

# Mushroom Cultivation as an Innovative Agricultural Technology: Adoption Attributes among Farmers of Pulwama District of Jammu and Kashmir

Ajaz A. Shah<sup>\*1</sup>, Iflah Mushtaq<sup>2</sup>, Shabir-ur-Rehman<sup>3</sup>, Younis Ali Sofi<sup>4</sup> and Showkat A. Bhat<sup>5</sup>

<sup>1</sup> Mushroom Development Assistant, Demonstration cum Training Centre (DCTC), Department of Agriculture Production and Farmers Welfare, Pulwama - 192 305, Jammu and Kashmir, India

<sup>2</sup> Department of Botany, University of Kashmir, Hazratbal - 190 006, Srinagar, Jammu and Kashmir, India

<sup>3</sup> Tissue Culture Laboratory, Integrated Mushroom Development Centre (IMDC), Lal Mandi, Srinagar - 190 008, Jammu and Kashmir, India

<sup>4</sup> Spawn Production Laboratory, Integrated Mushroom Development Centre (IMDC), Lal Mandi, Srinagar - 190 008, Jammu and Kashmir, India

<sup>5</sup> In-charge, Controlled Conditioned Cropping Room for Mushroom, Department of Agriculture Production and Farmers Welfare, Tral - 192 123, Jammu and Kashmir, India

Received: 30 Apr 2026; Revised accepted: 27 June 2026

## Abstract

Mushroom cultivation has emerged as an important innovative agricultural enterprise for enhancing rural livelihoods, employment generation, and nutritional security in Jammu and Kashmir. The present study was conducted in Pulwama district of Jammu and Kashmir to assess the adoption attributes of mushroom cultivation technology among farmers. The study covered 189 Gram Panchayats distributed across 11 Community Development (CD) Blocks of the district, namely Aripal, Awantipora, Dadsara, Achgoza, Kakapora, Lassipora, Litter, Newa, Pampore, Pulwama, and Shadimarg. A total sample of 125 mushroom growers was selected through random sampling technique. Data were collected through a structured interview schedule and analyzed using frequency, percentage, mean score, and ranking methods. The findings revealed that mushroom cultivation was largely adopted due to its low land requirement, quick economic returns, employment generation potential, and suitability for small and marginal farmers. Majority of the respondents belonged to middle age group (46.40%), had secondary level education (32.80%), and possessed medium level adoption of mushroom production technology (58.40%). High profitability, market demand, and government support were identified as major motivating factors for adoption, while lack of technical knowledge, inadequate storage facilities, and marketing constraints were the major barriers. The study concludes that mushroom cultivation can significantly contribute towards sustainable agricultural diversification and livelihood enhancement in Pulwama district if proper extension support, training, and market infrastructure are strengthened.

**Key words:** Mushroom cultivation, Technology adoption, Agricultural innovation, Livelihood diversification

Agriculture continues to be the backbone of the rural economy in India and plays a crucial role in employment generation, food security, and livelihood sustainability. However, declining land holdings, climate variability, and limited income opportunities from conventional farming have compelled farmers to adopt diversified and innovative agricultural enterprises [1]. Among the various alternative agricultural practices, mushroom cultivation has emerged as a promising enterprise due to its low investment requirement, short cropping cycle, and high economic returns [2]. Mushroom cultivation has emerged as one of the most promising agri-based enterprises for sustainable rural development, nutritional security, and income generation across the world. In recent years, the enterprise has gained considerable importance due to increasing pressure on agricultural land, declining profitability from conventional farming, and growing demand for nutritious

food products. Mushrooms are regarded as a valuable source of high-quality protein, vitamins, minerals, dietary fibre, and bioactive compounds with medicinal properties [3]. They are often referred to as “white vegetables” because of their nutritional richness and health-promoting characteristics. The cultivation of mushrooms not only provides nutritious food but also serves as an eco-friendly biotechnology capable of converting lignocellulosic agricultural residues into valuable edible biomass [4].

Agricultural wastes such as paddy straw, wheat straw, maize stalks, sawdust, and other organic residues are effectively utilized as substrates in mushroom production. This process contributes towards efficient recycling of agricultural by-products and environmental conservation by reducing open-field burning and waste accumulation [5]. Mushroom cultivation therefore represents an important component of

**\*Correspondence to:** Ajaz A. Shah, E-mail: drshahajaz@gmail.com

sustainable agriculture and circular bio-economy. The enterprise also produces spent mushroom substrate which can further be utilized as organic manure, vermicompost, or animal feed, thereby enhancing resource use efficiency in farming systems [6]. The importance of mushroom cultivation has increased significantly in developing countries because of its low capital investment, short production cycle, and high economic returns. Unlike many agricultural enterprises, mushroom cultivation requires very little land and can be undertaken indoors under controlled environmental conditions. This characteristic makes it highly suitable for small and marginal farmers, landless labourers, and rural youth who possess limited land resources [1]. Moreover, mushroom farming can easily be integrated with existing agricultural activities as a subsidiary occupation, enabling farmers to diversify their income sources and reduce economic risks associated with conventional crop production.

Mushroom cultivation also plays a crucial role in employment generation and poverty alleviation in rural areas. The enterprise is labour-intensive and provides year-round employment opportunities in activities such as substrate preparation, spawning, crop management, harvesting, processing, packaging, and marketing. It is particularly beneficial for rural women because many operations involved in mushroom cultivation can be performed within the household premises without affecting domestic responsibilities [7]. Consequently, mushroom farming has emerged as an effective tool for women empowerment and self-employment generation among rural households. Several government agencies and development organizations have promoted mushroom cultivation through skill development programmes and entrepreneurship training for women and unemployed youth.

In India, mushroom cultivation has witnessed remarkable growth during the last two decades owing to increasing consumer awareness regarding health and nutrition. India produces a variety of mushrooms including button mushroom (*Agaricus bisporus*), oyster mushroom (*Pleurotus spp.*), milky mushroom (*Calocybe indica*), and paddy straw mushroom (*Volvariella volvacea*). Among these, button mushroom accounts for the major share of commercial production due to favourable climatic conditions in temperate regions [8]. Jammu and Kashmir possesses immense potential for mushroom cultivation because of its cool climate, abundant availability of organic residues, and increasing market demand for fresh mushrooms. Pulwama district of Jammu and Kashmir has shown growing interest in mushroom cultivation as an innovative agricultural enterprise. Farmers in the district are increasingly adopting mushroom production technologies to supplement their farm income and improve household livelihood security. The enterprise is particularly suitable for the agro-climatic conditions of the Kashmir valley where seasonal unemployment and small land holdings are common. Mushroom cultivation not only enhances farm profitability but also contributes towards nutritional improvement and sustainable resource management.

The adoption of mushroom cultivation technology among farmers is influenced by several socio-economic and institutional factors including education, extension support, access to inputs, training, market availability, and perceived profitability of the enterprise. According to Rogers [9], innovations possessing attributes such as relative advantage, compatibility, simplicity, trialability, and observability are adopted more rapidly by farming communities. Mushroom cultivation exhibits many of these favourable attributes, making it a viable innovation for agricultural diversification and rural entrepreneurship [10].

