Effects of Different Lighting Conditions on Growth, Yield and Nutrient Content of White Oyster Mushroom in Vertical Farm

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ABSTRACT

The world population is continuously growing at a rapid rate, so a great challenge for this time is to ensure the security of food and nutrition for this increased population seeking for new crop as a source of food and nutrition. In such state mushrooms, a great source of protein, can be a favor that can be cultivated by landless people using agricultural waste material. The research work was about to analyze the effect of three lighting conditions namely dark condition (C1), medium lighting condition (C2), and sunlight (C3) on growth, yield, and nutrient content of *pleurotus ostreatus* (white oyster mushroom). Vertical farming technology was applied in mushroom production in order to minimize the land use. Three vertical structures each of three layers were used. This study also encompassed the effects of different layers (bottom later L1, middle layer L2, top layer L3) on the growth and yield of mushroom. The findings of this investigation revealed that there were significant differences in growth and yield at different conditions and structural layers. The highest average growth and yield (stalk height 3.87 cm, cap size 11.89 cm, stipe size 2.65 cm, crops per bag 15.78, fresh weight 60.03 g, and dry weight 17.03 g) was observed in dark condition (C1). On the other hand, lowest growth, and yield (stalk height 1.59 cm, cap size 3.67 cm, stipe size 1.51 cm, crops per bag 4.22, fresh weight 18.38 g, and dry weight 4.47 g) was found in sunlight (C3). Oyster mushroom cultivated in dark condition C1 also have high nutrient content. The study suggested that maintaining the absolute darkness is capable of producing high-quality white oyster mushroom.

Keywords: Growth, Lighting condition, Nutrient content, Oyster mushroom.

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I. INTRODUCTION

Agricultural sector has a crucial contribution in the economy of Bangladesh. It provides jobs for nearly 70% of Bangladesh's workforce. (Source: World Bank). Now a great challenge for the world is ensuring the food and nutritional security for the rising population seeking for new crops as a source of food and nutrition. In such situation mushrooms, a great source of protein, can be a favor that can be cultivated

by using waste material and even landless people can easily cultivate this crop.

Mushroom is an enlarged reproductive structure of complex above ground fleshy edible fungi, which is becoming popular in the world now a day for its nutritional and medicinal value. The consumption of mushroom is an age-old practice, as Chinese and Japanese gardeners have been growing mushrooms for more than 1000 years. As Bangladesh is an agricultural country, there is a large amount

of waste from agricultural and agricultural industry activities. These residues like rice bran, sawdust, straw etc. mostly tends to be disposed as wastes. Among the bio-conversion process, mushroom cultivation is a suitable technique for residue management in agriculture and agricultural industries. Mushroom cultivation can be considered as a sound way to extract bio resource left behind in agricultural residues. The production process is environmentally friendly [1]. Mushroom cultivation is now on the list of promising concepts for plant diversification, bio-conservation of inedible biomass residues into healthy foodstuff rich in protein. More than 250 edible mushroom species exist in nature, although only about 22 are largely cultivate [2]. Mushroom is produced in almost everywhere of the world. During last decades, the world production of mushroom is increased by about 10% [3]. The oyster mushroom can grow in a wide range of temperatures, and it utilizes several agricultural leftovers. For this reason, its cultivation has increased [4].

Mushroom cultivation in Bangladesh started in 1979 with support from the Japanese organizations JOCDV and JAICA. Later in 2003, Govt introduced mushroom development project under the Department of Agricultural Extension. In Bangladesh, 13 kinds of mushrooms are mainly cultivated (straw mushroom, button mushroom, oyster mushroom etc.). Oyster mushrooms are produced commercially on a large scale, accounting for about 60% of total production. It can grow at temperatures of 20-30°C and humidity levels of 55-70 percent, making it ideal for our climate [5]. Lighting condition plays the most significant role for fungi in the phototropic response of reproductive structures and their formation. The positioning of the stalk or stipe and cap is controlled by phototropic response. Phototropism is a growth response causing a bending towards or away from light. Cultivation of the oyster mushroom in darkness is better than a bright condition [6].

