**Mushroom Cultivation in relation to Vertical farming: A Booming Entrepreneurship**

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**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 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.

**Introduction**

India is an agriculture based country and it has one of the strongest economy 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.

**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 coined by Gilbert Ellis Bailey in 1915 who also wrote a book titled “Vertical Farming”. He also argued farming hydroponically in a controlled vertical environment which would provide economic and environmental benefits. With the aim of supplying the food to ever increasing population agricultural scientist stretched their innovative approaches to the tune of

developing hybrid/ improved high yielding varieties, improved techniques, improved tools and implements, integrated practices in water, nutrient management and insect, pest management, greenhouse technology and even the genetically modified crops.[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, Calocybe, 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 an urban and semi-urban areas, vertical farming can be an effective way to combine food production and local consumption. Land is becoming an important resource due to higher costs and limited availability. Above all, with the introduction of new food production, urban dwellers can be offered high-quality, non-toxic, more affordable farm-fresh products.[6] Recent advances in greenhouse technologies, soil-less farming, aeroponics, hydroponics, and aquaponics have offered a promising future for the vertical farm concept. These high-tech systems represent a paradigm shift in agriculture and food production systems, providing sustainable and efficient methods for urban agriculture, minimizing maintenance 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.

Current applications of vertical farming coupled with advanced technologies, such as specialized LED lights, have resulted in 10 times more crop yield than receive through traditional farming methods. Interference with ancient ecosystems causes climate change. Vertical indoor cultivation could significantly reduce the harmful effects of agriculture on ecosystems, preserving and restoring biodiversity and reducing the harmful effects on climate change.

**Food Security**

Food safety has become an increasingly important issue in recent days. Demographers expect the urban population to grow dramatically due to labour migration and quality lifestyles. Soil experts, agronomists, ecologists and geologists have warned of a growing shortage of arable land. Food prices have risen in recent decades and may increase due to the COVID-19 pandemic. Farmers predict rising prices due to rising oil prices and reduced availability of water, energy, farmland and agricultural resources.[6][32][33] The adoption of vertical farming can provide easy access to high quality foods that are free from the toxicity of agrochemicals. Effective and sustainable management of the production system can help solve many problems of pollution, climate change[27] and pest infestation. Because it simultaneously reduces energy consumption, saves water, reduces the use of fertilizers and agrochemicals, restores ecosystems, improves economic conditions and offers job opportunities and ultimately help in delivering good quality food at local level. In general, indoor cultivation provides a healthier environment for growing food.[36][35] Since indoor cultivation is independent of weather conditions, year-round operation can result in better yields and income.[34] Food costs can be reduced due to lower travel and packaging costs. Vertical farming can strengthen local economies by providing employment opportunities and help directly local food security. Vertical farming also helps to solve the lack of arable land.

**Various factors required for vertical farming**

The environment plays a crucial role in growth and development of all the plants. The behaviour of plants depends on the climate in which it grows. Light, humidity and temperature are the main modifiers of plant responses. Plants grown in humid areas have larger leaves for maximum breathability than plants grown in dry climates. Also, in cold conditions, plants store more food on hard stems. Evergreen plants growing in tropical regions receive a lot of heat from the sun. Plants grown in poor sunlight are slightly pale green in color compared to plants grown in full sunlight. Most vertical farming lighting systems differ from conventional solar lighting used in greenhouses. The main effects of photon energy on growth variability are significant, including changes in plant physiology, biology, morphology and photosynthesis.

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.

**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.To improve hunger and malnutrition in an exceedingly world of rising food process, cultivation of mushrooms may be a very reliable and profitable option.Growing of mushroom is an eco-friendly system and a part of sustainable agriculture, as it grows on stubble. In India plenty of agricultural waste is produced annually and burning of that is the source of pollution, affecting the health of human beings and also disrupting the balance of ecosystem.

**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 processes 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, Alzemerhic, Parkinson. They are anti-diabetic, antibacterial, antiviral and anti cancerous in nature as so many bioactive compounds are present in them (Table 3). 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 pickels 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* | Pyrogallol, flavonoids, hydroxybenzoic acid derivatives |
| *Auricularia* *auricula* | Glucan |
| *Boletus spp.* | 2,4,6-trimethylacetophenone imine, glutamyl tryptophan, azatadine, lithocholic acid glycine conjugate |
| *Cordyceps militaris* | Cordycepin, Cordymin |
| *Flammulina velutipes* | Polysaccharides, peptidoglycan, Flammulin |
| *Ganoderma lucidum* | Ganoderic acid, Ganopoly, Ganoderan A and B, Triterpenes, Lucidenic acid, Lanostane type triterpenic acid, Lingzhi-8 (protein), Ganodermin (protein) |
| *Lentinula edodes* | Lentinan, glucan, mannoglucan, Fucomannogalactan, Lentin (protein), Catechin, Flavonoids |
| *Pleurotus ostreatus* | Pleuran (beta-1, 3-glucan with galactose and mannose), Proteoglycan, Laccase, Pleurostrin |
| *Psilocybe cubensis* | Psilocybin (psilocin: 4-hydroxy-dimethyltryp-tamine) |
| *Volvariella volvacea* | Fip-vvo |

**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. *Pleurotus sp.* is a wood rotting basidiomycetes and laccase is the dominant ligninolytic enzyme synthesized by this species. The 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]. 0Laccase 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 plays a role in the morphogenesis and differentiation of sporulating and resting structures in basidiomycetes as well as lignin biodegradation of wood in 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]

Basidiomycetes, such as oyster mushroom, king oyster mushroom, winter mushroom and shiitake, can enzymatically degrade diverse substrates containing lignin, hemicellulose, and cellulose into soluble compounds of 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.

**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]

1. **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]

1. **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.

1. **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.

1. **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.

**Initiatives taken by State Government for mushroom development**

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

**Extension service :---**

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

**Market Scenario**

Marketing of mushroom in India not yet well organised. Fresh mushrooms have very short shelf life, that’s why they can not 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 through out 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.

Some of the suggestions to solve the marketing problems of mushrooms especially of white button mushrooms in India are given below :

1. Expand the market area and strengthen the demand :

 a) Popularize mushrooms using ICT as delicacy with nutritive and medicinal value, on mass media like Doordarshan , ads and posters.

 b) 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 avaoid 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.

**Conclusion**

Rising costs of traditional farming are rapidly closing the cost gap. For example, if mushroom growing farms are strategically located in sub-urban areas, it would be possible to sell a product directly to the consumer, reducing transport costs by eliminating the middleman. Start-up costs and site selection have been major constraints for vertical farming systems, recently creating a demand for simplified government policies and interventions. By the use of simple technology and intensive agricultural methods on these types of farms one can increase production exponentially. 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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