CHAPTER II

REVIEW OF LITERATURE

Edible mushrooms are a group of fleshy macroscopic fungi belonging to the order Agaricales of the class Basidiomycetes. The most cultivated mushrooms worldwide are button mushroom (Agaricus bisporus), shiitake (Lentinula edodes), oyster mushrooms (Pleurotus spp.), wood ear fungi (Auricularia spp.), straw mushroom (Volvariella volvacea), winter mushroom (Flamulina velutipes) and milky mushrooms (Calocybe indica) (Chang, 1999).

The total world production of mushrooms is estimated around 3.5 million tonnes per annum (FAO 2009) out of which about 46% is contributed by China, 10.5% by USA and 28.7% by countries of the European Union. However, the Chinese Association of Edible Fungi estimates world production over 25 million tonnes (Qi and Hui, 2010). During last three decades, mushroom production has achieved a growth rate of 6-7% (Singh, 2011). Mushroom cultivation is regarded as China’s sixth largest industry and has grown as a venture for community based technology for artificial cultivation of the edible mushrooms and the medicinal mushrooms at a low cost, creating an avenue for self - employment to about 30 million Chinese rural populations. The European Union and USA are the biggest market for mushrooms.

Oyster mushrooms, commonly known as Dhingri in India, are the third largest commercially cultivated mushrooms in the world and accounted for about 14.2% of the total world production of edible mushrooms during 1997 (Chang, 1999; Kues and Liu, 2000). China is the leading producer of oyster mushrooms, contributing about 88% of the total world production, followed by South Korea, Japan, Italy, Taiwan,
followed by a moderate range of temperature between 10-30°C (Zadrazil, 1976; Zadrazil, 1978; Balas and Szabo, 1979; Sohi and Upadhyay, 1999). They also grow on dead, decaying organic matters. As a result, unlike any other mushrooms, Pleurotus exhibits a much diversified adaptation to the varying agro-climatic conditions, which paves a wide range of cultivable species than any other edible mushrooms (Zadrazil and Dube, 1992).

Several species of Pleurotus are commercially cultivated in different parts of the world because of their culinary and medicinal properties (Garcha et al., 1993), short life cycle, reproducibility in the recycling of various agricultural and industrial wastes and low demand on resources and technology (Brenneman and Guttman, 1994). They are usually grown on a wide range of lignocellulosic materials including agricultural wastes and various grasses (Poppe, 2000) that are generally not required to be composted prior to mushroom inoculation as in case of button mushroom thereby cutting the amount of capital investment and minimizing the production time (45-60 days as compared to 80-100 days for button mushroom) and associated risk of poor productivity or crop failure. Besides, a variety of substrate available for cultivation of oyster mushrooms, its productivity per unit time is also very high as compared to all other cultivated mushrooms. It gives approx. 700 to 1000 kg of fresh mushroom from one tonne dry weight of paddy straw in 45-60 days, while with the same quantity of straw only about 500 kg of white button mushrooms are obtained in 80-100 days.

Oyster mushrooms also surpass many other food stuffs in its high protein content and gourmet food quality (Manzi et al, 1999). The nutritive values of these mushrooms are as good as the other edible mushrooms like that of button mushrooms, shiitake or paddy straw mushrooms (Tewari, 1986; Upadhyay, 2007). They possess
about 85 to 95% water, 3% protein, 4% carbohydrates, 0.1% fats, 1% mineral ions on fresh weight basis and vitamin B complex and vitamin C (Tewari, 1986). They have low calorific value and high dietary fibre content (Sharma and Madan, 1993) and about 25 to 30% essential amino acids in free form. However, various studies have established a correlation between substrate components of a culture medium and the amino acid composition in oyster mushrooms (Isikhuemhen, 2009). They are also excellent source of riboflavin, niacin (approximately ten times higher than any other vegetables) and panthotenic acid. However, the protein and carbohydrate content of the fresh oyster mushrooms varies and greatly depends upon the nature of the substrates used for their cultivation. The protein content of Pleurotus spp. has been found in the range of 19.0% to 35.0%, when grown on coconut biomass (Thomas and Rajagopal, 2003). A range of 46.6 to 81.8% for carbohydrates in differently dried samples of Pleurotus spp.; a range higher than 60% for Agaricus bisporus and 67.5% for Lentinula edodes has been recorded (Bano and Rajarathnam, 1982).

