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A review on scope and potentiality of vertical farming in India

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Abstract

Continuous rising population is necessitating the maximization of food production per unit area i.e. productivity. There has been already well known different advance methods like aquaponics, nutrient film technique (NFT), aeroponics, etc. but they do not have that much good land utilization. So, to conciliate this land problem vertical farming was introduced. It utilizes the vertical unused space which or else left unused in other farming systems. This can also facilitates the peoples to get the fresh cut vegetables regularly. Moreover, nowadays peoples are showing their keen interest towards their health and to meet their healthy food requirements, salad vegetables are the best options as due to nutritional values. The vegetables have high number of health benefits. They are rich sources of minerals, vitamins and various bioflavonoids which are essential for the growth and development of human beings. The vegetables can also be eaten raw in form of salad. The vegetables are also suited best under this structure as these are short duration and provides high net returns. These can be grown by using various growing substrates *viz.* perlite, coco-peat, vermiculite etc. to enable fast growing and high yield.

Keywords: Aeroponics, growing substrates, hydroponics, nutrient film technique, productivity and vertical farming

Introduction

The Vertical Farming is husbandry of crops, planted in vertically managed layers so as to harness the unaccustomed vertical area which is otherwise left unconsidered in almost every cultivation practices. As the list of the major issues in world is long, the population explosion is one among those major issues. It is estimated that there is approximately 800 million hectares of land that is designated to soil based farming globally, which constitutes about 38% of the total global land area. Moreover, about 80% of the total arable land is currently being utilized across the globe (Ellingsen & Despommier, 2008) [9]. The whole world is on the verge of population explosion and it is a challenge to feed this ever-increasing population (Sonawane, 2018) [25]. Some urban planners and agricultural leaders have argued that cities will need to produce food internally to manage the ratio of demand and supply to avoid falling food prices, harmful pollution and inflation (Kodmany, 2018) [16]. Since the era of green revolution, the technologies in agricultural sector keeps on developing. Every now and then new technologies are ensued which make the older ones obsolete. The current technologies used for growing crops are aquaponics, nutrient film technique (NFT), aeroponics, etc. These methods nowadays considered best for crop cultivation but however they may not be solely sufficient to run supply parallel to demand generated by the fast growing population. So, some scientists believed that urban agriculture could solve these problems by adopting vertical farming along with food production and consuming a place that suited the areas where land is expensive and limited.

Growing medias/substrates are the material in which the plant will grow and they plays a crucial role in the productivity as well. They provide anchorage for plant roots, air spaces and allow respiration and retain enough available water to enable plant growth. There are wide range of growth substrates available for growing plants. The growing medias are used solely or in combinations (ratios) for growing plants. Like as, when the vermicompost is applied to vegetables at an certain amount and time, it can enhance the growth and yield in field condition (Arancon N.Q and Edwards C.A, 2005) [1]. The types of combinations of medias varies from species to species of plants, also on choice of grower and stage of growing i.e. for nursery raising or for transplanting. Nowadays different types of growing media are available in the market *viz.* coco-peat, coir, vermicompost, perlite, bagasse, sawdust, etc., but sometimes some media (wood straw and palm-leaf straw in cucumber production) performed well, although they were not significant in yield. (Rawahya *et al.*, 2009) [22].

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This soil-less cultivation of plant can also be utilized for successful production of other crops like as salad corn i.e. baby corn (Fontana E. *et al.*, 2003)^[10].

Among all the Medias, composts are major source of interest to be used by scientist in their experiments as if they are supposed to have good nutritional values. When compost is used as or in combination with the available medias in an certain ratio, than the results obtained by it are far more better than any other mixers, it shows results like as enhanced plant height, dry matter content and oil content in sweet basil (Hewidy M. *et al.*, 2014)^[13]. On the other hand, rather than going only with hydroponics system for growing plants in vertical farming, the other alternative which can be used in vertical farming for plant growth could be aquaponics system. Though there is not much comparative studies between above mentioned former and latter systems, but the hydroponic system is what I believe could be more beneficial, if incorporated in vertical farming system for production purpose. Moreover, when the basil production is compared between systems these two systems, though the hydroponic system have more balanced supply of nutrients, it was the hydroponics in which the number of leaves and plant height is better (Wilson, 2017)^[31]. Moreover, from the verdict of various research makes support the statement that vertical farming is a major weapon to fight against the un-sustainability of the agriculture. Various firms related to agriculture, such as Plant-Lab, Farmed and Aero-Farms etc. have proved the potentiality of vertical farming in crop production (Carly Sills and Serbin, 2018)^[26]. The vertical farming is also considered as an ecofriendly practice of crop raising and any type of crop can be cultivated at any-time (Jegadeesh M & Verapand Ji, 2014)^[14].

