops normally accrue 4 to 8 times higher profits than other crops. This margin of profit can increase manifolds if some of these high value crops are grown under protected conditions, like greenhouses, net houses, tunnels, shade net etc. Following important protected structures are commonly used for smart urban farming.

- Naturally Ventilated Greenhouse
- Climate Controlled Greenhouse
- Insect Proof Net House
- Shade Net House
- Tunnel type Greenhouse
- Rain Shelter

All these protected structures can be used for adopting smart urban farming based on either soil or soilless system in both single and multi layers. The growing system can be modified and easily constructed as per the special requirement of the module adopted for crop production.

Such an agricultural production system could provide a more profitable source of income and employment in urban and peri-urban areas. The amount of post harvest losses in vegetables and cut flowers is very high (20-30%), which can be significantly reduced and productivity can be increased 5-10 through protected cultivation technologies by taking the crops round the year. Protected cultivation has very high entrepreneurial value and profit maximization leading to local employment, social empowerment and respectability of the growers. Environmentally safe methodologies involving GAP and IPM tactics reduce the hazards lacing the high value products.

Protected Cultivation Technology

Vegetable and flower production is significantly influenced by the seasonality and weather conditions. The extent of their production cause considerable fluctuations in the prices and quality of vegetables. Striking a balance between all-season availability of vegetables and flowers with minimum environmental impact, and still to remain competitive, is a major challenge for the implementation of modern technology of crop production.

The crop productivity is influenced by the genetic characteristics of the cultivar, growing environment and management practices. The plant's environment can be specified by five basic factors, namely, light, temperature, relative humidity, carbon dioxide and nutrients. The main purpose of protected cultivation is to create a favorable environment for the sustained growth of plant so as to realize its maximum potential even in adverse climatic conditions. Greenhouses, rain shelters, plastic tunnels, mulches, insect-proof net houses, shade nets etc. are used as protective structures and means depending on the requirements and cost-effectiveness. Besides modifying the plant's environment, these protective structures provide protection against wind, rain and insects.

Protected Structures for Smart Urban Farming:

Most of the traditionally used protected structures like greenhouse, nethouse, walking tunnel etc with little modifications can be used for hydroponics system. Hydroponics system normally requires specialized structures and micro-climate, which can be provided inside protected structures. Specialized structures required for hydroponics like stand, piping system, grow bags, troughs, containers, pot stands, chambers etc can be made or constructed inside protected structures with additional investment ranging from 10-30% of the overall cost of the structure. Micro-climate required for hydroponics in the form of temperature, humidity and sunlight intensity can be provided by installing additional system inside protected structures. Exhaust fan, cooling pad, chillers, dehumidifier, foggers, heaters etc are required for protected structures suitable for specialized hydroponics system. Simple

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hydroponics system can be installed in very primitive and traditional protected structures with little investment.

Protective Structures / Methods

The kinds of protective structures for crop production range from simple provisions such as rain shelters, shade houses, mulches, row covers, low tunnels, cloches to greenhouse structures with passive or active climate control. Salient points of various structures are as under;

Greenhouses

A greenhouse is quasi-permanent structure, covered with a transparent or translucent material, ranging from simple homemade designs to sophisticated pre-fabricated structures, wherein the environment could be modified suitable for the propagation or growing of plants. Materials used to construct a greenhouse frame may be wood, bamboo, and steel or even aluminum. Coverings can be glass or various rigid or flexible plastic materials.

Plant Environment and Greenhouse Climate

A plant grows best when exposed to an optimal environment for that particular plant species. The aerial environment for the plant growth can be specified by the following factors:

- Heat or temperature
- Light
- Relative humidity
- Carbon dioxide
- Materials of Greenhouses

As mentioned earlier, the purpose of a greenhouse covering is to allow sunlight to pass through it so that the energy is retained inside. Glass was the main covering material in the early greenhouses. With the introduction plastic materials, there are now several alternatives available for greenhouse coverings like glass, acrylic, polyethylene film, polycarbonate sheet etc.

Types and Designs of Greenhouses:

The greenhouses design and cost range from a simple plastic walk-in tunnel costing about Rs.200/m^2 to a climate-controlled, saw-tooth greenhouse with automatic heating, ventilation and cooling, costing more than Rs.3000/m^2. The selection of the greenhouse design should be determined by the grower's expectations, need, experience, and above all its cost-effectiveness in relation to the available market for the produce. Obviously, cost of greenhouse is very important and may outweigh all other considerations. Greenhouses are classified in different shapes, which also determine their cost, climate control and use in terms of crop production. Commonly used structural designs suitable for hydroponics greenhouse are gable, gambrel, skillion, raised arch and saw tooth.

