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RESEARCH ARTICLE

Influence of cultural and nutritional factors on the mycelial growth and yield of straw mushroom (*Volvariella volvacea*) under Odisha conditions

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Abstract

The paddy straw mushroom (*Volvariella volvacea*), a member of the genus *Volvariella*, order Agaricales, family Pluteaceae and division Basidiomycota, was studied to evaluate factors influencing mycelial growth, spawn viability and sporophore yield. Six different media, five pH levels, eight light conditions and various nutrient sources were tested. Among the media, maximum radial mycelial growth of 90 mm (PDA) and 88 mm (MEA) was found by the seventh day of inoculation. Optimal growth occurred at pH 8, yielding a maximum radial growth of 88.00mm and a mycelial dry weight of 568.40 mg. After 12 days of spawn preparation, dark incubation prompted maximum downward linear growth of 140 mm in the spawn bottle. Peptone was identified as the most effective nitrogen source, resulting in dense mycelial mats (220.50 mg) and 89 mmradial growth. Glucose and starch proved to be the best carbon sources on solid media, with 68.00 mm and 65.00 mm radial growth, respectively, whileglucose supported 285.00 mg mycelial weight in liquid media Booster Dose-1 was the macro and micronutrient supply that promoted the highest mycelia weight (210 mg), radial mycelial development (90 mm) and prospective yield (1014 g/bed). The percentage increase over standard procedureswas 35.17 % for glucose, 20.24 % for peptone and 35.20 % for Booster Dose-1.

Keywords: Carbon; light and colour intensity; macro and micro nutrients; media; nitrogen; pH; nitrogen; *Volvariella volvacea*

Introduction

In Odisha, the straw mushroom (*Volvariella volvacea*) has already become a successful commercial enterprise because of its great flavour as well as its strong market demand. According to scientific findings, straw mushrooms are classified as *Volvariella* spp., which are members of the genus Volvariella, class Agaricomycetes, order Agaricales, division Basidiomycota and family Pluteaceae. The hot and humid climate of Odisha is suitable for the cultivation of straw mushrooms. A temperature and relative humidity are necessary for the paddy straw mushroom to develop its hyphae and establish its fruiting body early is conducive in our state. Diverse agro-wastes suitable for mushroom production are also available in abundance. Its increasing popularity can be attributed to its straightforward production method, inexpensive initial investment, rapid return and extremely low land requirements. Straw mushrooms can be grown in Odisha because of its hot and muggy atmosphere. For optimal mycelia growth, the fungus needs a high temperature (35 ± 2 °C); however, for fruiting body production, a temperature of 28 °C-30 °C and a relative humidity of 85 %-90 % RH are typically required (1). In the coastal districts of Odisha, the mushroom is grown from March to October during both the summer and rainy seasons. Odisha is now the country's largest producer of mushrooms, with 19523 Mt produced. 12364 Mt of paddy straw mushrooms or 63 % of the total national production, are produced in the state alone. However, progressive farmers have been able to grow straw mushrooms virtually year-round by using polyhouses, altering some growing structures and changing some management techniques. *V. volvacea* needs a specific set of circumstances to grow and sporulate and the culture medium is the main element affecting the cultivation of fungi (2). Few publications exist on the cultural studies of *Volvariella* species, but there is a dearth of material on this aspect of *V. volvacea*. Limited literature is available on this aspect of *V. volvacea*; however, there are few reports on the cultural studies of this fungus (3, 4, 5, 6). The current studies were carried out to examine various cultural parameters and their impact on the mycelial growth and yield potential of *V. volvacea*,

given the significance of cultural studies in the cultivation process of a specific mushroom and the dearth of literature on this aspect of the species.

Materials and Methods

Experimental site

To test different cultural parameters against mycelial growth of *V. volvacea,* this trial was conducted in CTMRT, Department of Plant Pathology, OUAT, Bhubaneswar, in the year 2022-24 and the data were recorded. Eight isolates were collected from different districts of Odisha and were evaluated morphologically and molecularly, resulting VV-3 isolate as the best isolate. So the VV-3 isolate was taken for further observation.

Treatment details

Evaluation of *V. volvacea* (VV-3) culture on different growth media

A wide range of culture media, including Potato Dextrose Agar (PDA), Malt Extract Agar (MEA), Nutrient Agar (NA), Water Agar (WA), Compost Extract Agar (CEA) and Czapek's dox medium, were prepared according to the standard literature and the constituents were easily available in the locality. To prevent bacterial contamination, 0.75 g/L of streptomycin sulphate was added to the medium. The radial mycelial growth and growth pattern of the pure culture of *V. volvacea* isolates were measured using four-inch diameter petri dishes. A 250 mL conical flask was filled with 100 mL of each medium, which was then autoclaved for 15 min at 15 lb pressure for sterilization. Twenty millilitres of sterilized molten medium were aseptically added to each petriplate and petriplates were inoculated with a 5 mm mycelial disk from a ten-day pure culture that was actively growing using a previously sterilized cork borer. The diameter of the fungal colonies was measured at regular intervals to assess the effectiveness of each medium and the results were statistically evaluated using a completely randomized design (CRD). Three replicates of each type of culture medium under investigation were maintained in order to guarantee the accuracy of data and dependability.