People use these soil less mediums due to temperature fluctuations, moisture retention, nutrient gain, salinity, root aeration, undesirable microbial activities and unexpected soil problems caused by nematodes, diseases and pests (Sedaghat *et al.*, 2017)^[24]. There are no thumb rule for preparing ratios of medias but one can standardize different medias and their ratios for different crops and combinations of crops which can be directly used by others who are seeking for growing the same crop in soilless culture.

Background

The modern concept of vertical farming way back to 1999, when Dickson Despommier, Professor at Columbia University and his students come up with the thought of an huge skyscraper structure which could feed more than 50,000 people. From this point the concept of vertical farming becomes popular. The vertical farming coupled with the other agricultural technologies *viz.* hydroponics, artificial lights, etc. can be a best way for crop cultivation which provides high returns, fresh harvest to consumer and balance in food supply and demand chain.

Why vertical farming

Vertical farming have numerous of benefits if adopted. Some of the major and crucial advantages of the vertical farming are as listed below:

- It increases yield per unit area i.e. productivity even from a small piece of land.
- It Increases the amount of net return to the farmer.
- It helps in best utilization of the vertical area which is generally left unused.
- It provides fresh cut vegetables to the consumers.

Present Status of vertical farming in India

India is one of the strongest economy in the world. It is the hub of variety of cultivated species of plant. The majority of population of India is dependent upon farming for their livelihood. So, it is necessary to develop, explore and adapt of new techniques to in increase food resources with this continuously increasing urbanization (Bhangaonkar A.B. *et al.*, 2017)^[5]. Moreover, the India too have variety of climatic conditions which enhances its potentiality to grow a variety of crops throughout the year. This fact of diverse climate had made the India second largest producer of vegetables in the world after china (Anonymous, 2019). But, even though it is second largest producer, it still faces the scarcity of food. The per capita availability of vegetable is still below the recommended rate of 275gms and 300gms by ICMR for females and males respectively. The Indian population in 2020 is expected to be 1.39 billion with population density of 455 people per square kilometer and the net cultivated area is still 141 million hectares (Anonymous, 2019), and it's clear that this flock of people will keep on increasing. So, in upcoming years it may become very difficult for the growers to full fill the need of food from same small piece of land in hand. To cope with this situation, we need to find more sophisticated methods of cultivations which we can be used solely or along with the current methods of cultivation so as to maintain the demand-supply chain of market and there comes the vertical farming to our rescue. In vertical farming along with the use of other advance technologies the production which is achieved in 1000 m² is almost equal to outside 4000 – 30,000 m² (Cicekli M. & Barlas N.T, 2014)^[7]. And the amalgamation of the vertical farming system in skyscrapers or as greenhouse effect together can result in formation of high-tech agriculture system (Malek Al-Chalabi, 2015)^[2]. The vertical farming has been adapted by some of the countries like USA, Japan, etc. In India, the vertical farming is under testing period. Although, on a small scale it has been implemented in some major cities such as West Bengal and Punjab, etc. The researchers has been also looking for the feasibility of the skyscrapers in different metro cities of India *viz.* New Delhi, Kolkata, Mumbai and Chennai etc. (Sonawane M.S., 2018)^[25]. The Initial success of growing tomato and brinjal in vertical farming has also been recorded. If the vertical took up pace in India, then it might help peoples to get fresh cut vegetables easily throughout the year, helps the growers to gain high profits and this will cumulatively affect the National GDP in positive direction. It is a glimpse of today that more and more crops should be grown permanently to provide food to all. So to achieve this, integrating vertical farming and hydroponics is one of the best options (Kumar A, 2019)^[17].

Techniques used in vertical farming

The vertical farming allows merging the other sophisticated growing techniques to a single system to get higher productivity. The techniques *viz.* hydroponics and controlled environment conditions can be used to grow crops based on a common principle of vertical farming. These methods can be incorporated together or can be used solely to grow cops in vertical structures.