Naturally Ventilated Greenhouse:

It is the most common and most popular greenhouse type for Indian farmers. It is a zero energy model greenhouse with natural ventilation from sides and top. Saw tooth type greenhouse design has the maximum ventilation and is most effective and suitable for crop production. This type of greenhouse can be used for crop production ranging from 9-12 months depending upon the location and climatic factors. It is found to be suitable for hydroponics cultivation only in limited areas having mild climate.

Semi- Climate and Climate Controlled Greenhouse Design:

Apart from the basic specifications required for the naturally ventilated greenhouse as mentioned above, the following design specifications are required for the semi-climate and climate controlled greenhouse. It is found to be highly suitable for hydroponics cultivation.

- Exhaust Fans for removal of hot air inside greenhouse
- Cellulose Pads with Pumps for evaporative cooling
- Sprinklers for cooling
- Foggers for humidification
- Dehumidification fans

Fig. 1. Climatic Controlled Greenhouse for Smart urban Farming

Drip Irrigation and Fertigation Technology for Smart Urban Farming

Drip irrigation is the best available technology for the judicious use of water for growing vegetable in large scale on sustainable basis. Drip irrigation is a low labor intensive and highly efficient system of irrigation, which is also amenable to use in difficult situations and problematic soils, even with poor quality water. Irrigation water savings ranging from 30-80% can be affected by adopting a suitable Drip irrigation system. Drip irrigation or low volume irrigation is designed to supply filtered water directly to the root zone of the plant so as to maintain the soil moisture near to field capacity level for most of the time. Water and fertilizer saving around 25 and 30 percent respectively through drip fertigation system over traditional irrigation system was reported for various fruit crops for Delhi region.

The Field capacity soil moisture level is found to be ideal for efficient growing of vegetable plants. This is due to the fact that at this level the plant gets ideal mixture of water and air for its development. The device that delivers the water to the plant is called dripper. Water is frequently applied to the soil through emitter placed along a water delivery lateral line placed near the plant row. The principle of drip irrigation is to irrigate the root zone of the plant rather than the soil and getting minimal wetted soil surface. This is the reason for getting very high water application efficiency (90-95%) through drip irrigation. The area between the crop row is not irrigated therefore more area of land can be irrigated with the same amount of water. Thus water saving and production per unit of water is very high in drip irrigation. Also the important characteristics of irrigation water suitable for hydroponics have to meet specific standards in terms of its chemical properties and quality parameters as seen in Table 1.

Table 1: Characteristics of Irrigation Water Suitable for Smart Urban Farming

Parameters	Unit	Optimum Value
Ec	dS m^{-1}	0.5-2.0
pH	-	6.8-7.5
Bicarbonates	mol m^{-3}	2-6
Nitrates	mol m^{-3}	0.5-2
Ammonium	mol m^{-3}	0.1-1.0
Phosphorous	mol m^{-3}	0.3-1.0
Potassium	mol m^{-3}	0.5-2.5
Calcium	mol m^{-3}	1.5-5.0
Magnesium	mol m^{-3}	0.75-2.0
Sodium	mol m^{-3}	3-10
Chlorides	mol m^{-3}	3-10
Sulphates	mol m^{-3}	2-4
Iron	mol m^{-3}	<90
Boron	mol m^{-3}	30-100
Copper	mol m^{-3}	<15
Zinc	mol m^{-3}	<30
Manganese	mol m^{-3}	<10

Drip irrigation and fertigation system is the best available technology for the timely supply of water and nutrients in judicious manner to the crops grown in soil-less media inside grow bags or tailor made containers. In-line and stake drippers are specially suitable for soil-less media. Low volume high frequency irrigation concept is popularly used for different horticultural crops grown in soil-less media. Irrigation and fertigation scheduling are very sensitive to different soil-less media and therefore appropriate fertigation management is required for it. Table 2 shows important characteristics of greenhouse soil-less media from fertigation point of view.