Oyster Mushrooms are a variety of saprophytic mushrooms belonging to the genus *pleurotus*. It is a kind of vegetable with rich nutrition, great taste, completely halal and medicinal value. The economy of mushrooms lies in their use as food for human consumption. It contains large amount of iron content, vitamin B2 and B3. It is also an important source of selenium and folic acid in it helps treat anemia. Low sodium content of mushroom, suitable for patients with high blood pressure and diabetics. These mushrooms are a great source of starchy-free carbs, fiber, protein, the majority of amino acids, and vitamins [7]. Both fresh and dried oyster mushrooms are rich in protein (30.4%), fiber (8.7%) and ash (9.8%) with an energy value of 345 kcal per 100 g of dry weight [8]. Its cultivation requires being maintained optimum temperature, humidity, and environmental conditions. Mushroom cultivation is the only one source without which the survival of landless, who have no other source except home and labor, is impossible. It does not require any terrain and can grow in the room by vertical rake.

Vertical farm is a trade term in modern agriculture, which aims to minimize land use. In general, vertical farming is an agricultural system in which plants, fungi and other life forms are artificially placed vertically against each other to obtain food, fuel and fiber or other products or services. In fact, the limited soil areas can be utilized in maximum.

If vertical farming technology can be introduced in mushroom production, it will be more beneficial, because it can reduce the bacterial contamination rate and the space used in cultivation which is very high while cultivated horizontally. It is possible to get maximum yield and growth of mushroom by cultivating it in vertical farm as well as maintaining proper environmental condition, temperature, and humidity.

In addition, no analysis regarding the nutritional value of oyster mushrooms was done in Bangladesh. Therefore, the purpose of this work was to evaluate the growth and yield of *Pleurotus Ostreatus* under different light conditions in vertical farms, and to analyze its nutritional value.

On the basis of previous recommendations, this research was conducted for the following goals.

To determine the growth and yield of oyster mushroom in different layers of vertical farm under three different lighting conditions.

To analyze the nutritional value of Oyster Mushroom of these three conditions.

II. MATERIALS AND METHODS

Lighting condition is an important factor for mushroom production in vertical farm. In this study, *pleurotus ostreatus* was cultivated. To determine the best lighting condition, mushroom was cultivated in three different lighting conditions-dark room condition, medium lighting conditions, and in sunlight. This chapter focus on the methods and technique for growing mushroom in several lighting condition on vertical farming system.

A. Site Selection

This experiment was done in Agricultural and Bio-System Engineering Laboratory of Sylhet Agricultural University. Mushrooms were cultivated in three layered vertical structures. One structure was established in dark and another in normal room condition. The third structure was set on the rooftop at the exposure to the sunlight.

B. Vertical Farm Design

Before conducting the experiment, the vertical structure was designed. A design was planned as shown in Fig. 1. The vertical structure of the design was divided into three levels.

Fig. 1. Design of the vertical farm (3D).

C. Construction of Vertical Farm

The structures were made of plastic. The size of whole structure was length $\times$ width (17.01 $\times$ 13.2 cm). The distance between one layer to another was 8.5 cm. These structures were three layered and each layer containing three mushroom spawn bags.

D. Production of Oyster Mushroom (Preparing Potato Dextrose Auger Media)

To prepare 1000 ml PDA (potato dextrose auger) media, at first 250 g potatoes were washed, peeled and sliced. Then peeled and sliced potatoes were boiled in water to soften, then filtered with cheese cloth, and further water was added to obtain 1000 mL of media. After adding 250 mg tetracycline or 30 g agar and 2 g dextrose, it was heated and stirred for about 45 minutes. After that, 10ml of medium was added to each test tube, and the test tubes' mouths were covered with cotton and brown paper. Later, all the test tubes were sterilized in an autoclave at 121 °C and 1.5 kg/cm² for 20 minutes and kept in an inclined position to provide the greatest growth space for organisms in pure culture.

E. Tissue Culture

A slight portion of tissue sample was removed from the *Pleurotus ostreatus* fruiting body and placed in a sterile PDA medium in a laminar flow cabinet under aseptic conditions to generate a pure culture. Then, it was kept 5-7 days in an incubator at 20-25 °C for mycelium to develop enough. These purified cultures were used for the entire experiment.

F. Preparation of Mother Culture

Sawdust, wheat straw, calcium carbonate and water were mixed together thoroughly and then 300 g mixture was inserted into each polythene bag. Bags are tied by plastic neck tagging with rubber bands. Then these bags were holed almost up to bottom with a stick. The bags were stuck with cotton plug and covered with brown paper and tagged by rubber bands. Then the bags were kept in the autoclave machine in 120 °C and under 1.5 kg/cm² pressure for 1 hour to complete the process of autoclave. When the packets cooled down, mycelium inoculations were done from pure culture. After completing the process of inoculation, these packets were kept in incubation room in 20-25 °C temperature for 12-13 days. In that stage these packets were filled with mycelium and turned into white color which is known as mother culture.