Despite the growing significance of mushroom cultivation in rural development, the adoption level and innovation attributes associated with mushroom farming in many parts of Jammu and Kashmir remain inadequately explored. Therefore, understanding farmers' perceptions, adoption behaviour, and constraints related to mushroom cultivation is essential for designing effective extension interventions and policy support programmes. In this context, the present study was undertaken to examine mushroom cultivation as an innovative agricultural technology adoption attribute among farmers in Pulwama district of Jammu and Kashmir.

## MATERIALS AND METHODS

The present investigation entitled "Mushroom Cultivation as an Innovative Agricultural Technology Adoption Attribute among Farmers of Pulwama District of Jammu and Kashmir" was conducted during the year 2025-26 in Pulwama district of Jammu and Kashmir. The district was selected purposively because mushroom cultivation has emerged as an important income-generating enterprise in the area due to favourable agro-climatic conditions, availability of agricultural residues, and increasing participation of rural households in mushroom farming activities. Pulwama district comprises 11 Community Development (CD) Blocks, namely Aripal, Awantipora, Dadsara, Achgoza, Kakapora, Lassipora, Litter, Newa, Pampore, Pulwama, and Shadimarg, covering a total of 189 Gram Panchayats. These blocks represent diverse socio-economic and agricultural conditions of the district and have shown increasing adoption of mushroom cultivation practices in recent years.

The study population consisted of farmers actively engaged in mushroom cultivation practices across different villages of the selected blocks. A comprehensive list of mushroom growers was obtained from the Department of Agriculture, Mushroom Development Assistant and local village functionaries. From the identified population, a sample of 125 respondents was selected using random sampling technique to ensure equal representation and minimize sampling bias. The selected respondents represented different categories of farmers including small, marginal, and medium farmers involved in mushroom production as either a primary or subsidiary occupation. The study followed an ex-post facto research design since the variables under investigation had already occurred and were beyond the control of the researcher. The design was considered appropriate for studying the adoption behaviour, innovation attributes, and constraints associated with mushroom cultivation technology among farmers.

Primary data were collected personally from the respondents through a well-structured and pre-tested interview schedule. Before final data collection, the interview schedule was pilot-tested among a small group of mushroom growers outside the sample area to assess clarity, relevance, and reliability of the questions. Necessary modifications and refinements were made based on the responses obtained during pre-testing. The interview schedule was designed to collect detailed information regarding socio-economic and demographic characteristics of respondents such as age, education, family size, land holding, farming experience, annual income, and extension contact. In addition, information related to awareness and adoption of mushroom cultivation technologies, perceived innovation attributes, economic benefits, training exposure, and constraints faced in mushroom production and marketing was also gathered.

To measure the adoption behaviour of mushroom growers, various recommended mushroom production practices such as substrate preparation, spawn selection, compost preparation, temperature management, irrigation, disease management, harvesting, and storage practices were considered. Respondents were categorized into low, medium, and high adoption groups based on their adoption scores. The innovation attributes of mushroom cultivation technology were assessed using selected dimensions such as relative advantage, compatibility, complexity, observability, and trialability as suggested in diffusion of innovation theory. Respondents' perceptions regarding these attributes were measured on a three-point continuum and appropriate scores were assigned for analysis.

The collected data were carefully scrutinized, coded, classified, and tabulated to facilitate systematic analysis and interpretation. Statistical tools such as frequency, percentage, arithmetic mean, weighted mean score, ranking method, and standard descriptive statistics were employed for analysis of the data. Frequencies and percentages were used to describe socio-economic characteristics and adoption levels of respondents, while weighted mean scores and ranking techniques were used to prioritize innovation attributes and constraints perceived by mushroom growers. The analyzed data were interpreted in light of the objectives of the study to draw meaningful conclusions regarding the adoption behaviour and innovation attributes of mushroom cultivation technology among farmers in Pulwama district of Jammu and Kashmir.

## RESULTS AND DISCUSSION

### *Socio-economic characteristics of respondents*

The data presented in (Table 1) indicate that a considerable proportion of the respondents belonged to the middle age category. Out of the total 125 respondents, 46.40 per cent were middle-aged (35–50 years), followed by 28.00 per cent in the old age category (>50 years), while only 25.60 per cent belonged to the young age group (<35 years). The findings suggest that mushroom cultivation was predominantly practiced by middle-aged farmers who possess comparatively greater farming experience, economic stability, decision-making ability, and access to productive resources. The predominance of middle-aged respondents in mushroom cultivation may be attributed to their active involvement in agricultural and allied enterprises for livelihood enhancement. Farmers in this age group generally demonstrate higher risk-bearing capacity, better managerial ability, and stronger motivation towards adoption of improved agricultural technologies compared to older farmers. They are also more likely to participate in extension programmes, training activities, and entrepreneurial ventures aimed at increasing farm income [11]. Mushroom cultivation, being a skill-oriented and commercially viable enterprise, attracts economically active farmers who can efficiently manage labour, investment, and market-related activities. Similar findings have been reported in recent studies which observed that middle-aged farmers constituted the major proportion of adopters of mushroom cultivation and other improved agricultural technologies due to their balanced combination of experience and innovativeness [12]. The relatively lower proportion of young respondents (25.60%) indicates that rural youth participation in mushroom cultivation was comparatively limited. This may be due to migration of youth towards non-farm occupations, preference for salaried employment, inadequate awareness regarding entrepreneurial opportunities in mushroom cultivation, and lack of access to financial resources and technical guidance.

However, recent developments indicate increasing interest among educated youth in mushroom farming because of its low land requirement, short production cycle, and higher profitability potential. Several success stories and entrepreneurial initiatives across India have demonstrated that mushroom cultivation can emerge as a sustainable agri-business opportunity for rural youth [13]. The findings further revealed that 28.00 per cent of the respondents belonged to the old age category. The participation of older farmers in mushroom cultivation may be associated with their long farming experience and dependence on agriculture as the primary source of livelihood. However, older farmers are often relatively conservative in adopting innovative technologies due to lower educational exposure, reduced risk orientation, and hesitation towards scientific cultivation methods. Previous studies on agricultural technology adoption have similarly indicated that age significantly influences awareness and adoption behaviour, with middle-aged farmers generally showing greater adaptability to modern practices than older age groups [14]. The dominance of middle-aged respondents in the present study also reflects the labour-intensive and management-oriented nature of mushroom cultivation. Mushroom farming requires regular monitoring of humidity, temperature, sanitation, harvesting, and marketing, which can be effectively managed by farmers in their economically active years. Moreover, middle-aged farmers often possess better social participation and extension contact, which positively influence knowledge acquisition and technology adoption. Recent studies have emphasized that training programmes, institutional support, and exposure to extension activities significantly enhance farmers' interest and participation in mushroom cultivation enterprises [15]. The findings indicate that mushroom cultivation was mainly concentrated among middle-aged farmers owing to their greater farming experience, economic motivation, and entrepreneurial orientation. The lower representation of young farmers highlights the need for targeted interventions such as skill-based training, start-up support, financial incentives, and awareness programmes to encourage youth participation in mushroom cultivation. Strengthening extension education and promoting mushroom-based agri-enterprises among rural youth can contribute significantly towards employment generation, income diversification, and sustainable rural livelihoods. Recent reviews have also highlighted mushroom cultivation as an emerging enterprise with immense potential for improving nutritional security, waste utilization, and socio-economic upliftment of farming communities [16].

