

MUSHROOM CULTIVATION IN RELATION TO VERTICAL FARMING: A BOOMING ENTREPRENEURSHIP

Abstract

Vertical farming is the practice during which the crops are grown in a vertically stacked layers or integrated skyscraper or old warehouse etc. with use of less water and in the absence of soil. Vertical farming has many advantages viz. there is reliable crop production round the year, unaffected by adverse climate. It also minimises the use of water and uses space in a better way, provides completely organic yield, reduces transport costs, provides pesticide free cultivation, low labour cost and highly energy efficient crop.^[7]

There are many factors now-a-days which are demolishing the food availability and can cause a worse situation in future. The war between Russia and Ukraine may be one of those factors which can lead the globe to a severe food scarcity due to their high export-import value in India and other countries. Hence, it is important to go for another opportunity for food production. A large amount of agro-wastes are produced every year which is burnt by farmers and deteriorate the air quality and soil quality as well. Instead, we can use that as a substrate for creating compost for mushroom cultivation. For mushroom cultivation, vertical stands are required that solve the problem of less availability of land area. In small areas with less amount of water, mushrooms can easily be grown and can help in the economic growth of the country. In some states of country, due to flood, nutrient of the soil sweeps away and thus crops cannot be grown there. In those areas, cultivation of mushrooms can be a good alternative to get earnings.

Mushrooms are the fruiting bodies of some

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members of a lower group of plants called fungi. The fungi are characterized by the absence of chlorophyll and undifferentiated bodies except the spore bearing structures. Man started agriculture 10,000 years ago. The Chinese were reportedly the first to artificially cultivate tropical and sub-tropical mushrooms around thousands of years back but commercial production started in Europe with button mushrooms in caves during 16th and 17th centuries. Now, mushroom cultivation has spread all over the world. In India, mushrooms are being cultivated in every State. Government and Central government have launched many schemes to support farmers and youth to start with cultivation of mushrooms. Awareness programmes have been launched to make people aware about the nutritive and Entrepreneurship values of mushrooms. Through Mushroom cultivation, young generation and women can also set up small scale industry and start-ups and it is a growing era of start-ups in the field of mushroom cultivation and vertical farming [9][10][11][12].

Key words: Vertical farming, horticulture, mushrooms and nutrients.

I. INTRODUCTION

India is an agriculture based country and it has one of the strongest economies in the world. We are dependent on farming for our livelihood. Agriculture is basically dependent upon soil and its nutrient content. Due to globalization and global warming, the availability of soil for agriculture purposes is decreasing and clogging the production of various crops. Another components are pesticides and fertilizers that are added in the soil which also damage the soil health. These days population explosion is a major issue. Whole of the World is on verge of population explosion. It is estimated to reach 9.7 billion by 2050^[1]. To feed an increasing population is a great challenge. Agricultural Scientists, leaders and urban planners suggest that cities can grow food internally to meet their needs and supply chain, so that increased food prices inflation and pollution can be controlled. As the land in urban cities is expensive and limited, some alternative can be used to grow crops. The emergence of food crisis because of an ever increased world population and pandemic diseases have led scientists and technologists to tap the available sources and find some alternative of manufacturing cheap and quality food. In the field of agricultural sectors, new technologies have been developed under Green Revolution i.e. Hydroponics, Aeroponics and Nutrient Film Technique (NFT by Sparks & Stwalley).^[8] But these techniques cannot meet the increasing food demand of increasing population. Vertical farming can help in solving these problems. Monetary increase will also be there as multiple crops can be grown at a time. Crops will be healthy as it will be free from pesticides and chemicals. People living in urban areas can also adopt vertical cropping according to their needs.