Table 2: Important Characteristics of Greenhouse Soil-less Media

Parameters	Unit	Optimum Value
Ec	dS m^{-1}	<1.50
pH	-	5.5-6.0
Nitrates	mg L^{-1}	50-70
Ammonium	mg L^{-1}	3-6
Phosphorous	mg L^{-1}	3-5
Potassium	mg L^{-1}	50-100
Calcium	mg L^{-1}	50-80
Magnesium	mg L^{-1}	20-30
Sodium	mg L^{-1}	<90
Chlorides	mg L^{-1}	<90
Sulphates	mg L^{-1}	40-90
Iron	mg L^{-1}	0.5-1.0
Boron	mg L^{-1}	0.2-0.4
Copper	mg L^{-1}	0.05-0.1
Zinc	mg L^{-1}	0.1-0.2
Manganese	mg L^{-1}	0.2-0.4

Soilless Grow Bag Technology:

Soilless protected cultivation technology is used to grow high value vegetables and flowers round the year in protected cultivation. Different types of soil-less media like coco peat, perlite and vermiculite can be used in different protected structures like greenhouse, net house and shade net. Drip irrigation and fertigation is used with stake dripper and it can be pressurized or low pressure drip fertigation technology. Grow bag technology is recent soilless cultivation technique in which pre filled sterilized cocopeat and other suitable mixtures like perlite and vermiculite are filled in jute bag and packed readymade for growers. Grow bag is normally one meter long, 0.8 meter high and 0.20 meter width. Three vegetables and flowers normally can be easily grown in one grow bag. It can be safely used for three continuous years with one filling. This technology is growing popular as soil borne diseases and nematodes are becoming rampant problem in normal protected cultivation in soil. Water and nutrients are suitably given by drip fertigation in appropriate dosage.

Table 3: Total income, production and water saving from one unit of soil-less grow bag technology in protected cultivation (200 sq meter) for Smart urban Farming

Sr No	Crop and duration	Production (cut flower/ kg)	Total income per unit (Rs)	Water saving %
1	Chrysanthemum (8 months)	20,000	50,000/-	65
2	Cucumber (4 months)	800	24,000/-	70
3	Capsicum (9 months)	1200	60,000/-	60

Fig. 2. Soilless Grow Bag Technology under Climatic Controlled Greenhouse

Aeroponic:

Aeroponic is the process of growing plants in the air with the assistance of mist environment. No soil or aggregate medium is used or needed to support the plant. Aeroponics uses a nutrient enriched spray mist as a method to sustain hyper plant growth. Aeroponics system was indigenously designed with a standard dimension of 1.25 x 2.5 x 1m. The body of aeroponic system was made up with wood Plastic Compose (WPC) to avoid fungal and other infections to plants. Styrofoam was used as covering material and to make the plant root zone opaque thus maintaining the dark conditions for healthy root growth. Nine cone jet hollow ceramic spray nozzles were used for misting with a standard spacing of 50 cm apart. The nozzles used have the characteristic feature of ultra-low water usage of 27-30 LPH and produce 800 uniform misting angles for droplet size in the range of 40-50 micron

Fig. 3. Aeroponics under Climatic Controlled Greenhouse

at 4-6 bar operating pressure. Total 28 lettuce seedlings were planted with 30cm spacing distance between them. Two tanks with capacity of 100 liters each were used to supply water and fertilizer separately. Selec Timer (XT 546) was used for setting up the misting intervals. The misting interval of 4 minutes OFF and 30 Seconds ON during Day time and 6 minutes OFF and 30 Seconds ON during Night time were set. Self-priming monoblock pump with a capacity of 0.5 hp was used for pumping the water. The water consumption by the lettuce grown under this Aeroponic system uses almost 10 to 12 times less water as compared to the lettuce grown under open field conditions. The produce was harvested from 35 days till 60 days after transplanting.

Aquaponics

Aquaponics is a combination of hydroponics and aquaculture for efficient production of crops and fish. The plants in hydroponic part of the system get nutrients from fish waste in aquaculture part. The fish wastes are broken down into nutrients (nitrogen, phosphorous etc.) by bacteria and are used for growing plants. Aquaponics is basically a closed loop system i.e. wastes generated in system during production are recycled within the system. There are many types of hydroponic systems that can be used in aquaponics. The most common types are Nutrient Film Technique (NFT), Deep Water Culture (DWC), flood and drain, drip irrigation and vertical grow system. In all types of systems which use hydroponic principles, it is prime necessity to monitor and control level of electrical conductivity (EC) and pH of nutrient solution. When pH level varies beyond desired limit, a plant loses its ability to absorb different nutrients. The pH range 5.5 to 6.5 is ideal for optimum growth of most of the plants. EC indicates concentration of nutrients in solution. EC of water nutrient mixture should be less than 2.5 for optimum plant growth.