Effect of different pH on the growth of *V. volvacea* culture(VV-3)

To find the optimal pH for mycelial growth in both solid and liquid culture media, the isolate of *Volvariella volvacea* (VV-3) was examined in a pH range of 5 to 9. PDA media of pH 5 to 9 have been created by adding the necessary amount of HCl and NaOH using a pH meter to investigate the effects of different pH regimes on radial mycelial development. Each flask was then filled with medium containing 2 % agar and autoclaved for 15 to 20 min at 15 psi for sterilization. In each petriplate, a 5 mm mycelial disc of *V. volvacea* mycelia from a pure petriplate culture that had been incubated for 15 days was inoculated. Following three days of incubation until full growth, findings were gathered on different days, the diameters of fungal colonies were measured and the data were statistically assessed. For every pH value, four replications were maintained. Similarly, this experiment was conducted on a potato dextrose broth medium to measure the growth of mycelial dry mats. The inoculation flasks were maintained in the BOD incubator at 30 °C -32 °C for 21 days, or until the mycelial growth peaked. Whatman No. 1 filter paper was used to filter the mycelial mats from the conical flasks and the collected mats and filter papers were placed in a hot air oven set at 60° ± 1°C for 2-3 hr to dry completely. The dry weight of mycelia was then noted according to treatment.

Effect of different colours and light on the growth of the spawn of *Volvariella volvacea* (VV-3)

An experiment on light intensity and colour was conducted to determine how various light intensities, such as complete darkness, diffuse light, profuse light and different colours through transparent color paper that is red, blue, green, yellow and pink, affect paddy straw mushroom spawn in a lab setting. The spawn bottles were then wrapped in a variety of translucent coloured sheets. In case of diffuse light spawn bottle was kept under diffuse sunlight under laboratory conditions where whereas in case of profuse light, it was placed under fluorescent light in the laboratory. On the sixth, ninth and twelfth days following spawn preparation, mycelial growth was assessed. The observations were statistically examined and three replications were maintained.

Effect of different nitrogen sources on the growth rate of *V. volvacea* (VV-3)

The ability of *V. volvacea* (VV-3) to grow in different nitrogen sources was examined using Czapek's medium. In Czapek's Dox medium, eight distinct nitrogen sources, i.e. ammonium nitrate, peptone, calcium nitrate, sodium nitrate, urea, glycine and yeast extract, were used in place of sodium nitrate to provide the same amount of nitrogen in each instance. No nitrogen sources were added in place of the control. Both solid and liquid media were used to assess the treatments. To sterilize a 250 mL conical flask with 100 mL of medium, it was autoclaved for 15 to 20 min at 15 psi pressure. Five millimetre pieces of a seven-day-old culture were added to the flasks and observations were made for the period of 21 days. After passing the mycelia mat through Whatman No. 1 filter paper, the fresh weight was noted and the mat was oven-dried for two hours at 60 °C. By reweighing the filter paper and mycelium mat combination, the dried mycelial weight was determined. Three replications were maintained for each treatment.

For this objective, the experiment was also carried out to determine the contribution of various nitrogen sources to the yield of the *V. volvacea* (VV-3 isolate). 0.5 % of each nitrogen source was added to water to soak the necessary amount of straw. After bed preparation, spraying was done twice @ 1 % at 7 7-day intervals. In the control, water was sprayed. For every treatment, three replications were kept. In addition to the previously reported observations, yield data were obtained from a field experiment.

Effect of different carbon sources on the growth rate of *V. volvacea* (VV-3)

In Czapek's Dox medium, seven distinct carbon sources, such as glucose, maltose, manitol, fructose, starch, lactose, sorbitol and sucrose, were employed to evaluate the growth of *Volvariella volvacea* (VV-3). No carbon source was added in the control instance. Thus, eight treatments in total were administered. Similar to nitrogen sources, these treatments were assessed in both solid and liquid media. The previously mentioned treatments were also used for *in-vivo* studies, such as nitrogen sources. For every treatment, three replications were kept.

Effect of different macro and micro nutrients on the growth rate of *V. volvacea* (VV-3)

V. volvacea.(VV-3) growth was assessed by taking nine different

treatments, i.e. the booster Dose-1 (containing $CaCO_3$ 400 ppm + $CaCl_2$ 50 ppm + KH_2PO_4 50 ppm + NaCl 50 ppm + Na_2HPO_4 50 ppm) and Booster Dose-2 (containing $CaCl_2$ 400 ppm + Na_2HPO_4 100 ppm). Zinc (Zn), Copper (Cu), Iron (Fe), Boron (B), Molybdenum (Mo), Manganese (Mn), were taken in their sulphate form except boron, as the rest. 0.01 g of each nutrient was added in place of Ferrous sulphate. No nutrient was added to Czapeck's Dox medium in the control instance. The treatments were evaluated using both liquid and solid media. To determine the effects of various nutrients on colony growth, fungal biomass and yield potential of the straw mushroom, the experiment was carried out similarly to that of nitrogen and carbon. Three replications were maintained for each treatment. For the field study, the amount of sporophores, their average weight (g), yield/bed (g), days of primordial initiation, first harvest and biological efficiency were noted.

Statistical analysis

Experimental data were analysed and analysis of variance (ANOVA) was calculated statistically using CRD for lab work and RBD for field work with OPSTAT software. Inferences were made based on the Critical difference (CD) between the means at the 5 % level of significance.