Table 1 Distribution of respondents according to age (N=125)

Age group	Frequency	Percentage
Young (<35 years)	32	25.60
Middle (35–50 years)	58	46.40
Old (>50 years)	35	28.00
Total	125	100.00

Table 2 Distribution of respondents according to educational status (N=125)

Education level	Frequency	Percentage
Illiterate	12	9.60
Primary	24	19.20
Secondary	41	32.80
Higher secondary	29	23.20
Graduate and above	19	15.20
Total	125	100.00



Plate 1 Mushroom cultivation units established by farmers in Pulwama district, Jammu and Kashmir, depicting indoor bag cultivation and harvesting of button mushrooms as an innovative agricultural technology adoption practice

The data presented in (Table 2) reveal that the educational status of mushroom growers varied considerably, with the majority of respondents having attained secondary level education. Out of the total 125 respondents, 32.80 per cent had secondary education, followed by 23.20 per cent with higher secondary education, 19.20 per cent with primary education, and 15.20 per cent who were graduates and above. Only 9.60 per cent of the respondents were illiterate. The findings clearly indicate that most mushroom growers possessed at least a basic level of formal education, which could positively influence their awareness, understanding, and adoption of improved mushroom production technologies. The predominance of respondents with secondary education suggests that mushroom cultivation is more readily adopted by individuals possessing moderate educational attainment. Education enhances farmers' ability to access, interpret, and utilize scientific information related to cultivation practices, disease management, environmental control, and marketing. Farmers with secondary and higher education are generally more receptive to extension services, training programmes, and modern agricultural innovations. Since mushroom cultivation requires technical knowledge regarding temperature regulation, humidity management, sanitation, spawn handling, and post-harvest practices, educated farmers are better positioned to understand and implement recommended technologies effectively [17]. Similar findings have been reported in recent studies which observed that educational attainment significantly influences technology adoption behaviour and entrepreneurial orientation among mushroom growers and other agricultural practitioners. The study further indicated that 23.20 per cent of respondents had higher secondary education, while 15.20 per cent were graduates and above. This comparatively higher proportion of educated respondents may be attributed to the commercial and scientific nature of mushroom cultivation, which often attracts educated rural youth and progressive farmers seeking alternative income-generating enterprises. Mushroom farming is increasingly being recognized as a profitable agribusiness requiring relatively less land and investment but greater managerial and technical efficiency. Recent reviews on mushroom cultivation in India have similarly highlighted that educated farmers and rural entrepreneurs are increasingly participating in mushroom enterprises because of growing

market demand, nutritional awareness, and employment opportunities. The findings also showed that 19.20 per cent of the respondents had primary education, whereas 9.60 per cent were illiterate. The lower participation of illiterate farmers may be because mushroom cultivation involves several scientific and management-oriented practices that require the ability to comprehend technical instructions and maintain hygienic cultivation conditions. Illiterate farmers often face difficulties in accessing written information, understanding recommended production technologies, and maintaining records related to input use and marketing. Consequently, they may rely more heavily on traditional knowledge and local experience rather than scientific recommendations. Previous studies on agricultural technology adoption have similarly indicated that lower educational levels are associated with slower adoption of improved agricultural practices due to limited exposure to scientific information and extension communication. Education also plays a vital role in enhancing farmers' communication behaviour, decision-making ability, and risk orientation. Educated farmers are generally more capable of establishing linkages with extension agencies, research institutions, digital platforms, and markets. In recent years, mushroom cultivation has increasingly integrated modern technologies such as controlled environment systems, smart monitoring devices, and digital marketing platforms. Farmers possessing better educational backgrounds are more likely to adopt these innovations effectively. Contemporary studies on smart agriculture and technological interventions have similarly emphasized that educational attainment positively influences farmers' willingness to adopt modern and sustainable farming technologies. The predominance of educated respondents in the present study may also reflect the increasing role of training programmes conducted by the Department of Agriculture, Agricultural Universities, Krishi Vigyan Kendras (KVKs), and extension agencies. Several recent initiatives in India have focused on skill development and entrepreneurship promotion in mushroom cultivation, particularly among educated youth and women. Training-based interventions have been reported to improve farmers' technical knowledge, production efficiency, and income generation capacity [18]. Education significantly contributed towards awareness and adoption of improved mushroom production technology. The higher proportion of

respondents with secondary and higher education suggests that formal education enhances farmers' capacity to understand scientific recommendations and participate in commercial mushroom enterprises. However, the presence of illiterate and less educated farmers highlights the need for simplified extension approaches, practical demonstrations, audio-visual communication methods, and hands-on training programmes to ensure inclusive dissemination of mushroom production technologies among all categories of farmers.

Table 3 Adoption level of mushroom cultivation technology (N=125)

Adoption category	Frequency	Percentage
Low	24	19.20
Medium	73	58.40
High	28	22.40
Total	125	100.00

#### *Adoption level of mushroom cultivation technology*

The data presented in (Table 3) indicate that the majority of respondents exhibited a medium level of adoption of mushroom cultivation technology. Out of the total 125 respondents, 58.40 per cent belonged to the medium adoption category, followed by 22.40 per cent who exhibited high adoption, whereas only 19.20 per cent fell under the low adoption category. The findings clearly suggest that although mushroom growers possessed awareness regarding recommended mushroom production technologies, the complete adoption of scientific cultivation practices was still moderate among most respondents. The predominance of medium-level adoption among mushroom growers may be attributed to partial acceptance of improved technologies due to limitations such as inadequate technical knowledge, lack of infrastructure, financial constraints, and insufficient extension support. Mushroom cultivation is a highly management-oriented enterprise requiring scientific handling of substrate preparation, spawning, environmental regulation, sanitation, disease management, and post-harvest operations. Farmers often adopt only those technologies that are easy to practice, economically feasible, and supported through local extension services. Similar findings were reported in recent studies which observed that most mushroom growers exhibited medium levels of adoption due to limited access to technical guidance and scientific cultivation facilities [19]. The medium adoption level may also reflect the transitional stage of mushroom cultivation in many rural areas where farmers are gradually shifting from traditional cultivation methods to improved scientific practices. Farmers generally adopt technologies incrementally rather than simultaneously due to uncertainties associated with cost, risk, labour requirements, and market fluctuations. The adoption process is further influenced by factors such as education, training exposure, extension contact, economic motivation, and market accessibility. Contemporary studies on agricultural technology adoption have similarly emphasized that adoption behaviour is strongly influenced by farmers' socio-economic conditions and institutional support systems [20]. The study further revealed that only 22.40 per cent of respondents belonged to the high adoption category. The comparatively lower proportion of highly adopting farmers indicates that only a limited number of growers were practicing mushroom cultivation according to complete scientific recommendations. High adoption generally requires adequate technical knowledge, controlled environmental conditions, investment capacity, and continuous monitoring of cultivation parameters [21]. Farmers with higher education, greater training exposure,