In NFT system plant roots are continuously bathed in a flowing nutrient solution. This technique suspends plants above a stream of continuously flowing nutrient solution that washes over the ends of the plants root system. The channels holding the plants called as NFT pipes are tilted allowing the water to run down the length of pipe before draining into the reservoir below. Deep Water Culture (DWC) is simple and reliable technique which uses floating platform with holes or provision to support plants and allow plant roots to be submerged in water in reservoir. Plastic net pots are generally used to hold the plants on suspended platform. The dissolved oxygen content in the water is major struggle in such systems. Flood and drain system is a technique in which hydroponic unit is set on alternate cycle of flooding and draining. The hydroponic grow chamber is filled by nutrient rich water followed by period of draining. The soilless media such as clay balls, pea gravel, cocopeat, vermiculite, perlite, rockwool etc. is used to support plant roots while providing adequate drainage. Drip irrigation with soilless media and bucket culture (Dutch bucket) can be used for developing aquaponic systems. Vertical grow systems are suitable for growers in

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urban areas where growing space is constraint. This system maximizes production output of growing area by taking advantage of 3-dimensional space. Vertical grow systems includes multilayer NFT, DWC, grow towers etc.

In case of aquaponic culture, fish feed has 10 out of 13 essential nutrients required by the plants to survive in aquaponic conditions. The three potential limiting nutrients are Potassium (K), Calcium (Ca) and Iron (Fe). Except these three, remaining nutrients are available for plant use after consumption of feed by fish and excretion as waste material. Bacteria present in mature system processes these waste materials to liberate bioavailable nutrients. A mineralization tank with aeration facility is used for this purpose. The process of bacterial digestion and feed breakdown occur under aerobic conditions. Aeration is stopped periodically for 20-60 minutes for allowing solids to settle down at the bottom. This is helpful for clarification of water and upper layer of water is used in hydroponic unit for growing plants. Anaerobic digestion of fish wastes produces methane (CH_4) that can be captured and burned as electricity and generate CO_2 for the plants. It also generates liquid fertilizers that can be used in hydroponic systems and solid fertilizers that can be used for germination of seedlings.

Hydroponics

Hydroponic is one of the sophisticated techniques of growing plants in modern agriculture. It is technology of growing plants in nutrient solution with or without use of artificial media such as gravel, vermiculite, perlite, rockwool etc. The different parameters to be monitored and maintained for efficient hydroponic system are water and air temperature, nutrient concentration, dissolved oxygen in water, pH, EC, Light, CO_2 concentration in water and air. There are many types of hydroponic systems that can be used in aquaponics. One of the most common type is Nutrient Film Technique (NFT), in which plant roots are continuously bathed in a flowing nutrient solution. This technique suspends plants above a stream of continuously flowing nutrient solution that washes over the ends of the plants root system. The channels holding the plants called as NFT pipes are tilted allowing the water to run down the length of pipe before draining into the reservoir below. NFT system consists of two main components: (a) the reservoir and (b) grow tray or channel. The reservoir contains water and nutrients as per the requirement of plants. In a growing tray or channel, plants are grown with the help of net pots containing growing media such as cocopeat, rockwool, perlite etc. NFT system make use of pump to deliver water with nutrients to the grow tray and drain pipe to recycle unused water nutrient solution.

There are different types of NFT structures as per the design and arrangement of channels for growing plants but table top and A-frame are two commonly used types of NFT structures. Angular bars or square pipes are good for frame material of these structures as they have enough strength and easy to work. Locally available PVC channels either round or rectangular can be used for making NFT channels. Generally, 100 mm x 50 mm (L x W), 100 mm x 60 mm and 100 mm x 80 mm are commonly available sizes of rectangular NFT channels. NFT structures works by routing water in a single direction across each channel and by virtue of gravity down to the next level until it returns back to the reservoir. Therefore, inlet and drain connectors are used to link the channel with channel below it. The reservoir of water is essential in hydroponic NFT structures as it serves as mixing tank for nutrients as per the requirement. A submersible pump is placed at the bottom of the reservoir to lift the water from reservoir and distribute to NFT channels. The slope of NFT systems ranges between 1 to 4 percent and flow rates between 1 to 2 litres/minute.