G. Mushroom Spawns Bag Preparation

Sawdust, wheat straw, rice bran and were mixed thoroughly with 45-50% water on weight basis. Polythene bag of size 17.8 $\times$ 25.4 cm was made double by inserting one into another. Each bag was filled with 500 g of this compost and closed by plastic bends and rubber bends. A hole was made just at middle point of these bags with wooden stick. These bags were covered with brown paper and stuck by cotton plugs holding finishing rubber bands. With a view to make them free from germ or bacteria these packets were put under autoclave machine in 12 °C and under 1.5 kg/cm² pressure for 1 hour. When these packets became cool, put on a clean bench of the inoculation room. Then one inoculation spoon of mother from previously prepared mother culture was given into these bags, after finishing all these processes

these packets were kept in good arrangements on the rakes in laminar air flow or inoculation box, at incubation room. After keeping bags in the incubation room for 18-28 days in 25 °C, these bags were filled with the growth of mycelium which are treated as commercial spawn.

H. Cultivation of Spawn Bag

With a knife, two opposite ends of plastic bags were cut into a "D" form and opened by removing the plastic sheet. The thin white mycelium layer was then carefully wiped away from the substrate's opening surface using a knife. Then the spawn bags were soaked in water for 15 minutes and spaced for another 15 minutes to remove excess water. Then these bags were kept separately on several layer of vertical structures.

I. Observation of Weather Condition and Irrigation Schedule

One of the most important physical elements is temperature that influences the growth and development of oyster mushroom. The oyster mushroom has an advantage over other mushrooms because it can grow in a wide temperature range of 18 to 30 °C [9].

In this study, temperature was measured by a digital temperature meter and irrigation water was applied using a sprayer, three times at 1200 ml quantities. The weather condition was observed every day until harvesting of mushroom as given in Table I.

TABLE I: DAILY WEATHER CONDITIONS

Observation No.	Temperature		Humidity (%)	Irrigation Water (ml)
	Room (°C)	Outside (°C)		
1	24.3	24.8	67	1200
2	25.2	28.3	71	
3	25.8	27.5	69	
4	23.6	25.2	70	
5	22.8	24	68	
6	23	25.5	70	
7	23.8	25.5	72	
8	26	28.3	60	
9	27.2	28.5	65	
10	25.3	26.8	86	
11	23.6	24	66	
12	26	26.6	69	
13	25.6	27	71	
14	22	23.2	74	
15	22.8	24.6	72	
16	18	19.8	59	
17	27	28.2	63	
18	27.9	29.3	61	

III. COLLECTION OF YIELD DATA

A. Growth of Mushroom

Height of mushroom stalk, cap size, stipe size (thickness) was measured using a centimeter's stainless scale. To maintain the accuracy, measurement was taken from each mushroom replication, from 3 layers of 3 growing conditions.

B. Average Number of Fruiting Body/Bag

We have noted the number of well-developed fruiting body. Dry and pinheaded fruiting bodies were rejected on the other hand small fruit bodies were added in counting.

C. Yield of Mushroom

The weight of freshly harvested crops was measured in an electrical precision balance and dry weight was taken after drying mushroom samples in oven for 72 hours at 80°C.

IV. NUTRIENT ANALYSIS

A. Estimation Dry Matter

0.5 g sample was taken in a crucible and then the weight was measured. In oven the sample was kept for 72 hours at 80 °C. The crucible was removed from oven and again measured the weight. Then the dry matter was measured from following equation

$$\text{Dry matter \%} = \frac{\text{Dry weight of sample+ crucible}}{\text{initial weight of sample +crucible}} \times 100$$

B. Estimation of Crude Protein

For estimating the crude protein content at first the sample was dried and then grinded by a grinding machine. Then the sample's nitrogen content was determined and multiplied by 6.25. This is also known as Kjeldahl method. The crude protein % was determined using the equation below.

$$\text{Crude Protein (\%)} = \% \text{ N} \times 6.25$$

C. Estimation of Total Ash

The ash content of the samples was estimated by heating the pre dried samples in a muffle furnace for around 6 hours at 600°C until they reached a steady weight and a white or grayish white color. The ash percentage was estimated using the equation below:

$$\text{Ash content} = \frac{\text{Weight of ash} \times 100}{\text{Weight of sample taken}}$$