Hydroponics

The term 'Hydroponics' was derived from Greek word 'hydro' means water and 'ponos' mean labor. Hydroponics is a modern agriculture technique that uses nutrient solution rather

than soil for crop production (Bridgewood, 2003; Hochmuth and Hochmuth, 2001)^[23]. Generally, there are two techniques of hydroponics, named as solution culture method and media culture method. The former methods implies the application

of water to plants along with dissolved nutrients in it and the latter method enlist the use of various growing substrates *viz.* perlite, vermiculite, vermicompost, sand, coco-peat etc. for crop cultivation.

Table 1: Comparison between chemical nature of various growing medias (Ali AlShrouf, 2017).

Substrate	Total porosity (V/V)%	Air porosity (V/V)%	WHC (V/V)%	CEC (cmol/kg)	Bulk density (g/cm ³)	C/N%
Perlite	66.3	41.1	25.2	0.0	0.13	0.0
Sand	35.6	24.6	11	12	1.45	0.0
Peat	90	13.2	76.8	110.5	0.11	40.12
Rockwool	94.1	10.3	83.8	0.0	0.06	0.0
Coco peat	92	12.2	79.8	138.7	0.16	48.47

*WHC (water holding capacity), *CEC (cation exchange capacity)

The hydroponics also considered as a better option for crop cultivation rather than the other traditional methods because of its better result in a sense that we get early yield, high yield and very less chances of insect pest and disease are noticed in hydroponics cultivation. Results of Yield Comparisons between hydroponic and open field cultivation in different vegetables backed the uses and importance of hydroponic cultivation (Khan F.A et. 2018)^[18].

Potato *Solanum tuberosum*
Cabbage *Brassica oleracea var capitata*
Cauliflower *Brassica oleracea var botrytis*
Lettuce *Lactuca sativa*
Sweet Basil (Salad crop) *Ocimum basilicum*
Parsley *Petroselinum crispum*
Onion *Allium cepa*
Cucumber *Cucumis sativus*

Table 2: Yield comparison between hydroponics and open field cultivation

Name of crop	Hydroponics cultivation (Yield kg/hac)	Open field cultivation (Yield kg/hac)
Tomato	403,335.81	11,203.75 – 22,407.47
French bean	47,097.96	--
Beet	22,427.6	10,092.42
Potato	156,852.29	17,925.98
Cabbage	20,184.84	14,577.94
Cauliflower	33,641.4	11,213.8 – 16,820.7
Cucumber	31,398.64	7,849.66
Lady's finger	21,306.22	5,606.9 – 8,971.04
lettuce	23,548.98	10,092.42

Controlled environment conditions

Controlled environment is simply the modification of the current environment according to the suitability of the crop to be cultivated. This advancement in controlling the environment opens a great opportunity to continue the supply of crops even in their off season. So, this method can be used as a main technique for crop production in vertical structures. This controlled environment and hydroponics can be incorporated together to get higher returns and good productivity.

Vegetable crops suitable to grow in vertical farming

Economic factors typically limit a realistic set of crops that have a small growing habit (to maximize the number of plants grown in confined spaces) that are prolific producers (such as tomatoes on the vine), or grown and sold. Can be fast (e.g microgreens). Another feature of standing crops is their dependence on the fresh market. For many reasons, processing vegetables almost always has a much lower price than their fresh counterparts. Crops compatible for vertical structure include the following:

Tomato *Solanum lycopersicum*
Chilli *Capsicum annuum*
Brinjal *Solanum melongena*
Green Bean *Phaseolus vulgaris*
Bell Pepper *Capsicum annuum*