II. VERTICAL FARMING

Vertical farming is a type of farming which involves growing crops in controlled indoor environments with precise light, nutrients and temperatures. In vertical farming, growing plants are stacked in layers that will reach several storeys tall^[2]. The term “Vertical farming” was firstly coined by Gilbert Ellis Bailey in 1915 who is also an author of a book titled “Vertical Farming” in which he argued farming hydroponically in a controlled vertical environment which would provide environmental and economic benefits to us. The development of hybrid/improved high yielding varieties, improved techniques, improved tools and implements, integrated practices in water, nutrient management, insect, pest management, greenhouse technology, and even genetically modified crops were all driven by the need to feed an ever-increasing population.^{[3][4]} In 1980s, Swedish organic farmer Ake Olsson also proposed vertical farming as a way to produce the vegetables. The modern concept of vertical farming way back to 1999, when Dickson Despommier, Professor at Columbia University and his students came up with the thought of a huge skyscraper structure which could feed more than 50,000 people. From this point, the concept of vertical farming became popular.

The vertical farming coupled with the other agricultural technologies viz. hydroponics, artificial lights, etc. can be the best way for crop cultivation which provides high returns, fresh harvest to consumers and maintains a balance in food supply and demand chain^[15]. There has been an increasing need, being observed for the land and therefore the food as per population increases. So many attempts have been made to resolve this scarcity problem. There are some entrepreneurs and farmers who are setting out to search for space to grow more food. One solution to our need for more space may be well found within the

abandoned warehouses in our cities, new buildings built on environmentally damaged lands and even in used shipping containers from ocean transports.^[5] In this article, we are mentioning about the mushroom cultivation through vertical farming. People can keep their bags on the floor but that will be wastage of space by keeping the stands. Instead, one can use that area multiple times for the cultivation of mushrooms. As mushrooms are rich source of nutrients, rich in proteins, low in fat, high in calories, high in dietary fibers, rich in micronutrients and are rich source of various vitamins especially vitamin D. After sun light, mushrooms are the only source of vitamin D. They are the source of nutraceuticals and becoming the part of Pharma companies and can help in solving the problem of malnutrition. India is the main exporter of *Agaricus bisporus* mushroom, growing mostly in Haryana, Punjab, Bihar, Maharashtra, North Eastern states and various states of Southern India. About 80% button mushrooms, all around the world is grown in India. Now, we are growing other mushrooms like *Pleurotus*, *Cylocybe*, *Ganoderma*, *Cordyceps* and *Shittake* commercially. Although new species continue to be discovered in North America, about 22–55% of the mushroom species remain unexplored.^[13]

Why vertical farming?

Vertical farming have numerous benefits. Some of the major and crucial advantages of the vertical farming are as listed below ^[26]:

- 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.

In civic and semi-urban areas, Vertical farming or husbandry can be an effective way to combine food product and original consumption. Land is getting an important resource due to advanced costs and limited vacuity. Above all, with the preface of new food product, civic residents can be offered high-quality, non-toxic, more affordable ranch-fresh products.^[6] Recent advances in hothouse technologies, soil-less husbandry, aeroponics, hydroponics, and aquaponics have offered a promising future for the perpendicular ranch concept. These high-tech systems represent a paradigm shift in husbandry and food product systems, furnishing sustainable and effective styles for civic husbandry, minimizing conservation and maximizing yield. Vertical farming is not an entirely new possibility. Examples of this can be found in the ancient Hanging Gardens of Babylon, one of Philo's Seven Wonders of the Ancient World, built around 600 B.C. The crop yield obtained through current applications of vertical farming in conjunction with cutting-edge technologies, such as specialized LED lights, is ten times greater than that obtained through conventional farming techniques.