Results and Discussion

Growth of *V. volvacea* (VV-3) culture in different growth media

A significant difference was observed among all the growth media tested, with PDA showing significantly highest growth of 90.00 mm in the petriplate, which was at par with growth in MEA (88.00 mm). CEA and Czapek's dox recorded statistically similar growth patterns of VV-3 (Table 1). NA supported no growth for the tested pathogen. However, WA supported little, sparse growth of VV-3 (42 mm) 7 days after inoculation (Fig. 1). This suggests growth retardation by the components present in nutrient agar, as it lacks the complex carbon sources and optimal conditions the fungus requires. It may not be optimized for filamentous fungi; it doesn't support good hyphal extension.

Research indicates that *Volvariella volvacea* grows well in malt extract medium (6, 7). However, PDA was one of the best growing media for *Volvariella volvacea* (8, 9, 10). The findings of earlier workers support the present research result. In both media, dextrose and malt act as a source of carbon in PDA and MEA, respectively. Furthermore, glucose is the most appropriate carbon source for the majority of tropical edible macrofungi (11). This could be because the fungus readily makes cellular energy by quickly metabolizing glucose compared to other carbon molecules (12).

Effect of pH on growth of *V. volvacea* (VV-3 isolate)

Mycelium radial growth was assessed on the seventh day of inoculation and dry mycelium growth was assessed 21 days later. The analyzed data presented below revealed that colony growth on medium varied from 38.80 mm to 88.00 mm on the 7th day of inoculation (Table 2 and Fig. 2). pH 8 showed the greatest development (88.00 mm), followed by pH 7 (83.40 mm). The lowest radial growth of 38.80 mm was recorded at pH 5. The growing medium with a pH status of 8.0 yielded the mycelial dry weight with the greatest mean, 568.40 mg. According to the

Table 1. Growth of *V. volvacea* isolate (VV-3) in different growth media

Growth media	Mycelia growth 7th day after inoculation (mm)	Colony characteristics
T_1-Potato Dextrose Agar	90.00 (9.51)*	Dense mycelia and thick strands
T_2-Malt Extract Agar	88.00 (9.42)	Dense mycelia and thick strands
T_3-Compost Extract Agar	68.20 (8.30)	Thin growth
T_4-Nutrient Agar	0.00 (0.71)	No growth
T_5-Water Agar	42.00 (6.55)	Thin strand sparse growth
T_6-Czapek's dox	67.00 (8.25)	Thin strand
SE(m) ±	0.31	-
CD(0.05)	0.93	-

*Figures in the parentheses indicate the corresponding $\sqrt{(x+0.5)}$ transformed value

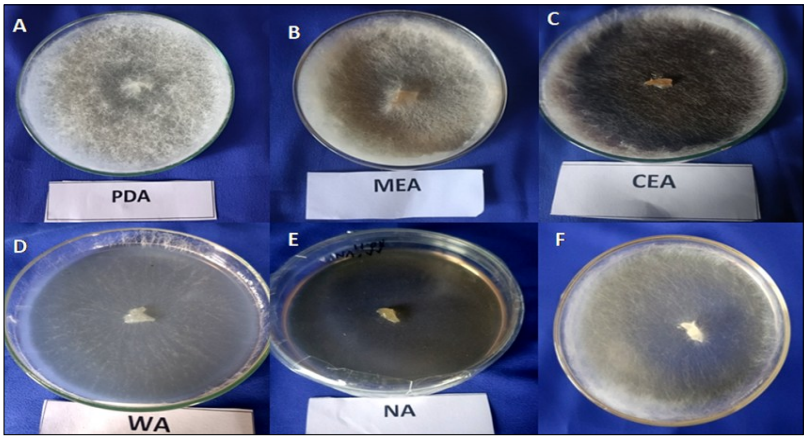

Fig. 1. Radial mycelial growth of *Volvariella volvacea* (VV-3) on different media on the 7th day, A. PDA (Potato Dextrose Agar), B.MEA (Malt Extract Agar), C. CEA (Compost Extract Agar), D. WA(Water Agar), NA (Nutrient Agar), F. Czapek's Dox Media.

Table 2. Effect of different pH on the growth of *V. volvacea* isolate (VV-3)

pH	Radial mycelial growth(mm) in 7th days	Mycelia dry weight (mg)	Aerial mycelia	
T_1-5	38.80	324.40	++	+
T_2-6	54.10	351.30	++	+++
T_3-7	83.40	537.70	++++	++++
T_4-8	88.00	568.40	++++	++++
T_5-9	66.30	354.30	+++	+++
SE(m) ±	2.80	3.80	-	-
CD(0.05)	8.44	11.46	-	-

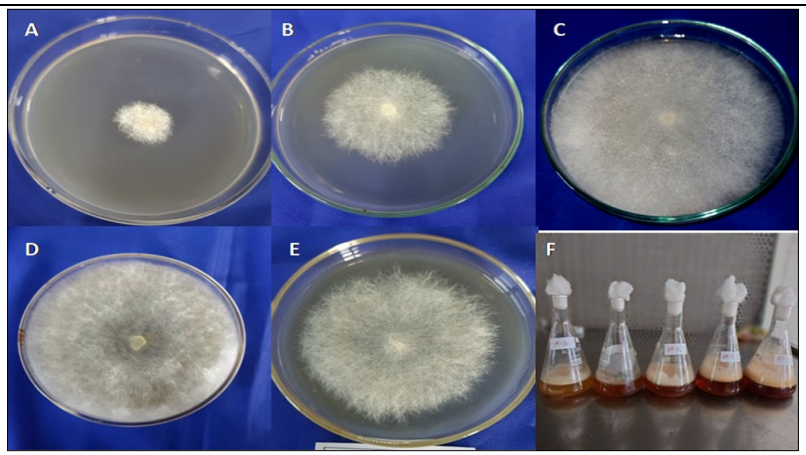

Fig. 2. Mycelial Growth of *V. volvacea* (VV-3*)* on PDA and PDB; 7 days old and 21 days old, respectively, with different pH, A. pH-5, B. pH-6, C. pH-7, D. pH-8, E. pH-9, F. mycelial growth on liquid media.