Pleurotus spp. also have other pharmacological applications such as anticancerous properties (Jose et al., 2000; Jose et al., 2002; Lavi et al., 2006) and antimicrobial activities (Ngai and Ng, 2004; Wang et al., 2007) apart from being important sources of antioxidant and immunomodulatory compounds (Hu et al., 2006a; Ken-ichiro Minato, 2008). They inhibit tumor growth, inflammation and lower blood lipid concentration (Zhang, et al., 1994; Wang et al., 2005; Hu et al., 2006b) and prevent high blood pressure and atherosclerosis (Gunde-Cimmermann, 1999). Recently, a polycyclic aromatic compound ‘pleurotin’ has been isolated from P. griseus which possess antibiotic properties (Upadhyay, 2007). Due to their low Na:K ratio, starch, fat and calorific value, the oyster mushrooms are considered suitable for
people with hypertension, obesity and diabetes (Quimio. 1976; Vijaya and Pandya, 1981; Wahid et al., 1988).

A total of 25 species of Pleurotus are commercially cultivated throughout the world, out of total 39 species recorded so far. Efficient strains of various species of Pleurotus suited to different climatic zones for cultivation, namely temperate, tropic and subtropic are either identified and domesticated from the wild natural flora or have been developed by various strain improvement programmes such as breeding, etc. (Jandaik and Kapoor, 1974; Chang et al., 1993).


Sporophore formation or fruiting in Pleurotus spp. requires different range of temperature, depending upon the nature and type of the species. Hence, on the basis of their temperature requirement for mycelial run and fruit body formation, oyster mushrooms have been categorized into two groups: winter species or low temperature requiring species, (10-22°C) such as P. ostreatus, P. florida, P. eryngii, P. fossulatus etc. and summer species or moderate temperature requiring species, (16 to 30°C) such as P. sajor-caju, P. flabellatus, P. sapidus, P. citrinopileatus, P. eous, P. membrandeeus, P. pulmonarius, P. djamore, P. tuber-regium, etc. The summer species are able to fructify at low temperatures but the winter varieties cannot fructify at high temperature.
P. ostreatus is the most preferred commercially cultivated species in temperate environmental conditions and gives the best yields on saw dusts and various cereal straws between 18 to 22°C (Guzman, 2000). However, P. ostreatus does not grow naturally in tropical regions. P. eryngii is also a temperate species commonly called the ‘King Oyster Mushroom’. Originally, it was cultivated in northern Italy and Switzerland but the commercial cultivation was done on large scale in Japan in 1995 (Ohga and Royse, 2004). To date, species that can grow at high temperature such as P. pulmonarius, P. tuber-regium and P. djamore are mainly cultivated in the tropics (Isikhuemhen and Okhuoya, 1996; Salmones and Duran Barrados, 2001). P. tuber-regium, a tropical and sub-tropical species (Hibbert et al., 1994; Isikhuemhen et al., 2000), is the only true tuber-like sclerotia producing species of Pleurotus that shows preference for temperature range between 26 to 36°C for its growth (Isikhuemhen, 1999).

Among various species of oyster mushrooms, P. sajor-caju has gained much importance as a commercial species in major parts of India in terms of yield, temperature range tolerance and biological efficiency (Jandaik and Kapoor, 1974). A temperature range of 20 to 26°C and relative humidity of 70-90 percent is ideal for growing P. sajor-caju. Nevertheless, a fairly good crop can be harvested up to 30°C (Zadrazil, 1975; Purkayastha and Jana, 1983).