Fig. 4. A- Frame and NFT Hydroponics System under Climatic Controlled Greenhouse

Fertigation Accessories for Hydroponics System:

- Pressure gauge for optimum pressure (2-6 bar)
- Filters (120-200 micron)
- PVC Tanks (200-1000 liter)

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- Venturi/Reciprocating Pump/Mixing tank for fertilizer injection
- Ec and pH measuring device
- Controllers/valves for automation
- Fertigation Management under Smart Urban Farming

Table 4: Standard Major Nutrient Solution for Fertigation in Hydroponics

Major Nutrient	Conc. (mmol/L)	Conc. (ppm)
Nitrate	14	196
Dihydrogen Phosphate	1	97
Sulphate	2	192
Potassium	6	240
Ammonium	1	14
Calcium	4	160
Magnesium	2	48

The growth of vegetables and flowers in greenhouses built on sandy dunes and with inert substrates requires a special and precise control of the fertigation because the CEC of these growing media are very low and therefore they do not provide nutrients. The only source of nutrients is fertigation. Growing plants in containers allows the collection of the leaching water and its comparison with irrigation water. The measurement of EC, pH and nutrients concentration of the leached solution indicates if fertilizers are being applied in excess or in deficient and therefore allows the consecutive correction of the fertigation regime. It is recommended to collect the leached solution from the containers and the solution from the drippers, and to compare both solutions on a daily basis. A higher value of EC in the leached solution than in the applied solution indicates that the plant absorbs more nutrients than water, therefore we must apply greater amount of water to the plant.

On the other hand, if the difference between the EC of the leached solution and the incoming solution is less than 0.4-0.5 dS/m, we must apply a leaching irrigation to wash the excess salt. The optimal pH value of the irrigation solution must be around 6 and the pH of the leaching solution should not exceed 8.5. A more alkaline pH in the leaching solution indicates that pH in the root zone reaches a value that causes phosphorus precipitation and decreases micronutrient availability. When pH in the leachate is higher than that of irrigation water we must adjust NH_4/NO_3 ratio of the irrigation solution by increasing the NH4 proportion. When

Table 5: Standard Micro Nutrient Solution for Fertigation in Hydroponics

Micro Nutrient	Conc. (µm-Mol/L)	Conc. (ppm)
Iron	25	1.4
Manganese	9	0.50
Zinc	0.75	0.05
Copper	0.3	0.02
Boron	46.3	0.50
Molybdenum	0.1	0.006

pH in the irrigation solution is higher than 6, we must add acid to the solution to lower the pH. The chloride accumulation in the root zone can be removed by applying irrigation without fertilizer. Standard major and micro-nutrient solution for fertigation in hydroponics are given in Table 4 and 5, respectively.

Fertigation Strategy for Soil-less Cultivation:

Due to compatibility issue among different water soluble fertilizers, it is recommended to use at least two tanks for stock solution. Tank A should contain Calcium and Magnesium related fertilizers and tank B should contain Phosphorous and sulphur related fertilizers. Nitrogen and potassium fertilizers can be used in both tanks, while chelated micronutrients should be a part of tank B. EC and pH should be regularly monitored. Proper striation of the solution is also required for effective fertigation.

Table 6: Chemicals needed to prepare 1000 L of nutrient solution for hydroponics fertigation (Albert Mixture) for Smart urban Farming

Nutrient	Weight in g
Potassium Nitrate	38
Calcium Nitrate	952
Mag. Sulphate	308
EDTA Iron	8
Zinc Sulphate	0.15
Boric Acid	0.20
Manganese Sulphate	1.15
Copper Sulphate	0.10
Mono Pot. phosphate	269
Potassium sulphate	423
Ammonium Molybdate	0.03

Table 7: Hydroponics/Aeroponics Lettuce Fertigation for 1000 Liter solution

Chemical/Salt	Amount (g)
Mono Potassium Phosphate	200
Mono Ammonium Phosphate	10
Potassium Nitrate (KNO_3)	630
Potassium Sulphate SOP	200
Fe EDTA	40
Calcium Nitrate Ca $(No_3)_2$	1000
$MgSO_4$	200
Copper	0.4
Zinc	3.0
Manganese	3.0
Borax	4.0
Sodium Molybdate	0.2

***(Developed by Dr M Hasan & Team, CPCT, ICAR-IARI, PUSA)**

The solution temperature should be kept in desirable level as per the climatic condition. The concept of ppm for nutrient concentration is found to be very effective for hydroponics cultivation. The necessary calculation as per the crop stage should be done in advance and then the fertigation should be done accordingly. Stock solutions are taken from both the tanks and mixed with irrigation water for effective dilution normally in the range of 1-3 L concentrated solution with 1000 L of normal irrigation water. EC and pH should be monitored finally before final delivery to the crop.