investigation's findings, the acidic range (5.0–6.0) generally did not encourage mycelial growth as well (324.40 mg and 351.30 mg, respectively). The mycelium was more robust and dense and the vegetative development was superior in the alkaline range. The alkaline range (7.0–8.0) was the best among the pH values analyzed, according to the study. The mycelial dry weight showed an increasing trend as the pH levels increased from 5.0 to 8.0.

The best pH for the growth of straw mushroom mycelia was pH 8 (13, 14). However, pH as high as 7 has been found suitable in various research (3, 9, 10). Extremely acidic or alkaline pH levels could lead to cell wall corrosion and disruption of the selective permeability function of the cell membrane (15). The lignocellulolytic enzymes secreted by *V.volvacea* show maximum activity and stability in a slightly alkaline environment, which supports faster substrate colonization and fruiting. Besides that, this pH suppresses the growth of many competitor moulds (e.g. *Trichoderma*, *Aspergillus*, *Penicillium*) as they prefer acidic to neutral pH (5–7).

Effect of different colours and light on the growth of the spawn of *V. volvacea* (VV-3)

Darkness supported maximum downward linear growth of 140.00 mm at 12 days of inoculation, followed by diffuse light (138.91 mm), which was at par with each other. Green light supported the least growth (109.56 mm) in all three phases. Growth of mycelium was varied from 30.82 mm to 47.90 mm on the 6th day of inoculation in the spawn bottle. 9th day after inoculation maximum of 98.90 mm of downward linear growth of VV-3 was recorded in the spawn bottle covered with paper, providing complete darkness. Delayed growth of 69.21 mm was observed in the spawn that were covered with green light. Similarly, downward growth on the 9th day of inoculation on the spawn varied from 69.21 mm to 98.90 mm (Table 3 and Fig.3). Significantly highest growth of 140.00 mm was observed in complete darkness, followed by 138.91 mm in diffuse light. The density and growth of aerial mycelium were found to be optimum in darkness and poor in green and red light conditions. Therefore, it was determined from the experiment that red and green colours are inhibitory and diffused light or darkness is necessary to provide good vegetative growth of the mushroom fungus.

The results are aligned with previously conducted work by the researcher (13). Research indicates similar observations in *Schizophyllum* species on PDA medium (16). Variety of colours to promote oyster mushroom development and the blue colour inhibited the growth of the oyster mushroom fungus, supporting the current findings (17). Darkness and diffuse light favour vigorous mycelial colonization and healthy fruit body formation in the test fungus, whereas profuse light causes stress, drying

Table 3. Effect of colour and light intensity on the growth of spawn of *V. volvacea* (VV-3)

	Day to spawn run		
Light type	6th day(mm)	9th day(mm)	12th day(mm)
T_1-Red light	31.90	72.20	112.91
T_2-Green light	30.82	69.21	109.56
T_3-Blue light	35.00	74.63	115.02
T_4-Yellow light	34.11	75.75	116.44
T_5-Pink light	33.01	73.80	114.06
T_6-Diffuse light*	44.60	91.34	138.91
T_7-Profuse light**	37.71	80.61	128.62
T_8-Darkness	47.90	98.90	140.00
SE(m) ±	0.21	0.46	0.70
CD(0.05)	0.64	1.38	2.11