III. FOOD SECURITY

Safety of food can never be ignored while taking development of country into account. In recent years, safety of food even has become a threatening issue. Experts in the field of soil, agronomy, ecology and geology have warned of an increasing need for arable land. The cost of food has been on the rise in recent decades and is expected to continue to rise in the future. Farmers anticipate a rise in food prices due to the increasing cost of oil and the decrease in the availability of water, farmland and other agricultural resources.^{[6][32][33]}

The implementation of vertical farming can offer access to high quality food that is free from agrochemicals and can be managed in a sustainable manner. This can help to address a range of issues such as pollution^[27], climate change and pest infestation, as well as reduce energy consumption, water usage, restore ecosystems, improve economic conditions and provide employment opportunities. Additionally, vertical farming can help to provide local food security. Generally, indoor cultivation of any crop offers a healthier and contamination free environment for food production.^{[36][35]} Year-round operation can lead to improved yields and income.^[34] Food costs can also be reduced due to reduced travel and packaging costs.

IV. VARIOUS FACTORS REQUIRED FOR VERTICAL FARMING

For all plants, the environment is critical for their growth and development. Plant behaviour is impacted by the environment in which they are grown. The key modifying factors of plant responses are light, humidity, and temperature. For optimal airflow, plants produced in humid regions have bigger leaves than those grown in dry ones. Additionally, in cold weather, plants store extra food on their tough stems. Tropical climates provide a lot of heat for evergreen plants to flourish in. In comparison to plants nurtured in full sunshine, those cultivated in little sunlight have a somewhat paler green hue. The majority of lighting solutions for vertical farming are distinct from the traditional solar illumination used in greenhouses. Changes in plant growth are among the primary impacts of the energy of photons on growth variability that are important. As for horticulturist, growing of crops, green vegetables and microgreens come under vertical farming. Being a mycologist, mushroom farming for us also comes under vertical farming. Among the varied food sources for humans, microbes is the important source as SCP and edible fungi will be the most important group. Malnutrition is another problem in developing countries is solved by the consumption of mushrooms. Mushrooms have all essential amino acids, vitamins, proteins and fibers. They have more proteins than legumes except soyabean. They have 4 times more vitamins than vegetables and 12 times more vitamin than fruits.

V. MUSHROOMS CULTIVATION: A LINK WITH VERTICAL FARMING

Mushrooms are edible fungi which are generally classified as vegetable but mushrooms are not vegetable as it belongs to group fungus. Mushrooms are known for their flavor, texture, nutritional value and high productivity per unit area and are identified as a superb food source to combat the malnutrition in developing countries. Reason for quick acceptance of mushroom is its nutritive content. Mushroom can be eaten as a substitute of meat in taste and flavor. Generally, edible mushrooms are low in fat and calories, rich in B complex and C, contain more protein than the other food of plant origin and also a rich source of mineral nutrients (Table 1.) . Currently, high biofuel prices have caused a rise in food prices and food scarcity in many countries. Consumption of mushrooms can be an alternative to combat the nutrient and high prices of food. In a small area one can grow tons of mushrooms and can earn lot of money. Mushrooms have got many medicinal properties as well as they are having Niacin as a component which promotes healthy skin and make sure that our digestive system and nervous system function properly. Mushrooms are a good source of Vitamin B as well as it plays a vital role in maintenance of Nervous system^[17]. Mushrooms are rich in Riboflavin which is responsible for maintaining healthy RBCs. They have pantothenic acid which helps in the production of hormones and also play an important role in nervous system. Growing mushrooms is an eco-friendly system and a part of

sustainable agriculture, as it grows on stubble. In India, where a lot of agricultural waste is produced each year and burning it is the source of pollution, affecting human health and upsetting the balance of the ecosystem, growing mushrooms may be a very reliable and profitable option to reduce hunger and malnutrition.

Table 1: Nutritional Value of Edible Mushrooms ^{[37][38][39]}

Types of Lipids	Types of Carbohydrates	Types of minerals	Types of proteins
Linolenic Acid	Xylose	Calcium	Antimicrobial proteins
Palmitic Acid	Fructose	Sodium	Laccases
Oleic Acid	Glucose	Phosphorus	Ribosomes inactivating proteins
Ergosterol	Mannose	Potassium	Ribonuclease
Tocopherols	A and B glucans	Copper	Lectins
Linoleic Acid	Xylans	Zinc	
Arachidonic Acid	Trehalose	Iron	

Employment can be generated by growing mushroom for the young generation. Small scale and large scale industries can be developed by growing mushrooms even women empowerment can also be done. Not only growing of mushrooms, another process like spawn formation, compost making and casing soil formation can also help in generating the business for our youth. To get good quality of spawn is a fight in our country.