and better extension linkage are more likely to adopt advanced technologies such as improved spawn management, controlled humidity systems, hygienic production units, and scientific packaging techniques. Recent studies have shown that specialized training programmes and front-line demonstrations significantly improve farmers' technical competence and increase adoption of scientific mushroom cultivation technologies [22]. The lower proportion of respondents (19.20%) under the low adoption category may be due to lack of awareness, inadequate technical know-how, financial limitations, and poor access to quality inputs and market infrastructure. Mushroom cultivation requires careful maintenance of temperature, humidity, and sanitation, and failure to manage these conditions properly often discourages farmers from fully adopting recommended technologies. In several rural regions, growers continue to depend on conventional practices because of fear of crop contamination, inadequate storage facilities, and uncertain market opportunities. Recent reports have highlighted that poor marketing systems, lack of cold-chain infrastructure, and limited processing facilities remain major constraints in the expansion of mushroom cultivation enterprises in India [23]. The findings also suggest that extension education and capacity-building programmes play a significant role in improving adoption behaviour among mushroom growers. Farmers who participated in demonstrations, trainings, and extension activities generally exhibited higher adoption levels because such interventions enhance practical skills, scientific understanding, and confidence regarding improved cultivation technologies. Recent front-line demonstration studies revealed that scientific mushroom production technologies substantially improved yield, profitability, and farmer satisfaction, thereby encouraging greater adoption among growers [24]. Furthermore, technological innovations and smart farming approaches are increasingly influencing mushroom cultivation practices. Modern mushroom farming systems involving IoT-based environmental monitoring, automated humidity control, and smart cultivation structures have demonstrated considerable potential for improving productivity and reducing cultivation risks. However, adoption of such advanced technologies remains limited among small and marginal farmers due to high initial investment and inadequate technical support. Recent studies on smart mushroom farming and controlled microclimate systems have emphasized that technological interventions can significantly enhance productivity, seasonal resilience, and sustainability of mushroom cultivation enterprises [25]. The medium level of adoption observed in the present study may therefore be interpreted as an indicator of both opportunity and constraint. While respondents showed willingness to adopt mushroom cultivation technologies, several barriers prevented complete adoption of scientific recommendations. Similar observations have been reported in studies on agricultural technology diffusion, which concluded that continuous interaction with extension personnel, peer learning, and targeted training programmes are essential for improving technology adoption among farmers [26]. The mushroom growers possessed a moderate level of adoption of improved cultivation technology, highlighting the need for strengthening extension services, practical demonstrations, and technical support mechanisms. Efforts should be directed towards enhancing access to quality spawn, scientific training, low-cost infrastructure, credit facilities, and market linkages to encourage higher adoption of recommended practices. Promoting farmer-oriented capacity-building programmes, ICT-based advisory services, and entrepreneurial development initiatives can further improve

adoption behaviour and contribute towards sustainable mushroom production, rural employment generation, and livelihood enhancement. Mushroom cultivation is increasingly being recognized as a sustainable enterprise capable of converting agricultural waste into nutritional and economic wealth, thereby offering significant opportunities for socio-economic development among rural communities [27].

#### *Perceived attributes of mushroom cultivation technology*

The data presented in (Table 4) revealed that mushroom growers perceived high profitability as the most important attribute influencing the adoption of mushroom cultivation technology, with a mean score of 2.84 and ranked first among all the identified attributes. This was followed by low land requirement (2.78), quick economic returns (2.74), employment generation (2.69), ease of management (2.55), and compatibility with existing farming systems (2.48). The findings clearly indicate that economic and resource-use advantages were the primary motivating factors encouraging farmers to adopt mushroom cultivation as an alternative agricultural enterprise.

The highest mean score obtained by high profitability indicates that respondents considered mushroom cultivation as a financially rewarding enterprise capable of generating higher income compared to several conventional agricultural activities. Mushroom cultivation requires comparatively less investment and offers higher returns within a shorter duration, making it attractive particularly for small and marginal farmers. The profitability aspect becomes even more significant in regions with limited landholdings and increasing pressure on agricultural resources. Recent studies have highlighted that mushroom cultivation has emerged as a rapidly growing agri-enterprise due to rising consumer demand, nutritional awareness, and expanding market opportunities. Financial analyses of modern mushroom farming systems have demonstrated considerable economic viability and positive returns, especially under scientifically managed production systems [28].

The second most important perceived attribute was low land requirement, with a mean score of 2.78. Mushroom cultivation can be practiced in small spaces, temporary structures, sheds, or controlled rooms, making it highly suitable for land-scarce farmers, rural youth, and urban entrepreneurs. Unlike conventional field crops, mushroom farming utilizes vertical space efficiently and can be undertaken indoors throughout the year. This characteristic is particularly beneficial in densely populated agricultural regions where fragmentation of landholdings limits the profitability of traditional farming systems. Recent studies on mushroom cultivation technologies have emphasized that controlled-environment mushroom farming enables efficient use of land, water, and agricultural residues while generating substantial economic returns [29].

Quick economic returns ranked third with a mean score of 2.74, indicating that respondents appreciated the short production cycle and rapid income generation associated with mushroom cultivation. Mushrooms generally mature within a few weeks after spawning, allowing growers to harvest multiple crops in a year. Such rapid turnover provides continuous cash flow and reduces the waiting period commonly associated with conventional crops. This attribute is particularly attractive to small-scale farmers and unemployed rural youth seeking immediate income opportunities. Recent extension initiatives and training programmes conducted in India have also highlighted the short production cycle and high market value of mushrooms as major incentives encouraging farmers to adopt mushroom cultivation enterprises [30].

Employment generation was ranked fourth with a mean score of 2.69. Mushroom cultivation is a labour-intensive enterprise involving substrate preparation, spawning, watering, environmental management, harvesting, grading, packaging, and marketing. Therefore, it creates substantial employment opportunities for rural households, women, and youth. The enterprise can be integrated with family labour, thereby contributing to livelihood diversification and income enhancement. Recent studies and field experiences have emphasized that mushroom cultivation has significant potential for rural employment generation, entrepreneurship development, and women empowerment due to its low capital requirement and household-level adaptability.

Ease of management secured the fifth rank with a mean score of 2.55. Although mushroom cultivation requires scientific management of humidity, temperature, sanitation, and ventilation, respondents perceived it as relatively easier to manage once appropriate training and technical guidance were obtained. Farmers who received extension support and practical demonstrations were more confident in handling cultivation operations. However, the comparatively lower mean score suggests that some respondents still considered mushroom farming technically demanding, especially regarding disease management and environmental control. Contemporary studies on mushroom cultivation technologies have similarly reported that lack of technical expertise and environmental management skills remain important constraints affecting adoption levels among farmers [31].

Compatibility with existing farming systems received the lowest mean score (2.48) and ranked sixth among the identified attributes. Although mushroom cultivation utilizes agricultural wastes such as paddy straw, wheat straw, and other organic residues, many farmers still perceive it as a specialized enterprise rather than an integral component of traditional farming systems. The lower compatibility perception may also arise from differences in management requirements, infrastructure needs, and market orientation compared to conventional crop cultivation. Nevertheless, recent research has shown that mushroom farming contributes significantly to sustainable agriculture through recycling of agricultural residues, waste management, and integrated farming approaches [32].