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Fig. 5. Water and Nutrient Balance Study for Hydroponics cultivation

Fig. 6. Monitoring of Ec, pH and Moisture for Hydroponics Cultivation

Plug Tray Nursery Raising Technology under smart urban farming

The plug-tray nursery raising technology is aimed to produce disease-free, vigorous and season-independent seedlings using protected environment. Depending on the objective, different types of protected structures, like greenhouse, net-house and poly-tunnels are used to take care of biotic and abiotic stresses during seedling raising period. In order to raise high density seedlings without root-borne diseases, plastic pro trays and sterilized soil-less growing media are used. The type and ingredients of soil-less media used for nursery raising have been standardized as also the size and volume of the cells of pro-trays for different vegetable crops. Irrigation and fertigation schedules have also been standardized for raising of seedlings of different vegetables in different seasons. The root development under this system of nursery raising is so vigorous that no mortality occurs during transplanting period.

This technology has a very high potential of adopting as an agro-enterprise supporting production of most horticultural crops. A suitable protected structure, depending on the local climate and scale of operation, is constructed. All the required ingredients of the process, like plastic trays, growing media, nutrients, seeds etc are commercially available. The technology provides a package of processes required to raise healthy nursery in a give time frame. The highlights of the technology are summarized below:

It is an excellent proposition to grow high-density seedlings and propagate any suitable plant material required for higher productivity of horticultural crops.

It is possible to raise disease-free nursery independent of season. Nursery of cucurbits during off-season can be raised to get higher returns from the crop. It can be adopted as self-employed enterprise by agri.-graduates or progressive farmers for enhancing incomes.

Fig. 7. Greenhouse Plug Tray Nursery Raising Technology for Smart Urban Farming

Roof Top Gardening:

It is commonly practiced for growing vegetables, flowers, herbs and seedlings on roof top inside pots or container with soilless media. It is important component of urban farming widely adopted by common citizens. It helps in growing healthy horticultural crops round the year with self-involvement. It also helps in controlling solar radiation and pollution. It is environment friendly technology and helps in saving energy.

Components of Roof Top Gardening

- Soilless and hydroponic technology
- Pot and Container
- Shade Net and Insect net
- Micro Irrigation
- Protected Cultivation

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Benefit of Roof Top gardening

- Healthy vegetables and flowers availability
- Energy saving
- Environmental friendly
- Water and nutrient saving

Fig. 8. Roof Top Gardening

Vertical Farming:

Vertical farming is the example of smart farming mostly done inside protected structures for growing high value horticultural crops. In this type of farming plants are grown in vertical layers with the help of special infrastructure consisting of channel & frame, stake drip fertigation system and plant support system. Soilless, hydroponics and Aeroponic system are mostly used in vertical farming. Five to seven layers of farming with each layer of depth 20-40 cm with or without artificial light are commonly used in vertical farming. Leafy green vegetables like Lettuce, Pok Choi, Spinach, Coriander, Mint, Herbs and similar other crops are mostly grown in the Vertical farming system. Initial investment in such system is high due to infrastructure, energy and input costs. The major advantages of Vertical farming are round the year availability of high value crops, less crop duration, higher crop production, high quality and very high water and nutrient use efficiency. Commercially big projects related to vertical farming are done inside climate controlled greenhouse with artificial light and use of automation, sensors and IoT. Vertical farming is like industry which needs constant attention and precise management. Farmers can also do vertical farming inside low cost protected structures like insect proof net, shade net and tunnels.

Integral Components of Vertical Farming:

- Protected structure
- Vertical Frame and channel

- Hydroponics
- Aeroponics
- Soilless
- Artificial Light
- Sensors
- Controller
- Drip Fertigation

Protected structures suitable for Vertical farming:

- Naturally Ventilated Greenhouse
- Climate Controlled Greenhouse
- Shade Net
- Insect Proof Net House
- Tunnel Type Greenhouse
- Growing System for Vertical Farming
- Hydroponics
- Soilless
- Aeroponics
- Aquaponics

Types of Vertical Frame suited for Vertical Farming

- A Type
- Bench Type
- Ladder Type
- Types of Sensors used in Vertical Farming
- Ec Sensor
- pH Sensor
- Temperature sensor
- Humidity sensor
- Light Sensor
- DO and BOD sensor
- Plant nutritional sensor
- Plant disease diagnostic sensor

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IPM, GAP and Food Safety of Urban Farming

Food and health safety are most important for entire production to processing chain in agriculture from workers to consumers. Indeed the latest surge in urban farming, especially after the COVID related complications, for the availability and safety of food preferably in the dependable confines of homes, has emerged as one of the key issues in urban life style. Food safety measures include maintenance of hygiene involving - hand washing, clean toilet facilities, personal hygiène, health and microbial food safety risk awareness, vaccination of workers against diseases particularly infections, not allowing handling with open wounds etc. Similarly, standards of safety of food from pesticide residues or infections are fully taken care of as per good agricultural Practices (GAP) standards in place. Besides this, proper labelling of the product with traceability records are necessary for GAP compliances. GAP standards require procedural and operational compliances as per buyer demands in case of marketing models. Since GAP standards are primarily market or buyer driver, urban farming for self-consumption seldom require GAP compliances.