D. Estimation of Crude Fiber

0.5 g sample free of moisture and fat was kept in a conical flask and 100 ml sulphuric acid solution was added in it. The mixture was heated for 30 minutes and the volume remained constant by adding water to a frequent interval. After that, the mixture was filtered through a muslin cloth and rinsed with hot water to remove the acid residue. The substance was then transferred to the same beaker and 6.25 g of sodium hydroxide solution was added. The mixture was filtered through a muslin cloth after 30 minutes of boiling (the volume remained constant), and the residue was washed with hot water until it was free of alkali, then washed with alcohols and ether. It was then weighed after being transferred to a crucible and dried overnight at 80-100 °C. The crucible was heated for 5-6 hours at 600 °C in a muffle furnace, then cooled and reweighed. The weight of crude fiber was represented by the difference between these two weights, and the percentage was computed using the following equation:

$$\text{Fiber content} = \frac{\text{DM-Ash}}{\text{Total sample weight}} \times 100$$

where empty crucible weight = a (g).

$$\text{Crucible weight +DM (Dry matter)} = b \text{ (g)}$$

$$\text{Crucible weight +Ash} = c \text{ (gm.)}$$

$$\text{DM} = b - a$$

$$\text{Ash} = c - a$$

V. DATA ANALYSIS

“Statistix 10” software was used to statistically analyze the growth and yield of mushroom at different layers of vertical farm under three different conditions. Growth and yield production was analyzed in terms of stalk height, cap size, stalk size, no. of crops per bag, fresh weight and dry weight. Nutritional value was analyzed in context of protein, fiber, dry matter and ash content.

VI. RESULT AND DISCUSSION

A. Effects of Lighting Condition and Layer on Growth (Stalk Height)

Two-way interaction of lighting conditions and layers showed highly significant ($p < 0.01$) effect on stalk height of mushroom. The bottom layer in dark condition gave the maximum stalk height (4.36 cm). On the other hand, top layer in sunlight condition showed the minimum stalk height (0.97 cm). Because sunlight prevents the vegetative growth of mushroom. It is clear that maintaining the absolute darkness during vegetative development (stalk height) is the major factor behind the success of mushroom cultivation as given in Table II:

TABLE II: EFFECT OF LIGHTING CONDITIONS AND LAYERS ON STALK HEIGHT (CM)

Condition	Layer			Mean
	L1	L2	L3	
C1	4.36	3.77	3.47	3.87
C2	3.23	2.63	2.0	2.62
C3	2.2	1.6	0.97	1.59
Mean	3.27	2.67	2.14	
% Of CV value			7.98	
LSD _{0.05}	C= 0.21	L= 0.21	C*L= 0.37	
LoS	*	*	NS	

Legend: C-Lighting conditions: (C1-Dark, C2-medium, C3-sunlight), L-Structure layer: (L1-bottom, L2-medium, L3-top), * indicate LoS- Level of Significance at 1%, NS- Not significant.

Single effect of lighting condition and layers also found the significant ($p < 0.01$) effect on stalk height of mushroom production. The result showed that on an average in dark condition the maximum stalk height C1 (3.87 cm), whereas sun lighting condition C3 was found the minimum stalk height (1.59 cm). Similarly maximum stalk height was found in bottom layer L1 (3.27 cm) and minimum was found in top layer L3 in this experiment (2.14 cm).

B. Effects of Lighting Condition and Layer on Growth (Cap Size)

Two-way interaction of lighting conditions and structural layer exhibited significant ($p < 0.01$) effect on cap size of mushroom. The bottom layer in dark condition was found the maximum cap size (13 cm). On the other hand, top layer in

sunlight condition showed the minimum cap size (1.72 cm). Because mushroom is the fruiting body of fungus, and the fungi cannot tolerate sunlight. From the Table III, it was found that the degree of darkness determines the growth (cap size) of mushroom.

TABLE III: EFFECT OF LIGHTING CONDITIONS AND LAYERS ON CAP SIZE (CM)

Condition	Layer			Mean
	L1	L2	L3	
C1	13	12	10.67	11.89
C2	10.67	9.5	8	9.39
C3	6.57	2.72	1.72	3.67
Mean	10.07	8.07	6.79	-
% of CV value	7.61			
LSD _{0.05}	C= 0.63	L= 0.63	C*L = 1.09	
LoS	*	*	*	-

Legend: C-Lighting conditions: (C1-Dark, C2-medium, C3-sunlight), L-Structure layer: (L1-bottom, L2-medium, L3-top), * indicates LoS- Level of Significance at 1%.