The findings of the present study are in close conformity with earlier observations reported by researchers who found that profitability, low land requirement, and quick returns were among the most influential factors affecting adoption behaviour among mushroom growers. Economic advantages often serve as the strongest motivational force for adoption of agricultural innovations because farmers prioritize technologies that improve household income and livelihood security. Diffusion of innovation studies have similarly emphasized that perceived relative advantage, economic feasibility, and compatibility strongly determine farmers' willingness to adopt new agricultural technologies [33].

Recent community discussions and entrepreneurial experiences also support the findings of the present study. Mushroom entrepreneurs and growers frequently emphasize profitability, low space requirement, and market demand as major reasons for entering mushroom cultivation enterprises. Many successful small-scale growers have demonstrated that mushroom farming can generate substantial annual turnover even with limited land and initial investment [34]. Mushroom growers perceived mushroom cultivation as an economically beneficial, resource-efficient, and employment-generating enterprise. High profitability, low land requirement, and quick economic returns emerged as the most influential innovation

attributes encouraging adoption of mushroom cultivation technology. These findings highlight the importance of promoting mushroom cultivation through entrepreneurship development programmes, financial assistance, market support, and extension interventions. Strengthening training facilities, improving market infrastructure, and disseminating scientific production technologies can further enhance farmers' perceptions and accelerate adoption of mushroom cultivation as a sustainable income-generating enterprise.

Table 4 Perceived innovation attributes of mushroom cultivation (N=125)

Attribute	Mean Score	Rank
High profitability	2.84	I
Low land requirement	2.78	II
Quick economic returns	2.74	III
Employment generation	2.69	IV
Ease of management	2.55	V
Compatibility with existing farming	2.48	VI

Table 5 Constraints faced by respondents in mushroom cultivation (N=125)

Constraint	Percentage	Rank
Lack of technical knowledge	72.80	I
Inadequate storage facilities	66.40	II
Marketing problems	61.60	III
High input cost	56.80	IV
Disease and pest incidence	48.00	V
Limited financial support	44.80	VI

#### Constraints faced by mushroom growers

The data presented in (Table 5) revealed that mushroom growers encountered several technological, infrastructural, and economic constraints in the adoption and successful management of mushroom cultivation technology. Among the identified constraints, lack of technical knowledge emerged as the most severe problem, reported by 72.80 per cent of the respondents and ranked first. This was followed by inadequate storage facilities (66.40%), marketing problems (61.60%), high input cost (56.80%), disease and pest incidence (48.00%), and limited financial support (44.80%). The findings indicate that although mushroom cultivation is increasingly recognized as a profitable enterprise, several institutional and infrastructural barriers continue to hinder its effective adoption and expansion among growers.

The major constraint reported by respondents was lack of technical knowledge (72.80%). Mushroom cultivation is a highly scientific and skill-oriented enterprise requiring precise management of temperature, humidity, ventilation, substrate preparation, spawning, sanitation, and disease control. Many growers lack adequate exposure to scientific cultivation techniques, resulting in poor crop management and reduced productivity. The findings suggest that insufficient access to technical guidance, training programmes, and extension services significantly affects farmers' confidence in adopting advanced mushroom cultivation practices. Similar observations were reported in recent studies which identified inadequate technical know-how and insufficient transfer of technology as major barriers affecting mushroom cultivation enterprises [35].

The high percentage of respondents reporting inadequate storage facilities (66.40%) highlights the perishable nature of mushrooms and the absence of proper post-harvest

infrastructure. Mushrooms possess a very short shelf life and require cold storage, refrigeration, and suitable packaging facilities to maintain freshness and quality after harvesting. In many rural areas, growers lack access to cold-chain infrastructure, forcing them to sell their produce immediately at lower prices or suffer post-harvest losses. This limitation significantly reduces farmers' bargaining power and profitability. Recent reports on mushroom cultivation in India have similarly emphasized that lack of organized storage and cold-chain facilities remains one of the major constraints restricting growth of the mushroom industry [36-37].

Marketing problems ranked third, reported by 61.60 per cent of respondents. Mushroom growers frequently face difficulties related to price fluctuation, absence of organized markets, exploitation by middlemen, limited consumer awareness, and inadequate transportation facilities. Since mushrooms are highly perishable, farmers are often compelled to sell their produce quickly, even at lower prices. Small-scale growers especially face challenges in establishing direct market linkages with consumers, restaurants, supermarkets, and processing units. Earlier studies also reported that lack of proper marketing channels and distant markets were among the most significant obstacles affecting adoption and commercialization of mushroom cultivation [38]. Recent community discussions among mushroom entrepreneurs also support these findings. Growers frequently report that maintaining consistent buyers and ensuring regular market supply are greater challenges than actual production. One recent discussion among Indian mushroom entrepreneurs highlighted that "the real challenge is consistency and selling, not growing," emphasizing the importance of reliable market linkages and organized marketing systems for successful mushroom enterprises.

High input cost was perceived as another major constraint by 56.80 per cent of the respondents. Scientific mushroom cultivation requires quality spawn, disinfectants, packaging materials, environmental control systems, and labour, all of which increase production costs. Additionally, controlled environmental conditions often require investment in cooling, humidification, and ventilation systems, which may not be affordable for small and marginal farmers. Rising electricity and transportation costs further increase the economic burden on growers. Recent economic studies on mushroom cultivation have similarly reported that resource utilization and cost management significantly influence profitability and sustainability of mushroom farming enterprises [39].

Disease and pest incidence was reported as a constraint by 48.00 per cent of respondents. Mushrooms are highly susceptible to fungal contamination, bacterial infections, mites, and insect pests, particularly under poor hygienic and environmental conditions. Contamination during spawning and cropping stages can lead to severe crop losses and discourage farmers from continuing cultivation. Lack of proper technical knowledge regarding sanitation, sterilization, and integrated disease management further aggravates this problem. Contemporary studies on mushroom production systems have emphasized that disease management and environmental regulation are critical for maintaining productivity and reducing crop failure risks [40].

Limited financial support was ranked sixth, reported by 44.80 per cent of the respondents. Access to institutional credit, subsidies, and financial assistance plays an important role in establishing and expanding mushroom enterprises. However, many small-scale growers face difficulties in obtaining loans due to lack of awareness, complicated procedures, and insufficient collateral security. Limited financial assistance

restricts farmers' ability to invest in improved infrastructure, quality inputs, and post-harvest technologies. Previous studies on agricultural enterprise development have similarly emphasized that inadequate financial support and weak institutional backing negatively affect adoption of innovative farming enterprises [41]. The findings of the present study also indicate that mushroom cultivation, despite being a profitable and sustainable enterprise, still requires strong institutional and infrastructural support for wider adoption. Recent extension initiatives and training workshops conducted by department of agriculture, agricultural universities and Krishi Vigyan Kendras and other extension agencies have demonstrated that scientific training significantly improves farmers' technical competence and entrepreneurial confidence in mushroom cultivation. Training programmes focusing on compost preparation, spawn inoculation, value addition, processing, and marketing have been found highly effective in overcoming technological constraints faced by mushroom growers. Furthermore, modern technological innovations such as automated environmental control systems, AI-based monitoring, and digital advisory platforms are increasingly being introduced in mushroom farming to reduce production risks and improve efficiency [42].