- The data requirements to be recorded may include some of the details given below:
- Max. and min. temp. outside/ inside
- RH outside and inside
- Measurements on inputs such as dose of pesticide, EC, pH of water etc.
- Date/frequency of inputs
- Dates/frequency of harvest
- Fuel consumption.
- Leachate EC and nutrient conc.
- Lux meter recording for light intensity
- Plant tissue analysis (periodical) Plant tissue analysis results, e.g. sap readings.
- Fertilizer stocks, charts of applications and adjustments
- Irrigation scheduling including data on EC/pH etc.
- List of visitors
- Attendance of workers
- Accidents/hazards report/action taken

Advantages of Adopting GAP

- GAP ensures sustainable agricultural through resource optimization – land, water, human capital and enhances information sharing, thereby increasing agricultural productivity, lowers production costs and reduces overall losses to the growers and processing units
- Improvement in the environment as well as soil/substrate fertility
- Development of basic infrastructure at the field level
- Traceability through complete integration of food chain i.e. from farm to fork, the

produce must be traceable for its origin including all inputs

- Worker safety and welfare from production to processing
- GAP supports long term thinking and assists evolving strategies on agricultural practices to be in tune with latest developments, technologies and trade practices
- Reputation in the international market as a producer
- Build up the culture of following good agricultural practices by the farmers/growers/producers
- Good quality and safe produce
- Removal of Technical Barriers to Trade (TBTs) faced by exporters of agro products – in simpler terms the local growers can become eligible to export their products as GAP certified products and hence the growers can increase in their income considerably. The GAP protocols would vary from country to country and possibly from buyer to buyer.

Pest Management and IPM for Urban Gardening/Farming

Kitchen or vertical gardening is a diverse engagement. It is a simple yet patience-demanding engagement as water, nutrient and pest management requires regular attention. Pest avoidance is the key that can take care of about 50% of the pest problems. This includes regular monitoring of pest population and controlling them before their problems become serious. Use of healthy, resistant and high yielding seeds treated preferably with bioagents (biofortified) as also healthy nursery, bulbs or other planting materials is half battle won against pests and pathogens. Early detection and quick control is another crucial element in pest management. Use of biorationals and natural enemies are next level of pest control while judicious use of chemicals is used as a last resort only. For a kitchen garden, chemical pesticides are virtually profane. Therefore, pest avoidance and biorational pest management are the mainstay for kitchen gardens. Pest management is a complex science, but understanding the same is more important. We have to play simple and basic. Sometimes a mere spray of water controls the whiteflies, while even hordes of chemical sprays at late stage would fail. Similarly, neem or garlic based sprays are also fairly effective in keeping several pests at bay. However, the key to pest management is regular monitoring of pest incidences, either directly or through various contrivances like light, sticky or pheromone traps.

Methods of Pest Avoidance: Selection of seeds, variety, treatment, time of sowing, preparation of soil (ploughing, keeping old and sick soil of pots in polythene and left to solarize will emerge fairly pathogen-free), soil solarization, mixing of organic matter, biorationals, biopesticides and beneficials, crop hygiene, proper water drainage, ridge sowing, removing or roguing out diseased and old plant parts and crop residues, disinfestation of tools with bleaching solution, use of steam, crop rotation, inter-cropping, habitat and

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canopy management, plain water sprays, physical control, use of plastic reflective mulches, use of alkathene bands above tree bases, a host of indigenous technical know-how etc. Maintaining ultimate level of hygiene, segregation or removal of diseased plants is crucial.

Methods of Natural Pest Control: Neem (oil, cake, seed powder oiled and deoiled), garlic (extract or products), pongamia (karanj), horticultural oil, jojoba oil, agrospray, sulfur dusting, panchgavya, cow urine based leaf extracts of neem, garlic, karanj, etc. are some of the popular remedies for common pests.