Result and Discussion

Vertical farming is an emerging technology, which aims to increase crop production per unit area of land in response to increased pressure on agriculture (Beacham *et al.*, 2019)^[6]. Various scientists had worked and some are still working on the betterment of the technologies to be used in agriculture so as to get high yield from a small land along with good net return. The concept of utilization of the vertical area is not a latest discovery but instead it is known to everybody from old ages, this is so in a sense that the peoples make their houses two or more storied. This making of houses is nothing but utilization of the vertical area. So, if peoples can live vertically why not the crops? From this, we get a direct idea that crops can be grown vertically. The vertical farming can be carried out in a small structure to large sky scrapers. Vertical farming involves growing of crops vertically in controlled atmosphere using technology like LED lighting, heating, ventilation and air-conditioning (HVAC) systems, sensors and smart software, drones, mobile apps to maintain total control over the environment (Sonawane M.S., 2018)^[25]. It is also pressing need to grow more & more crops in a sustainable way to provide food to everyone and vertical farming and hydroponics are one of best alternatives to be integrated into (Kumar A, 2019)^[17]. The vertical farming allows us to grow a wide variety of crops such as fruits crops, vegetables crops and condiments etc. But if the vertical farming is done by using vegetables, this would not only provide good returns but also helps in minimizing the major problem of malnutrition (which is more prone among nowadays kids and younger generations) as vegetables are considered as best source of different types of vitamins, minerals bioflavonoids etc. which helps in maintaining the metabolism of organism & hence the vegetables are also termed as protective food. When the vertical farming is carried out with help of hydroponics and controlled environmental conditions, the outcomes are far more-better than if they are used solely. The vertical farming produced 13.8 times more crop, calculated as a ratio of yield (kg Fresh Weight) to occupied growing floor area (m²). However, mean FW (g) for lettuce crops grown within the horizontal hydroponic system was significantly higher than those grown

within the vertical farming. Comparison of the productivity of the vertical farming system (VFS) and horizontal hydroponic system (HHS) (Touliatos D *et al.*, 2016).

Parameters	HHS	VFS	Results
Shoot fresh weight (g)	138 ± 95	±	$P < 0.001^*$
Yield per occupied growing floor area ¹ (kg FW·m ⁻²)	6	6	VFS/HHS = 6.9/95 = 13.8
Number of plants per occupied growing floor area ¹ (plant number m ⁻²)	50	1000	VFS/HHS = 20

1HHS growing floor area: 0.4 m², VFS growing floor area: 0.02 m².
*Student's t- test on square root transformed data, t (78) = 5.65

The hydroponics is currently considered as promising strategy for growing different short duration crops like vegetables throughout the year in very limited spaces with low labour and utilize the resources efficiently (Sharma *et al.*, 2018) [27]. The vertical farming along with other techniques like as hydroponics can be used to year round production of some important vegetables like as onion with increase in productivity as shown in Table 3 (Pascual M.P *et al.*, 2018) [21] and can also prevents the sudden hike in the prices.

Table 3: Increase in bulb size of onion grown in Vertical Farming along with hydroponics

Days	Average diameter of onion bulb (cm)	Days	Average diameter of onion bulb (cm)
1	2.0	16	2.8
2	2.0	17	2.9
3	2.1	18	2.9
4	2.1	19	3.0
5	2.2	20	3.1
6	2.2	21	3.2
7	2.3	22	3.2
8	2.4	23	3.3
9	2.5	24	3.5
10	2.5	25	3.6
11	2.6	26	3.8
12	2.6	27	4.1
13	2.7	28	4.1
14	2.7	29	4.2
15	2.8	30	4.3

In hydroponics various types of growing media are used so if we talk about the growing substrate, than it can be said that the response of these medias are different for different crops. Like as one scientist working in standardizing media for tomato find out that the perlite is best media for its cultivation which is followed by the rock-wool (Wilson, 1986) [29] while another scientist found out growing media for greenhouse tomato production to get high yield, better quality and good vegetative growth is 1:1 ratio of perlite and coco-peat which gives out far more better result than the other mixtures used by him (Sedaghat *et al.*, 2017) [24]. The vertical farming also enables the harvesting of the crops earlier than the open environment condition (Stapleton and Hochmuth, 2001) [23]. As it enhances the productivity, so it is also best for the cultivation of those crops in which the leafy part is useful and these crops are none other than salad crops which are mostly vegetables. From these working results of different scientist, one can use them as per his environmental conditions or availability for growing crops in vertical structures. From the above discussed researches conducted by various scientists we can clearly see benefits of growing crops in the hydroponics system & controlled environment. It had also become clear that, when these systems are incorporated

together and used in vertical farming to grow crops than the results are far more-better. So it can be said that the vertical farming have a wider list of benefits over the other growing methods and is an better alternative of crop growing as per the current scenario where the population is growing rapidly. If one analyses the current scenario of population explosion, than it is predictable that what would our condition is going to be in upcoming years. So we need to find a better alternative to maintain the food demand of population and for that the vertical farming is a milestone.

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