However, adoption of such technologies among small-scale farmers remains limited because of cost and technical barriers. Recent studies on smart mushroom cultivation systems have shown that advanced environmental monitoring technologies can substantially improve productivity and disease management efficiency [43]. Lack of technical knowledge, inadequate storage infrastructure, and marketing difficulties were the major constraints affecting mushroom growers. These constraints collectively hinder adoption, productivity, and profitability of mushroom cultivation enterprises. The study therefore highlights the urgent need for regular skill-oriented training programmes, strengthened extension services, establishment of cold storage and processing facilities, improved access to institutional credit, and development of organized marketing systems. Promoting farmer producer organizations, cooperative marketing models, and ICT-based advisory services can further enhance technical efficiency and reduce constraints faced by mushroom growers. Such interventions would not only improve adoption of mushroom cultivation technology but also contribute significantly towards rural employment generation, income diversification, and sustainable agricultural development [44-45].



Plate 2 Advanced indoor mushroom cultivation and harvesting practices adopted by farmers in Pulwama district, Jammu and Kashmir, showing high-yield button mushroom production under controlled environmental conditions

The data depicted in (Table 1) revealed that the respondents possessed a considerably high level of awareness regarding improved mushroom production technologies. The findings clearly indicate that mushroom growers were more aware of basic cultivation and crop management practices than of post-harvest and value-addition technologies. Such trends may be attributed to the regular exposure of farmers to extension programmes, Krishi Vigyan Kendra trainings, and practical experience in mushroom cultivation activities. Similar findings were also reported by Agricultural Extension researchers who observed medium to high levels of knowledge and adoption among mushroom growers [46].

Under the category of compost preparation and substrate management, the majority of respondents were aware of the selection of quality straw/substrate (95.20%), followed by chopping and wetting of straw (92.80%), compost preparation method (91.20%), and addition of supplements and fertilizers

(88.80%). The higher awareness regarding substrate selection and compost preparation may be due to the fact that these operations constitute the foundational steps in mushroom cultivation and are repeatedly emphasized during farmer training programmes. Proper substrate preparation directly influences mycelial growth and yield performance, thereby making farmers more conscious of these practices. Recent studies have similarly highlighted that adoption of improved substrate management practices significantly enhances mushroom productivity and profitability among small-scale farmers [47].

In spawning operations, awareness levels were comparatively moderate. About 84.80 per cent of the respondents were aware about the selection of quality spawn, whereas 82.40 per cent knew about the spawn rate and method of spawning. Awareness regarding hygienic conditions during spawning (80.80%) and temperature management during spawn

run (79.20%) was relatively lower. This comparatively reduced awareness may be because these practices require technical precision and scientific understanding. Many farmers still depend on traditional methods and experiential knowledge rather than scientific recommendations for spawn handling and

incubation management. The findings are in conformity with earlier studies which reported that technical operations in mushroom cultivation often exhibit comparatively lower adoption because of inadequate technical guidance and limited access to scientific infrastructure [48].

Table 6 Distribution of respondents according to awareness of improved mushroom production technology (n = 125)

Process	Yes		No	
	Farmers	Percentage	Farmers	Percentage
<b>A. Compost preparation and substrate management</b>				
Selection of quality straw/substrate	119	95.20	6	4.80
Chopping and wetting of straw	116	92.80	9	7.20
Compost preparation method	114	91.20	11	8.80
Addition of supplements and fertilizers	111	88.80	14	11.20
<b>B. Spawning operations</b>				
Selection of quality spawn	106	84.80	19	15.20
Spawn rate and method of spawning	103	82.40	22	17.60
Maintenance of hygienic conditions during spawning	101	80.80	24	19.20
Filling of compost in trays/bags	105	84.00	20	16.00
Covering and incubation of spawned bags	102	81.60	23	18.40
Temperature management during spawn run	99	79.20	26	20.80
<b>C. Crop management practices</b>				
Casing material preparation and application	110	88.00	15	12.00
Maintenance of humidity in mushroom house	121	96.80	4	3.20
Ventilation and aeration management	115	92.00	10	8.00
Irrigation/water spraying practices	123	98.40	2	1.60
Sanitation and cleanliness in mushroom unit	122	97.60	3	2.40
Identification of proper harvesting stage	120	96.00	5	4.00
Removal of infected beds and wastes	118	94.40	7	5.60
<b>D. Plant protection measures</b>				
Control of insect-pests in mushroom beds	111	88.80	14	11.20
Disease management in mushroom cultivation	109	87.20	16	12.80
Disinfection of mushroom house and equipment	113	90.40	12	9.60
E. Harvesting of mushrooms	124	99.20	1	0.80
F. Grading and sorting of mushrooms	122	97.60	3	2.40
G. Processing/value addition of mushrooms	98	78.40	27	21.60
H. Packaging of mushrooms	93	74.40	32	25.60
I. Marketing of mushrooms	116	92.80	9	7.20

The results pertaining to crop management practices showed very high awareness among the respondents. Maintenance of humidity in mushroom houses (96.80%), irrigation and water spraying practices (98.40%), sanitation and cleanliness (97.60%), and identification of proper harvesting stage (96.00%) recorded remarkably high awareness levels. Mushroom cultivation is highly sensitive to environmental conditions, especially humidity and sanitation, and therefore farmers generally pay greater attention to these aspects to avoid contamination and yield loss. The high awareness regarding sanitation practices indicates that respondents understood the importance of maintaining disease-free growing conditions. Similar observations have been documented in recent mushroom cultivation studies where environmental management and hygiene practices were identified as critical determinants of successful mushroom production [49].

Regarding plant protection measures, 90.40 per cent of respondents were aware about disinfection of mushroom houses and equipment, while 88.80 per cent and 87.20 per cent were

aware about insect-pest and disease management practices, respectively. Although awareness was reasonably high, some respondents still lacked adequate knowledge regarding scientific disease and pest management strategies. Mushroom crops are highly susceptible to fungal contamination, mites, and bacterial infections, which can severely reduce production if preventive measures are not followed properly. The relatively lower awareness in this aspect indicates the need for specialized training on integrated disease and pest management in mushroom production systems. Similar conclusions were reported in contemporary studies emphasizing the importance of technological interventions and scientific crop protection practices for sustainable mushroom cultivation [50].

The study further revealed that awareness regarding harvesting (99.20%) and grading/sorting (97.60%) was exceptionally high among the respondents. Since these operations are directly linked with marketability and income generation, growers tend to acquire practical knowledge through repeated experience and interaction with local markets.