Growing of mushrooms in small area saves the land area and less water is required for its cultivation. Mushrooms are full of nutrients, rich in dietary fibres, low in carbohydrates, fats, low in calories and high in proteins so they have taken place in the list of functional foods (Table 2). They are rich source of potassium, magnesium and selenium so helps in cure of many diseases like AIDS, Alzheimer, Parkinson. They are anti-diabetic, antibacterial, antiviral and anti cancerous in nature as so many bioactive compounds are present in them (Table3). Various types of mushrooms are available in market, out of those some can be edible and while others can also be medicinal in value. Some mushrooms are parasitic, saprophytic or in mycorrhizal associations. They can be primary decomposers or secondary decomposers. Mushrooms are ligno-cellulolytic in nature they can be grown on agriculture waste like wheat husk, rice husk, cotton waste, sugar cane baggage waste, paper waste, coffee seed waste even on leaf waste. Farmers in India used to burn these agricultural waste and cause air pollution, climate change and global warming. By growing mushrooms on these agricultural waste not only solves the problem of environmental pollution but also solves the problem of unemployment among the youth. Small scale and large scale industries can be established by using agriculture waste. For so many people, employment can be generated, labour can be hired for this work. Women can establish small scale industries by making papad, breads, biscuits, mushroom powder and pickles by using mushrooms.

Table 2: Common Edible Mushrooms with Respective Protein Content ^[40]

Mushrooms	Protein Content (gram)	% daily value
Agaricus bisporus (Button Mushrooms)	3.1 g	6%
Lentinula edodes (Shiitake Mushrooms)	2.2 g	4%
Flammulina filiformis (Enoki Mushrooms)	2.7 g	5%
Pleurotus ostreatus (Oyster Mushrooms)	2.9 g	5%
Volvariella volvacea (Straw Mushrooms)	3.5 g	5%
Morchella conica (Morel Mushrooms)	35 g	70%

Table 3: Bioactive Compounds Present In Mushrooms

Mushrooms	Bioactive Compounds
Agaricus bisporus (Button Mushrooms)	Pyrogallol, flavonoids, hydroxybenzoic acid derivatives
Auricularia auricula (Jelly Ear Mushrooms)	Glucan
Boletus spp.	2,4,6-trimethylacetophenone imine, glutamyl tryptophan, azatadine, lithocholic acid glycine conjugate
Cordyceps militaris (Scarlet Caterpillar club fungus)	Cordycepin, Cordymin
Flammulina velutipes (Winter's mushroom)	Polysaccharides, peptidoglycan, Flammulin
Ganoderma lucidum (Lingzhi/Reishi Mushrooms)	Ganodermin protein, Ganoderic acid, Ganoderan A and B, Triterpenes, Lucidenic acid, Lanostane type triterpenic acid, Lingzhi-8 (protein)
Pleurotus ostreatus (Oyster Mushrooms)	Pleuran (beta-1, 3-glucan with galactose and mannose), Laccase, Pleurostrin and Proteoglycan
Lentinula edodes (Shiitake Mushrooms)	Lentinan, glucan, mannoglucan, Fucomannogalactan, Lentin (protein), Catechin, Flavonoids
Psilocybe cubensis (Magic Mushrooms)	Psilocybin (psilocin: 4-hydroxy-dimethyltryptamine)
Volvariella volvacea (Straw Mushrooms)	Fip-vvo