*growth under diffuse sunlight **growth under fluorescent light

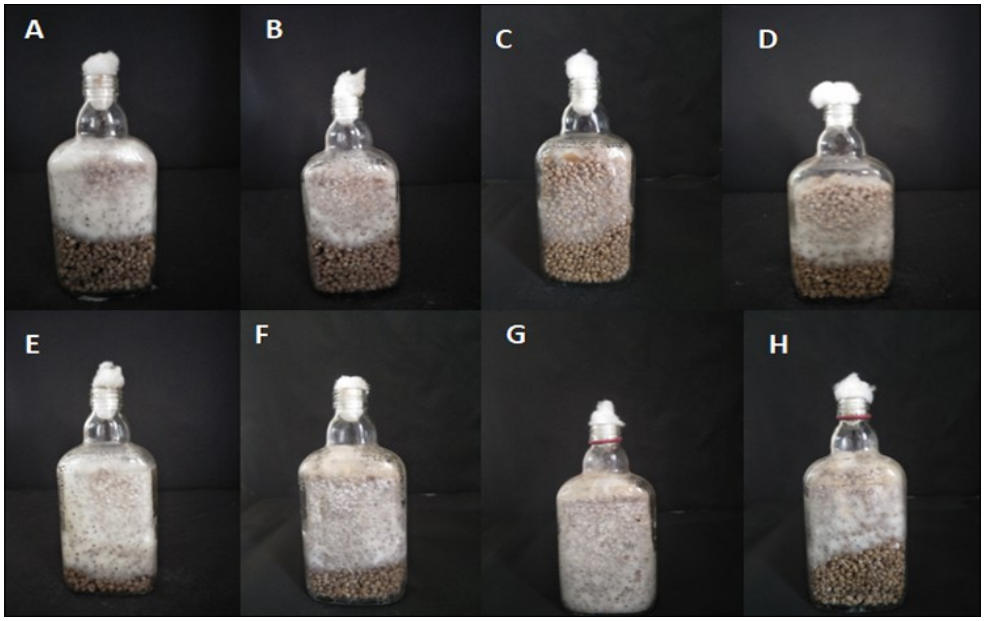

Fig. 3. Downward linear mycelial growth of *V. volvacea* (VV-3) spawn on different colours and light (12 days old), A. Red colour, B. Green colour, C. Blue colour, D. Yellow colour, E. Diffuse light, F. Profuse light, G. Darkness, H. Pink light.

and premature differentiation, leading to reduced growth. However strong, profuse light often acts as a signal for differentiation (fruit body initiation), which can slow down mycelial spread.

Effect of different nitrogen sources on the growth rate of *V. volvacea* (VV-3)

Peptone was identified as the most effective nitrogen source on a solid base medium with an average diameter growth of 89.00 mm, followed by potassium nitrate (88.01 mm), which were statistically at par out of the eight nitrogen sources tested against our test fungus. After 21 days of incubation, the dry mycelia weight was measured (Table 4 and Fig.4).

Peptone also favoured the greatest fungal biomass production (220.50 mg), which was followed by potassium nitrate (214.10 mg). The influence of various nitrogen sources resulted in a notable variation in production, with the peptone-treated bed exhibiting the highest yield of 1022.00 g/bed with a biological efficiency of 14.60 % followed by Potassium nitrate with 1011.00 g of yield and 14.40 % biological efficiency (Table 5, Fig. 5). Least productivity was obtained from yeast extract with 2.8 % BE. The percentage increase over standard procedures was 18.94 % for potassium nitrate and 20.24 % for peptone-treated beds. Urea inhibited the mycelia development in solid and liquid media significantly, while peptone was best (7, 9, 14). However, it was also found that the use of potassium nitrate also enhanced good growth of *V. volvacea* (17, 18). Peptone provides readily available amino acids that the mushroom can directly use for protein synthesis, which may reduce the energy cost of nitrogen assimilation, so the fungus can grow fast. Similarly in potassium nitrate provides nitrate along with potassium, an essential macronutrient for enzyme activation, osmotic balance, carbohydrate transport and enhances metabolism and mycelial vigour. So these may be the reasons for the significant difference in the yield of VV-3 fungus. However less growth in urea may be due to ammonia toxicity in the medium caused during the hydrolysis of urea and which inhibits fungal growth. In case of ammonium nitrate, ammonium is toxic at high concentrations, lowering the pH of the medium and rapid ammonia

Table 4. Effect of different nitrogen sources on the mycelia growth rate of *V. volvacea* (VV-3)

Nitrogen sources	Radial mycelia growth (mm) 5 days	Colony morphology	21 days after inoculation
			Dry weight of mycelia (mg)*
T_1-Ammonium nitrate	83.10 (9.14)*	Thin, uniform growth	209.20 (14.47)
T_2-Potassium nitrate	88.01 (9.41)	Thin transparent	214.10 (14.64)
T_3-Peptone	89.00 (9.46)	Thin, fluffy at the corner	220.50 (14.85)
T_4-Sodium nitrate	72.04 (8.52)	Thick transparent	170.00 (13.05)
T_5-Calcium nitrate	35.12 (5.97)	Thin strand, sparse, irregular growth	65.20 (8.10)
T_6-Urea	0 (0.71)	No growth	0 (0.71)
T_7-Glycine	58.11 (7.66)	Thick regular uniform	140.20 (11.85)
T_8-Yeast extract	43.21 (6.61)	Thin transparent	107.40 (10.38)
T_9-Control	56.00 (7.52)	Thin transparent	113.50 (10.67)
SE(m) ±	0.44	-	0.34
CD(0.05)	1.31	-	1.01

*Figures in the parentheses indicate the corresponding $\sqrt{(x+0.5)}$ transformed value

Table 5. Bioefficacy of different sources of nitrogen on the yield of *V. volvacea* (VV-3)

Nitrogen sources	Yield parameters		
	Yield(g)	Biological Efficiency (%)	Percentage of increase over normal practices (%)
T_1-Ammonium nitrate	910.00	13.00	7.06
T_2-Potassium nitrate	1011.00	14.40	18.94
T_3-Peptone	1022.00	14.60	20.24
T_4-Sodium nitrate	850.00	12.10	0.00
T_5-Calcium nitrate	500.00	7.10	-41.18
T_6-Urea	250.00	3.50	-70.59
T_7-Glycine	455.00	6.50	-46.47
T_8-Yeast extract	200.00	2.80	-76.47
T_9-Control	850.00	12.10	-
SE(m) ±	25.09	-	-
CD(0.05)	75.54	-	-