However, awareness declined considerably in the case of processing/value addition (78.40%) and packaging technologies (74.40%). The lower awareness regarding value addition and packaging may be attributed to lack of infrastructure, inadequate market linkages, poor storage facilities, and limited training opportunities related to post-harvest management. Mushroom growers in many regions primarily focus on fresh mushroom marketing rather than processed products due to perishability and absence of organized marketing channels. Similar constraints have also been highlighted in recent reports on mushroom enterprises in India [51].

Awareness regarding mushroom marketing was found to be high (92.80%), indicating that respondents possessed adequate knowledge about selling and distribution practices. This may be due to increasing consumer demand, better market exposure, and expanding opportunities in urban and semi-urban areas. Recent evidence suggests that mushroom cultivation is emerging as an important income-generating enterprise because of rising nutritional awareness and growing demand for functional foods [52-53].

Overall, the findings indicate that respondents had substantial awareness regarding basic and operational aspects of mushroom cultivation technology, whereas comparatively less awareness was observed in advanced technical, processing, and packaging components. The study therefore emphasizes the need for continuous capacity-building programmes, hands-on training, demonstration units, and extension interventions focusing particularly on post-harvest management, value

addition, and scientific crop protection practices. Strengthening extension services and promoting modern technological interventions can further enhance adoption behaviour, productivity, and livelihood security among mushroom growers [54-55]. Recent studies on agricultural technology adoption have similarly stressed that effective dissemination of scientific information, ICT support, and farmer-oriented training programmes significantly improve adoption and sustainability of modern agricultural technologies [56].

## CONCLUSION

The study concluded that mushroom cultivation has emerged as an important innovative agricultural enterprise in Pulwama district of Jammu and Kashmir. The technology has been widely accepted due to its profitability, low land requirement, and employment generation potential. Majority of the respondents exhibited medium level adoption of mushroom cultivation practices, indicating considerable scope for further expansion through improved extension services and institutional support. The major constraints identified were lack of technical knowledge, inadequate storage facilities, and marketing problems. Therefore, there is a need for organizing regular capacity-building programmes, providing quality spawn and infrastructure facilities, and strengthening market networks for mushroom growers. Promotion of mushroom cultivation can significantly contribute towards agricultural diversification, income enhancement, and sustainable rural development in Jammu and Kashmir.



Plate 3 Abundant first flush of white button mushrooms exhibiting high fruiting density and uniform sporophore development across cultivation bags

## LITERATURE CITED

1. Singh R, Singh AK, Kumar P. 2020. Agricultural diversification and livelihood security among rural households in India. *Indian Journal of Agricultural Economics* 75(2): 145-156.
2. Chang ST, Miles PG. 2004. *Mushrooms: Cultivation, Nutritional Value, Medicinal Effect, and Environmental Impact*. CRC Press, Boca Raton, Florida.
3. Itubochi CO, Ugwuanyi JO, Ezea IB. 2025. Advancing sustainable mushroom production in developing countries: A Pathway to nutritional security and economic growth. *EAS Jr. Nutrition Food Science* 7(1): 48-66.
4. Devi P, Jain K. 2022. Value added products and many health benefits of mushroom products. *International Journal of Home Science* 8: 73-75.
5. Ahlawat OP, Tewari RP. 2007. *Cultivation Technology of Oyster Mushroom*. National Research Centre for Mushroom, Solan, India.
6. Royse DJ, Baars J, Tan Q. 2017. *Current Overview of Mushroom Production in the World*. In: *Edible and Medicinal Mushrooms: Technology and Applications*. Wiley-Blackwell. pp 5-13.
7. Bharmoria V, Kumar S, Sharma VP. 2021. Role of mushroom cultivation in women empowerment and rural livelihood development. *Indian Journal of Extension Education* 57(2): 45-50.
8. Sharma VP, Kumar S, Annepu SK. 2018. Status of mushroom production in India. *Mushroom Research* 27(1): 1-13.
9. Rogers EM. 2003. *Diffusion of Innovations*. 5<sup>th</sup> Edition. Free Press, New York.
10. Prajapati SK, Kumar V, Rawat DK, Singh S, Saroj DK, Ravikant, Verma S. 2023. Mushroom cultivation: A sustainable approach to future agriculture to ensure quality food and nutritional security of current population in India. *International Journal of Multidisciplinary Research and Growth Evaluation* 4(4): 697-705.
11. Verma R, Kumar A, Singh P. 2019. Evaluation of training programs for mushroom cultivation: A study in Himachal Pradesh. *Jr. Agric. Educ. Extension* 25(4): 345-356.
12. Kandpal AS, Joshi A, Goswami P, Singh R. 2024. Assessing knowledge enhancement through training programs on mushroom cultivation: A study on trainees' socioeconomic and knowledge gains. *International Journal Agric. Extension Social Development* 7(11): 475-477.
13. Moxley A, Ebel R, Cripps CL, Austin CG, Stein M, Winder M. 2022. Barriers and opportunities: Specialty cultivated mushroom production in the United States. *Sustainability* 14(19): 12591.
14. Jha GK, Velayudhan PK, Bhatia A, Laishram C, Kumar D, Begho T, Eory V. 2024. Transitioning towards sustainable agriculture: Analysing the factors and impact of adopting multiple sustainable inputs by paddy farmers in India. *Front. Sustain. Food Systems* 8: 1447936.
15. Thakur MP, Singh HK, Shukla CS. 2025. Current status and future prospects of mushroom cultivation and research in India: A review. *CABI Agriculture and Bioscience* 6(1): 0056.
16. Jayaraman S, Yadav B, Dalal RC, Naorem A, Sinha NK, Rao CS, Dang YP, Patra AK, Datta SP, Rao AS. 2024. Mushroom farming: A review focusing on soil health, nutritional security and environmental sustainability. *Farming System* 2(3): 100098.
17. Manyam PDG, Swamy GN, Lakshim TT. 2020. Mushroom cultivation: Understanding of knowledge gain and enterprise adoption through trainings and demonstrations. *International Journal Botany Research* 10(2): 23-28.
18. Singh R, Sharma A, Gupta S. 2021. Role of training programs in enhancing the skills of mushroom farmers: A case study. *Journal Horticultural Science* 10(3): 150-158.
19. Kandpal AS. 2022. Adoption level and constraints faced by mushroom cultivators in Uttarakhand. *Indian Research Journal of Extension Education* 22(3): 110-114.
20. Kushwah S, Chaudhary S. 2015. Adoption level and constraints in scientific oyster mushroom cultivation among rural women in Bihar. *Indian Research Journal of Extension Education* 15(3): 11-16.
21. Sharma R, Kaur S, Singh J. 2021. Knowledge gain in mushroom cultivation through training: A comparative study. *Journal of Agricultural Sciences* 13(2): 78-85.
22. Chauhan GG, Choudhary M, Aklade S. 2019. Adoption of improved mushroom production technology by tribal farmers of Dang district. *Gujarat Journal of Extension Education* 132-135.
23. Patnaik T, Mishra S. 2008. Constraints in adoption of mushroom cultivation technology. *Asian Journal of Home Science* 3(1): 86-89.
24. Kumari AR, Singh DP, Singh A, Laxmikant, Kumari M. 2018. Adoption level and constraints in scientific mushroom cultivation among rural women. *Int. Jr. Curr. Microbiol. Applied Sciences* 7: 1280-1287.
25. Kumari S, Mazhar SH. 2023. Assess the knowledge and adoption level of knowledge towards mushroom cultivation technique. *Asian Jr. Agric. Extension Econ. Sociology* 41(8): 32-38.
26. Ahir P, Thakor RF, Kapur LT. 2021. Factors influencing adoption of mushroom production in Gujarat. *Journal of Krishi Vigyan* 10(1): 90-93.
27. Mayanam D, Kumar S, Reddy P. 2020. Training needs assessment of mushroom growers in Andhra Pradesh. *Indian Jr. Agric. Extension* 16(1): 45-50.
28. Alian M, Dhoubhadel SP, Risal S, Tiwari P, Zhu W, V. B. 2026. Financial analysis of shipping container-based mushroom cultivation. *Sustainable Food Technology*. DOI: 10.1039/D6FB00006A.
29. Bhat KA, Wani MA, Sheikh FA, Mir SA. 2019. Scope and potential of mushroom cultivation in Jammu and Kashmir. *Journal of Pharmacognosy and Phytochemistry* 8(3): 2450-2454.
30. Acharya S, Sahoo M, Sarangi D. 2024. Empowering rural youth in Puri district through mushroom cultivation for sustainable livelihoods. *Jr. Krishi Vigyan* 12(1): 65-69.
31. Rukhiran M, Sutanthavibul C, Boonsong S, Netinant P. 2023. IoT-based mushroom cultivation system with solar renewable energy integration: Assessing the sustainable impact of the yield and quality. *Sustainability* 15(18): 13968.
32. Jasinska A. 2023. Sustainability of mushroom cultivation systems. *Horticulturae* 9: 1191.