VI. ENZYMES PRODUCED BY MUSHROOMS

The various enzymes present in mushrooms are lignocellulolytic enzymes amylase (EC 3.2.1.1), cellulase (EC 3.2.1.4), laccase (EC 1.10.3.2) and xylanase (EC 3.2.1.8). SMS (Spent Mushroom Substrate) is composed of fungal mycelia, extracellular enzymes secreted from mushrooms for degradation of substrates and unused lignocellulosic substrates. SMS has been used in production of value-added products such as biogas and bulk enzymes, for bio-conversion into organic fertilizer, for use as an animal food supplement and for degradation of

pentachlorophenol. A wood rotting basidiomycetes known as *Pleurotus* sp. produces laccase as the main ligninolytic enzyme synthesized by this species. Laccase-redox-mediator system is one of the most-investigated enzyme reactions in ligninolytic enzyme systems^{[28][29]}. This system has been used to remove many emerging contaminants that are difficult to decompose, such as dye-based industrial pollutants and endocrine-disrupting compounds^{[30][31]}. Laccase and other ligninolytic activities have been previously reported to be related to the stationary phase of growth in different fungi and are often triggered due to nutrient limitation. Laccase is involved in the differentiation and morphogenesis of basidiomycete sporulating and resting structures as well as the biodegradation of wood's lignin by white-rot fungi. Laccase is responsible for pigment formation in mycelia and fruiting bodies, improves cell-to-cell adhesion, assists in the formation of rhizomorphs and is also responsible for the formation of polyphenolic glue that binds hyphae together. Various plant pathogens also produce extracellular laccases that enable the fungus to overcome the immune response of the host.^[41]

Oyster, king oyster, winter, and shiitake mushrooms are examples of basidiomycetes that can enzymatically break down a variety of substrates containing lignin, hemicellulose, and cellulose into soluble compounds with low molecular weight. Laccase enzyme and other enzymes have high commercial benefits such as Laccases are used in paper industry, biobleaching done by laccases, waste detoxification and decontamination, decolorization of dyes, textile industries and food and beverage industry etc.

VII. GOVERNMENT POLICIES TO PROMOTE MUSHROOM FARMING

- 1. APEDA (Agricultural and Processed Food Products Export Development Authority):** This organization helps in the development of Export in Agriculture and Food Industry.^[19,18] Various schemes has been launched by APEDA for providing assistance to beneficiaries, R&D Organizations, Infrastructure Development, Transport Unit, exporters, producers and quality development and maintenance.^[22]
- 2. NHB (National Horticulture Board):** The schemes under this Boards are for the establishment of Commercial Unit , Primary processing and Post harvest management. The projects gets 50% assistance as a subsidy in Hilly areas up to the cost of 37.50 Rs Lakh^[20]. This board also helps in Post Harvest Management , relating to Pack House, Refer- Van, Retail Outlets, 50% subsidy is given to the project of the cost of 72.50 Rs lakhs in hilly areas.^[23]
- 3. DMI (Directorate of Marketing and Intelligence):** This scheme is with the idea of Integrated Development of Marketing related to Agriculture and allied produce in the country. Purpose of this scheme is to strengthen and develop agriculture marketing, infrastructure, grading and develop infrastructure for post harvest requirement and marketing and management of surplus produce^[21].

It may cover functional infrastructure like collection, drying, cleaning, grading standardization, sanitary and photo- sanitary measures, labelling, packaging, value addition and certification. Assistance is also provided to post harvest operations like refrigerated vans used for transporting agricultural produce to maintain cold supply chain.

4. **SFAC (Small Farmer's Agriculture Consortium):** It is a registered society comes under the Department of Agriculture and Cooperation, Government of India. It works for Agribusiness Development through venture capital assistance and project Development facility ^[25]. Nationalised Banks participates in the promotion of Investment in Agribusiness projects. The venture capital is up to 10% of total project cost of Rs. 75 lakh in Agri business. Higher venture capital can be provided to farmers under special cases.
5. **Rashtriya Krishi Vikas Yojna:** Under this scheme Government provides assistance of 80,000 Rs. to mushroom growers for installation of racks, kits, tools, compost and spawn.