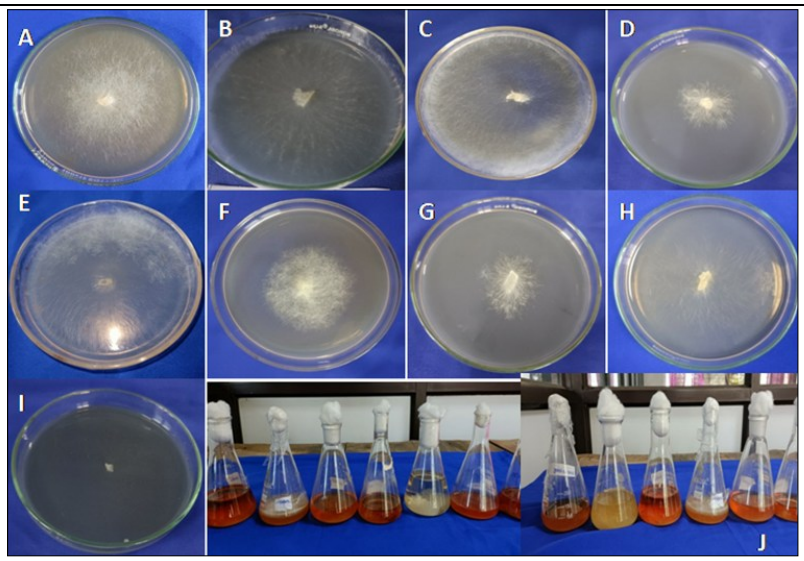

Fig. 4. Mycelial growth of *Volvariella volvacea* (VV-3) on Czapek's dox media (both solid and liquid) influenced by different nitrogen sources, A. Ammonium nitrate, B. Potassium nitrate. Peptone, D. Sodium nitrate, E. Calcium nitrate, F. Glycine, G. Yeast extract, H. Control, I. Urea, J. Growth of *V.volvacea* (VV-3*)* on different nitrogen sources (liquid media).

Fig. 5. Yield potential of *V. volvacea* (VV-3) influenced by different nitrogen sources, A. Peptone, B. Potassium nitrate, C. Control.

uptake reduces mycelial growth.

Effect of different carbon sources on the growth rate of *V. volvacea* (VV-3)

The highest growth of 68 mm with aerial thin growth in petriplates was supported by glucose out of all these carbon sources, whereas starch supported 65 mm with aerial thick uniform development. However, fructose had the least amount of development, measuring 25.30 mm. Similarly, sucrose also supported poor mycelia growth of 42.10 mm with a thin, less aerial growing pattern (Table 6 and Fig. 6). The Same trend was observed as in dry mycelia weight (21 days of incubation) of the fungus. Glucose as a carbon source supported maximum mycelia weight (285.00 mg), followed by starch (250.20 mg). Glucose and starch achieved maximum colony growth, biomass production and both are statistically at par. The lowest biomass (55.90 mg) was obtained from fructose. The results indicate that the fungus displayed significantly different growth when exposed to various sources of carbon. The glucose-treated bed had the highest yield of 1060.00 g and the best biological efficiency of 15.1 % which was at par with starch. Starch came in second with a yield of 1010.50 g and a biological efficiency of 14.44 % (Table 7 and Fig. 7). Fructose significantly reduced yield

Table 6. Effect of different carbon sources on the mycelia growth rate of *V. volvacea* (VV-3)

Carbon sources	Radial mycelia growth (mm) 5 days	Colony morphology	21 days after inoculation
			Dry weight of mycelia(mg)
T_1-Starch	65.00	Aerial thick uniform	250.20
T_2-Maltose	62.00	Irregular dense growth	228.00
T_3-Glucose	68.00	Aerial thin growth	285.00
T_4-Manitol	54.00	Thick transparent	73.40
T_5-Sorbitol	59.00	Thin, uniformly projecting	181.20
T_6-Sucrose	42.10	Thin less aerial	107.60
T_7-Fructose	25.30	Thin transparent	55.90
T_8-Control	51.00	Thin transparent	167.30
SE(m) ±	4.26	-	14.44
CD(0.05)	12.78	-	43.30

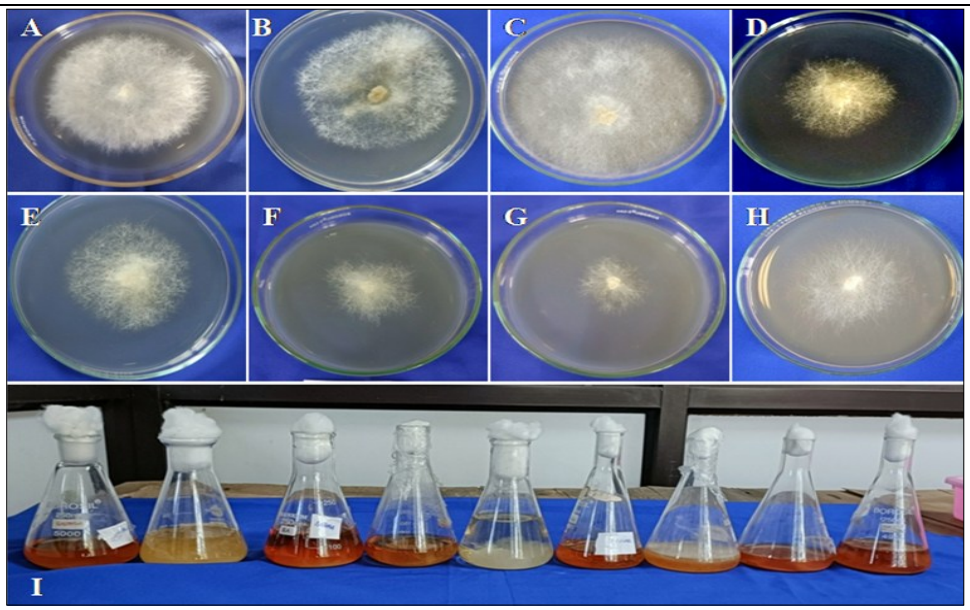

Fig. 6. Mycelial growth of *Volvariella volvacea* (VV-3) on Czapek's dox media (both solid and liquid) influenced by different carbon sources, A Starch, B. Maltose, C. Glucose, D. Manitol, E**.** Sorbitol, F. Sucrose, G. Fructose, H. Control, I. Growth of *V.volvacea* (VV-3*)* on different Carbon sources (liquid media).