Methods of Biological Control: Antibiotics like validamycin, streptomycin for bacterial diseases, similarly, sulfur, treatment for fungal diseases particularly powdery mildew; biopesticides like- Trichoderma harzianum, T. viride, T. virens, Pseudomonas fluorescens, Bacillus subtilis, Metarrhizium anisopliae, Purpureocillium lilacinum, Beauveria bassiana are some of the common bioagents while a host of beneficial fungi and bacteria like PSBs (Phosphate solubilizing bacteria) and VAM (vesicular arbuscular mycorrhiza), besides good help from earthworm can work towards pesticide free pest control. However, the key issue is quality of products besides the dose and timing of application.

Some of the key pests and diseases and their management practices are given in brief as under:

Sucking pests: Whitefly, thrips, mites, aphids and jassids are some of the key sucking pests. Management: Sucking pests should be monitored regularly using yellow sticky traps. However, it is better to avoid the use of chemicals, instead organic oils such as neem oil, pongamia oil, agrosprays, horticultural mineral oil or garlic extracts may be sprayed to dispel the pests. If yellow sticky traps are not available, yellow polythene pieces, may be used on which grease is applied by brush. Spray of plain water mixed with azadirachtin or neem oil can also be of considerable use for repellence or management. Prefer green pesticides like spinosad and abamectin.

Borers: Tobacco caterpillar, diamond back moth, Cutworm, American Bollworm

Management: Monitoring of borer population may be done regularly using pheromone traps. It is better to control borers in kitchen or small terrace gardens manually/physically destroying them or cutting by scissors and keeping strict watch. Besides, light traps with a tub filled with water and kerosene oil may be used for the management of these pests in small kitchen gardens and terrace farms. Spray of green chemicals like emamectin benzoate, coragen may be considered as last resort. Antifeedants like azadirachtin also help in discouraging the feeding by these pests. Biorational pesticides like Nucleopolyhedral Viral (NPV) or Bt may be sprayed for effective management of borers.

Fruitfly: Fruitflies infest guava, mango and cucurbits are very regular pests of kitchen garden.

Management: Monitoring with methyl eugenol and yellow stick traps can help control them in kitchen gardens effectively. Bagging of fruits of cucurbits in the kitchen garden at early stage of fruit formation is the safest bet against such pests.

Diseases: Damping off, Fusarium/bacterial wilt, early/ late blight, viruses like mosaic, leaf curl etc.

Management: Treatment of seeds with Trichoderma harzianum or T. viride @ 10 g/kg seed with given quality of fungal culture. Root dip treatment with Pseudomonas fluorescens. Soil drenching with bavistin 2 g/L of water. In case of other diseases soil treatment with Aliette or copper oxychloride or chlorothalonil 2-3 g/L of water.

Note: Kindly resort to organic pest management or atleast Integrated Pest Management (IPM) using synthetic chemicals judiciously as last resort only.

Government of India (GOI) initiatives for smart urban farming

Smart urban farming has great prospects for Indian agriculture. It is one of the potential technologies for doubling farmers income. In the changing scenario of food habits and growing fad for green vegetables, herbs and fruits, Smart urban farming is going to play a major role for sustainable and round the year production in urban and peri-urban areas. As this technology is capital intensive and requires technical knowhow, GOI has launched many schemes to promote this technology through different agencies.

Some of the major agencies to promote Smart urban farming are as follows.

1. ICAR – Ministry of Agriculture, GOI
2. National Horticultural Board (NHB)
3. National Horticultural Mission (NHM)
4. Horticulture Mission for North East & Himalayan States
5. State Govt. Initiatives

Credit linked projects relating to establishment of Commercial production units in protected conditions for Hydroponics cultivation are supported financially by National Horticultural Board NHB. The details of the schemes are available through the link (www.nhb.gov.in). National Horticultural Mission (NHM) and Horticulture Mission for North East & Himalayan States also indirectly support Hydroponics related projects through the protected cultivation initiatives. Farmers and entrepreneurs can avail these schemes as per the eligibility and suitability.

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Addresses of Firms Dealing with Smart Urban Farming

Barton & Breeze, Gurgaon.
Mr. Shivender Singh, CEO
www.bartonbreeze.com
M - 8529726141

URBAN GRO, DELHI
Mr. Raminder Singh, CEO
www.smarturbanfarmingexpo.com
M -9810157669

Aeroganic Pvt Ltd Noida
Mr. Aditya Bhalla, CEO
www.aeroganics.in
M – 7838034884

Greenhack Pvt Ltd
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