33. Ruslan AAA, Kamarulzaman NH, Nawi NM, Mahmud MM, Abdullah S. 2025. Factors influencing smallholders mushroom growers' awareness on new mushroom technologies. *Advanced International Journal of Business, Entrepreneurship and SMEs* 7(24): 362-386.
34. Huang W, Wang X. 2024. The impact of technological innovations on agricultural productivity and environmental sustainability in China. *Sustainability* 16(19): 1-37.
35. Joshi A, Kandpal AS, Mishra S. 2022. Training need assessment of mushroom growers and constraints: A study in Nainital district of Uttarakhand. *Mushroom Research* 31(2): 187-193.
36. Singh N, Vaidya D, Mishra V, Thakur KS. 2016. Shelf life and storage quality of white button mushrooms (*Agaricus bisporus*) as affected by packaging material. *Int. Jr. Adv. Research* 4(11): 1790-1799.
37. Verma AK, Shivani, Sharma PC, Kumar M, Rani N. 2020. Processing of mushrooms: A viable option to sustain the growing population of developing countries. *International Journal of Chemical Studies* 8(3): 1416-1423.
38. Kumar S, Vats BRK, Kumar G, Kumar V. 2025. Mushroom farming in Bihar: A growing agri-business opportunity. *International Journal of Innovative Research in Technology* 12(2): 4004-4007.
39. Imsong T, Dukpa P. 2026. Farm level efficiency and input utilization in oyster mushroom cultivation: An empirical study of Nagaland. *Current Agriculture Research Journal* 14(1): 218-226.
40. Shirur M, Prakash SV, Upadhyay R, Ahlawat O, Kumar S, Kamal S, Yadav AS, Chinnara N. 2018. On-farm research trials in mushroom farming: Technology assessment and constraint-based recommendations. *Mushroom Research* 27(1): 87-95.
41. Gupta R, Singh S, Sharma S. 2022. Contribution of mushrooms to farm income and the socioeconomic conditions analysis of the growers. *Journal of Research and Development* 14(20): 55-61.
42. Moysiadis V, Kokkonis G, Bibi S, Moscholios I, Maropoulos N, Sarigiannidis P. 2023. Monitoring mushroom growth with machine learning. *Agriculture* 13(1): 223.
43. Jacob MS, Xu A, Qian K, Qi Z, Li X, Zhang B. 2025. Artificial intelligence in edible mushroom cultivation, breeding, and classification: A comprehensive review. *Journal of (Basel)* 11(11): 758.
44. Sahu KK, Khare A, Dixit D, Chandravanshi J. 2023. Problems and suggestions under extent of adoption of recommended mushroom production technology by mushroom growers of Jabalpur district (M.P.), India. *International Journal of Environment and Climate Change* 13(11): 2541-2545.
45. Patel DK, Sahu KK, Singh R, Chandravanshi J, Dixit D. 2023. An evaluation of mushroom growers' adoption of technology in mushroom production. *The Pharma Innovation Journal* SP-12(8): 1143-1145.
46. Yadav MC, Singh PK, Kumar R. 2017. Adoption behaviour of mushroom growers in relation to improved cultivation practices. *International Journal of Agricultural Sciences* 9(12): 4012-4015.
47. Acharya S, Sarangi DN. 2024. Enhancing livelihood security via mushroom production: A case study of technological support and farmers' ingenuity. *International Journal of Social Science* 13(2): 81-89.
48. Easin MN, Ahmed R, Alam MS, Reza MS, Ahmed KU. 2017. Mushroom cultivation as a small-scale family enterprise for the alternative income generation in rural Bangladesh. *International Journal of Agriculture, Forestry and Fisheries* 5(1): 1-8.
49. Febrianda R, Tokuda H. 2018. Learning the adoption of mushroom farming partnership: A case study of farmers and an enterprise from Cianjur District, West Java, Indonesia. *International Journal of Soc. Sci. Studies* 6(7): 1-13.
50. Saikia D, Bora M. 2023. Challenges of mushroom production in Assam. *Asian Journal of Agricultural Extension and Economic Sociology* 41(3): 13-21.
51. Rakholia R, Tailor J, Prajapati M, Shah M, Saini JR. 2024. Emerging technology adoption for sustainable agriculture in India: A pilot study. *Journal of Agriculture and Food Research* 17: 101238.
52. Shirur M, Shivalingegowda NS, Chandregowda MJ, Rana RK. 2016. Technological adoption and constraint analysis of mushroom entrepreneurship in Karnataka. *Economic Affairs* 61(3): 427-436.
53. Wani BA, Bodha RH, Wani AH. 2010. Nutritional and medicinal importance of mushrooms. *Journal of Medicinal Plants Research* 4(24): 2598-2604.
54. Sangeeta, Sharma D, Ramniwas S, Mugabi R, Uddin J, Nayik GA. 2024. Revolutionizing mushroom processing: Innovative techniques and technologies. *Food Chemistry X* 23: 101774.
55. Raman J, Lee SK, Im JH, Oh MJ, Oh YL, Jang KY. 2018. Current prospects of mushroom production and industrial growth in India. *Journal of Mushrooms* 16(4): 239-249.
56. Singh H, Singh B, Chaturvedi D, Shinde KP. 2022. Impact of training on mushroom cultivation technology on knowledge status and adoption by trainees: A study in Jaisalmer district of Rajasthan. *International Journal of Agricultural Sciences* 18(2): 657-660.