Table 7. Bioefficacy of different sources of carbon on the yield of *V. volvacea* (VV-3)

Carbon sources	Yield parameters		
	Yield (g)	Biological efficiency (%)	Percentage of increase over normal practices (%)
T_1-Starch	1010.50	14.44	27.91139
T_2-Maltose	755.00	10.79	-4.43038
T_3-Glucose	1060.00	15.14	34.17722
T_4-Manitol	610.40	8.72	-22.7342
T_5-Sorbitol	520.20	7.43	-34.1519
T_6-Sucrose	450.10	6.43	-43.0253
T_7-Fructose	202.00	2.89	-74.4304
T_8-Control	790.00	14.44	-
SE(m) ±	26.87	-	-
CD(0.05)	80.90	-	-

Fig. 7. Yield potential of *V. volvacea* (VV-3) influenced by different carbon sources, A. Starch, B. Glucose, C. Control.

with 202.00 g of mushrooms. Yield under normal conditions was 790.00 g, which was greater than that of the bed sprayed with the remaining carbon sources. As regards yield attributes, a 34.17 % and 27.91 % increase over normal practices was obtained in glucose and starch, respectively.

Minimal growth was observed in media infused with fructose as a carbon source (7, 18). However, starch supported excellent growth of *Volvariella* spp. was also observed (19). Glucose is a monosaccharide and its utilization may be due to its ready metabolism for the production of cellular energy compared to starch. In the case of starch fungus may transform complex carbon compounds to simpler ones for easy metabolism. Straw mushroom directly utilizes glucose via glycolysis for rapid growth, while starch first requires extracellular enzymes to break it down into glucose, making the process slower and energy-costly. Thus, glucose is the preferred carbon source and starch supports growth only after enzymatic adaptation. Fructose supports less growth of the straw mushroom because it is a secondary carbon source, less efficiently transported and metabolized.

Effect of different macro and micronutrient sources on the growth rate of *V. volvacea* (VV-3)

Booster dose-1 showed dense, fluffy, thick mycelia growth of 90.00 mm, while Molybdenum (Mo) showed sparse growth of 12.00 mm. Additionally, it was shown that Booster-1 produced more dry mycelia weight (mg) than Booster-2. Growth of *V. volvacea* was vigorous in Booster dose-1, having yielded the significantly highest mean mycelial dry weight of 210.00 mg. Molybdenum (Mo) used as nutrient source rather inhibited mycelial growth (44.90 mg) as observed in the investigation (Table 8 and Fig. 8). Perusal of the data indicated that Booster dose-1 registered significantly highest yield of 1014 g/bed with a corresponding biological efficiency of 14.49 % followed by 915 g/bed (13.07 % of BE) in Booster dose-2 and 879 g/bed (12.56 %) in Zinc (Zn). The lowest biological efficiency of 3.64 % was observed in the bed soaked and sprayed with Copper (Cu). 35.20 % increase over normal practices was identified in beds treated with Booster dose-1 (Table 9 and Fig. 9).

Booster Dose-1 supported maximum growth of *Volvariella volvacea*, while soaking and spraying them; these findings are consistent with previous study outcomes (19). This might be because a higher alkali content greatly accelerated the microbiological and enzymatic breakdown of straw, which raised the usage of carbohydrates and sporophore yield and bioefficiency. The most suitable micronutrient for oyster mushroom cultivation was discovered to be zinc (20). Zinc is essential for several fungal enzymes, including those that are involved in DNA and RNA synthesis and intermediate metabolism. Pectinolytic enzymes, which are thought to be involved in the initiation of development and enlargement of fruit bodies, would have been produced if the boosters, Booster Dose-1 and Booster Dose-2 had been sprayed during the pinhead formation process (21, 22).

Table 8. Effect of different nutrient sources on the mycelia growth rate of *V. volvacea* (VV-3)

Nutrient sources	Doses used in media (Czapek's Dox media)	Radial mycelia growth (mm) 5 days	Colony morphology	21 days after inoculation
				Dry weight of mycelia(mg)
T_1-Booster Dose-1	0.01gm/lit	65.00	Dense fluffy thick	210.00
T_2-Booster Dose-2	0.01gm/lit	60.00	Thin, aerial	170.10
T_3-Fe	0.01gm/lit	46.00	Thin transparent	83.80
T_4-Mn	0.01gm/lit	51.00	Thin, sparse growth	93.40
T_5-Mo	0.01gm/lit	12.00	Sparse growth	44.90
T_6-B	0.01gm/lit	14.00	Thick uniform growth	55.10
T_7-Cu	0.01gm/lit	45.00	Thick aerial growth	82.00
T_8-Zn	0.01gm/lit	54.00	Thin, aerial growth	105.30
T_9-Control	0	43.00	Uniform thick growth	98.90
SE(m) ±		3.63	-	6.70
CD(0.05)		10.78	-	19.92