VIII. INITIATIVES TAKEN BY STATE GOVERNMENT FOR MUSHROOM DEVELOPMENT

- Training on mushroom cultivation, 7 to 10 days training camps providing information regarding cultivation of mushrooms.
- Preference to women, SC/ST and unemployed graduates in training.
- It provides extension services to the mushroom growers.
- It provides consultancy to the private sector and cooperative for setting of mushroom unit.
- Helps in setting the marketing channel for the industry and suitable marketing.
- Department of Horticulture provides good quality spawn, compost and casing soil to the mushroom growers.
- NABARD and NHB provide bank loans to the mushroom growers.

Extension Service;

- Provides free of cost guidance to mushroom growers ^[24].
- Distributes literature related to mushroom cultivation to the growers, whether they are small scale or large scale growers.
- Make aware related to develop disease free compost and spawn.
- At various places KVKs have been established to support the farmers, they can get training and information from there.

IX. MARKET SCENARIO

Marketing of mushroom in India not yet well organised. Fresh mushrooms have very short shelf life, that's why they cannot be transported to long distance without proper refrigerated transport facility. It can be sold at local market and around the production area. The cultivation of white button mushroom under the controlled condition can be grown throughout year. But during the months of Dec.-Feb, it experiences market problem that time about 75% of the annual production comes in market and are forced to sell their produce at highly low prices. If producer sells it directly to retailer it has its own limitations^[16]. In India consumption of mushroom is very less in comparison to other countries. In India, it is less than 50 gm than one kg in various countries. Serious efforts have not been made, to promote the product to strengthen and expand the market in order to increase its consumption.

Below are some ideas for addressing the issues with mushroom marketing particularly that of white button mushrooms in India:

1. Expand the Market area and Strengthen the Demand :

- Popularize mushrooms using ICT as delicacy with nutritive and medicinal value, on mass media like Doordarshan , ads and posters.
- Break consumer resistance by creating awareness in new areas. Demonstration of recipes and free samples in new areas. Distribution of free recipe booklets.

2. From co-operatives for sale:

- Create cold storage facility
- Create refrigerated transport facility
- Create processing facility
- Create distributor function for big cities.

3. Good prepacks that should be eye appealing.

4. Decrease the cost of production and bring down the sale price to boost the demand.

5. Train retailers about handlings, storage, food value and recipes.

6. Approach supermarket, chain vegetable stores, mother dairy retail counters for retail sale.

7. States should fix minimum support price.

8. Public sector market, processing and export organisations should come forward.

9. Assured supply throughout the year at a reasonable cost.

Now a days, mushroom is going to be in demand for processed and fast foods. Mushroom can be canned to avoid the damage in the off-season and in the non-producing areas. Regarding the problems of sale/export of canned mushrooms, serious thought has to be given to bring down the cost of production of mushrooms and its processing in order to compete in the international market.

X. CONCLUSION

The cost difference is quickly shrinking as traditional agricultural prices rise. For instance, if mushroom farms were strategically positioned in suburban areas, it will be able to convey a product specifically to the customer, cutting out the intermediary and lowering transportation expenses. Vertical farming systems have lately been subject to significant restrictions due to start-up expenses and site selection, which has led to a desire for more straightforward government interventions and rules. On these kinds of farms, productivity may be dramatically increased by the application of straightforward technology and intensive practises in agriculture. When stands or beds are up to 4 to 5 floors, production of mushroom will be more. That will be beneficiary and cost effective. The cost of production will be less and profit will be more. That will help in controlling the problem of malnutrition, nutrient deficiency, employment and other problems like import of food. It can improve our economy of country when we will combine mushroom cultivation by vertical farming. We can be self-sufficient to meet our food demand and if food is surplus, we can export that.

GROW MUSHROOMS, EAT MUSHROOMS AND STAY HEALTHY.

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