Single effect of lighting condition and layers also represented the significant effect ($p < 0.01$) on cap size of mushroom. On an average in dark condition C1 gave the maximum cap size (11.89 cm), whereas sun lighting condition C3 gave the minimum cap size (3.67 cm). Similarly maximum cap size was found in bottom layer L1 (10.07 cm) and minimum was found in top layer L3 in this research (6.79 cm). The interaction of condition and layer was also significant in this case.

C. Effects of Lighting Condition and Layer on Growth (Stipe Size)

Two-way interaction of lighting conditions and structural layer showed significant ($p < 0.01$) effect on stipe size of mushroom. The bottom layer in dark condition represented the maximum stipe size (2.69 cm). On the other hand, top layer in sunlight condition showed the minimum stipe size (1.15 cm). Because sunlight prevents the vegetative growth of mushroom. From the table, it is clear that maintaining the absolute darkness during vegetative development (stipe size) is the major factor behind the success of mushroom cultivation.

TABLE IV: EFFECT OF LIGHTING CONDITIONS AND LAYERS ON STIPE SIZE (CM)

Condition	Layer			Mean
	L1	L2	L3	
C1	2.69	2.66	2.61	2.65
C2	2.54	2.53	2.48	2.52
C3	2.0	1.38	1.15	1.51
Mean	2.41	2.19	2.08	
% Of CV value	5.41			
LSD _{0.05}	C= 0.12	L= 0.12	C*L = 0.21	
LoS	*	*	*	

Legend: C- Lighting conditions: (C1-Dark, C2-medium, C3-sunlight), L-Structure layer: (L1-bottom, L2-medium, L3-top), * represents LoS- Level of Significance at 1%.

Single effect of lighting condition and layers also showed the significant ($p < 0.01$) effect on stipe size of mushroom. On an average in dark condition C1 provided the maximum stipe size (2.65 cm), whereas sun lighting condition C3 showed the minimum stipe size (1.15 cm). Similarly maximum stipe size

as found in bottom layer L1 (2.41 cm) and minimum was found in top layer L3 in this experiment (2.08 cm).

D. Effect of Lighting Condition and Layer on Yield (Crops per Bag)

Two-way interaction of lighting conditions and structural layer showed significant ($p < 0.01$) effect on crops per bag (yield) of mushroom as shown in Table V. The bottom layer in dark condition showed the maximum no. of crop (17.67). On the other hand, top layer in sunlight condition had the minimum no. of crop (1.33). It happens because a large number of fruiting bodies could not be sprouted and some were damaged for the exposure of sunlight. In dark condition damage rate was low.

TABLE V: EFFECT OF LIGHTING CONDITIONS AND LAYERS ON CROPS PER BAG (NO.)

Condition	Layer			Mean
	L1	L2	L3	
C1	17.67	16.33	13.33	15.78
C2	11.67	9.67	7.67	9.67
C3	6.33	5	1.33	4.22
Mean	11.89	10.33	7.44	-
% Of CV value	23.41			
LSD _{0.05}	C=2.31	L= 2.31	C*L= 4.00	
LoS	*	*	NS	-

Legend: C- Lighting conditions: (C1-Dark, C2-medium, C3-sunlight), L-Structure layer: (L1-bottom, L2-medium, L3-top), * indicates LoS- Level of Significance at 1%, NS- Not significant.

Single effect of lighting condition and layers also showed the major ($p < 0.01$) effect on no. of crops per bag of mushroom. On an average in dark condition C1 the maximum no of. Crop (15.78) was found, whereas sun lighting condition C3 had the minimum no of Crop (4.22). Similarly maximum no. of crop was found in bottom layer L1 (11.89) and minimum was found in top layer L3 in this experimentation (7.44).

E. Effect of Lighting Condition and Layer on Yield (Fresh Weight)

Two-way interaction of lighting conditions and structural layer showed significant ($p < 0.01$) effect on fresh weight of oyster mushroom. The bottom layer in dark condition the maximum fresh weight (63 g) was found. On the other hand, top layer in sunlight condition showed the minimum (6.9 g). This happens because the growth and yield were interrupted by sunray. As normally mushroom contains high moisture content, sun drying was happened in sunlight condition, which reduced fresh weight.