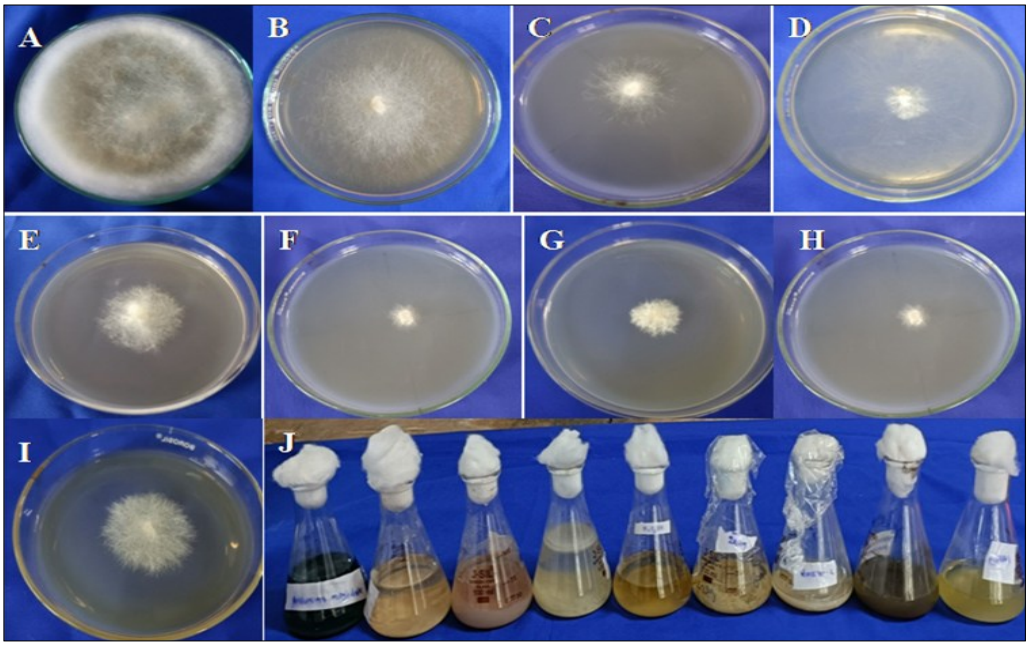

Fig. 8. Mycelial growth of *Volvariella volvacea* (VV-3) on Czapek's dox media (both solid and liquid) influenced by different macro and micronutrient sources, A. Booster Dose-1, B. Booster Dose-2,C.Iron(Fe), D. Manganese (Mn), E. Boron (B**)**, F. Molybdenum (Mo), G. Copper (Cu), H. Zinc (Zn**),** I. Control, J. Growth of *V.volvacea* (VV-3*)* on different macro and micronutrients (liquid media).

Table 9. Bioefficacy of different sources of macro and micronutrients on yield of *V. volvacea* (VV-3)

Nutrient sources	Yield parameters		
	Yield (g)	Biological Efficiency (%)	Percentage of increase over normal practices (%)
T_1-Booster Dose-1	1014.00	14.49	35.20
T_2-Booster Dose-2	915.00	13.07	22.00
T_3-Fe	640.00	9.14	-14.67
T_4-Mn	637.80	9.11	-14.96
T_5-Mo	286.00	4.09	-61.87
T_6-B	460.50	6.58	-38.60
T_7-Cu	255.00	3.64	-66.00
T_8-Zn	879.00	12.56	17.20
T_9-Control	750.00	10.71	0.00
SE(m) ±	15.67	-	-
CD(0.05)	47.19	-	-

Fig. 9. Yield potential of *V. volvacea* (VV-3) influenced by different macro and micronutrients sources, A. Booster Dose-1, B. Booster Dose-2, C: Control.

Conclusion

Potato dextrose agar was found most suitable among the tested media for *Volvariella volvacea* growth, achieving full plate colonization of 90.00 mm. Maximum radial growth of 88.00 mm and 568.40 mg of mycelia dry weight of the fungus was achieved at pH 8. Dark incubation promoted faster mycelial colonization (140 mm) in spawn bottles within 12 days. Peptone and glucose emerged most effective nitrogen and carbon sources, respectively, promoting significant radial growth and dense mycelial mats(220.50 mg peptone and 285.00 mg with glucose). Booster Dose-1 significantly enhanced mycelial biomass (210 mg), radial growth (90 mm) and sporophore yield (1014 g/bed). The percentage of increase over normal practices was found to be 20.24 % in peptone, 34.17 % in glucose and 35.20 % in Booster Dose-1. These findings support optimised, large-scale production under variable climatic conditions, especially in Eastern regions. Optimized substrates, supplements and dark incubation enhance spawn quality, shorten crop cycles and boost yields while reducing contamination. Adaptability of the test fungus to alkaline pH and nutrient supplementation ensures stable growth and economic sustainability in tropical climates.

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Authors' contributions

SB conceptualized the research work and contributed to data curation. MKM carried out the formal analysis and participated in drafting the manuscript. NC conducted the investigation and assisted in methodology development. AKS contributed to the visualization and supported manuscript writing. PRM developed the methodology and refined the manuscript draft. AS performed the statistical analysis and contributed to editing. UB assisted in statistical analysis and critically revised the manuscript. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: The Authors do not have any conflict of interest to declare.

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