TABLE VI: EFFECT OF LIGHTING CONDITIONS AND LAYERS ON FRESH WEIGHT (G)

Condition	Layer			Mean
	L1	L2	L3	
C1	63	59.97	57.13	60.03
C2	51	45.43	37.23	44.56
C3	28.23	20	6.9	18.38
Mean	47.41	41.8	33.76	
% Of CV value	5			
LSD _{0.05}	C= 2.05	L= 2.05	C*L = 3.55	
LoS	*	*	*	

Legend: C-Lighting conditions: (C1-Dark, C2-medium, C3-sunlight), L-Structure layer: (L1-bottom, L2-medium, L3-top), * refers LoS- Level of Significance at 1%.

Single effect of lighting condition and layers indicated the noteworthy ($p < 0.01$) effect on fresh weight of mushroom. On an average in dark condition C1 the maximum fresh weight was (60.03 g), on the contrary sun lighting condition C3 showed the minimum fresh weight (18.38 g). Likewise maximum fresh weight was found in bottom layer L1 (47.41 g) and minimum was found in top layer L3 in this experiment (33.76 g).

F. Effect of Lighting Condition and Layer on Yield (Dry Weight)

Two-way interaction of lighting conditions and structural layer showed significant ($p < 0.01$) effect on dry weight of mushroom. The bottom layer in dark condition the maximum dry weight was (18.97 g). In contrast top layer in sunlight condition the minimum dry weight was found (1.53 g). The quality as well as production was very poor in sunlight.

TABLE VII: EFFECT OF LIGHTING CONDITIONS AND LAYERS ON DRY WEIGHT (G)

Condition	Layer			Mean
	L1	L2	L3	
C1	18.97	16.5	15.63	17.03
C2	14.27	11.77	9.03	11.69
C3	7.27	4.6	1.53	4.47
Mean	13.5	10.96	8.73	
% of CV value			5.34	
LSD _{0.05}	C= 0.21	L= 0.21	C*L= 0.37	
LoS	*	*	**	

Legend: C- Lighting conditions: (C1-Dark, C2-medium, C3-sunlight), L- Structure layer: (L1-bottom, L2-medium, L3-top), * and ** show LoS- Level of Significance at 1% and 5% respectively.

Single effect of lighting condition and layers denoted the significant ($p < 0.01$) effect on dry weight of mushroom. On an average in dark condition C1 the maximum dry weight was (17.03 g), whereas sun lighting condition C3 showed the minimum dry weight (4.47 g). Similarly maximum dry weight was found in bottom layer L1 (13.5 g) and minimum was found in top layer L3 in this experiment (8.73 g).

G. Effect of Lighting Condition on Nutrient Content

There was slight difference in case of dry matter and ash content for 3 lighting condition. But protein and fiber content was very high in dark condition.

From different studies of *P. ostreatus* mushroom it has been observed that, in per 100 grams of dry fruiting, protein content ranges from 17 to 42 g [10]. In this investigation, the dark condition had the highest protein content (33%).

The highest fiber (15%) and ash content (8.5%) found in this study for dark condition, is near about the findings of Alam [10]. The best nutrient content was found for dark condition compared to medium and sunlight. It was probably because of good quality yield in dark.

Fig. 2. Nutritional value of mushroom in different conditions.

VII. CONCLUSION

This paper attempts to cultivate white oyster mushroom to study its growth rate, yield and nutritional content. The nobility of this research lies in the cultivation of *Pleurotus Ostreatus* in different light conditions on the vertical farm. Our experiment showed, there was significant difference in yield production among the structures of different conditions. The best quality growth and yield was found in dark condition (height 3.87 cm, cap size 11.89, stalk size 2.65 cm, no. of crops/bag 15.78, fresh wt. 60.03 g, and dry wt. (17.03 g). Also, the highest production can be found in bottom layer applying vertical farming technique in medium lighting and sunlight. Lowest yield and growth rate was observed in top layer of sunlight condition. If mushroom can be grown in proper dark condition, the production rate as well as nutrient content will be high. When cultivate in medium light and sunlight, vertical farming technology is preferable, as it gives highest yields in bottom layers. Since Bangladesh is an agricultural country, mushroom cultivation can be one of the most profitable agribusinesses. It can use agricultural waste to produce food and help to dispose of it in an environmentally friendly way. The climatic condition of Bangladesh is also suitable for mushroom cultivation. Therefore, its benefit per unit area is more economical than any other vegetables in Bangladesh.

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CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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