Pleurotus spp. are efficient colonizers and degraders of lignocellulosic materials (Rajarathnam and Banu, 1987). They are also highly adaptable to grow and to produce fruit bodies on a wide variety of agro-industrial, lignocellulosic wastes due to their capability to synthesize relevant hydrolytic (cellulases and hemicellulases) and unique oxidative (ligninolytic) extracellular enzymes that play a significant role in degradation of various substrates resulting into mushroom growth and fruit body
production (Bisaria et al., 1987; Kuforiji and Fasidi, 2008; Kurt and Buyukalaca, 2010).

During the growth and development of mushroom mycelia, these extracellular enzymes are produced as a result of various biochemical changes and convert the insoluble large lignocellulosic components of the substrate materials into soluble, low-molecular weight compounds, which are subsequently taken up by the mushroom mycelia for growth and development. Studies have revealed that the structure of lignocellulosic materials, species of mushroom under cultivation as well as method of mushroom cultivation have important role on the type and amount of enzyme produced by the mushrooms (Tan and Wahab, 1997; Reddy et al., 2003; Kapich et al., 2004; Elisashvili et al., 2006; Elisashvili, et al., 2008). Among the various enzymes produced by *Pleurotus* spp., laccase is an important oxidase enzyme involved in the biodegradation of lignin and its derivatives and also participates in the adaptation of the fungus to the substrates on which it grows (Guzman, 2000).

Cellulose, hemicellulose and lignin are the three basic compositions required in an ideal substrate for growing oyster mushrooms and various species of *Pleurotus* have been grown successfully on a wide range of lignocellulosic materials (Guzman, 2000; Sanchez, 2004). However, the mushroom yield or biological efficiency of a species is directly related to strain type, nutritional composition of the substrate material and growth conditions (Manu-Tawiah and Martin, 1986; Geetha and Sivaprakasan, 1998). However, the size of the sporophore mostly depends on the nature and the types of the substrate material being used for cultivation. One of the important factors limiting the saprobiotic mycelial colonization and more particularly quantitative and qualitative yield of the mushroom is nutrient composition of the substrate (Manu-Tawiah and Martin, 1986; Tshinyangu and Hennebert, 1995;
Mukhopadhyay et al., 2002). The variation in biological efficiency of *Pleurotus* spp. occurs due to varying nutrient concentration in the substrate material as has been reported by various workers (Thomas et al., 1998; Obodai et al., 2000; Chandrasekhar and Savalgi, 2003; Obodai et al., 2003; Thomas and Rajagopal, 2003). Substrates rich in cellulose are preferred by the mushroom mycelia, as evidenced by the significant reduction in the cellulose content in the substrate with the growth of the fungal mycelia during cultivation (Rai and Saxena, 1992; Geetha and Sivaprakasam, 1998).

Various agro-forest by-products, industrial wastes, pulps and lignocellulosic organic wastes, waste papers, saw dusts of broad leaved hardwood are some of the most ideal substrates for growing oyster mushrooms (Philipoussis et al., 2001; Zervakis, et al., 2001). The most commonly used lignocellulosic materials as substrates in oyster mushroom cultivation include paddy straw, wheat straw, corn cobs, sugarcane baggase, sugarcane leaves, coir pith, coconut refuges, pea nut wastes and saw dusts (Jandaik and Kapoor, 1974; Singh and Tandon, 1987; Cangy and Peerally, 1995; Raganathan et al., 1996; Nageswaran, et al., 2003; Shah et al., 2004; Anakalo et al., 2008). Although paddy straw is the mostly sought substrate in terms of yield for growing oyster mushrooms (Thomas et al., 1998), its increased demand for biogas production, as cattle feed and other livestock management, its higher cost, composting and otherwise, less availability in most of the regions become a limited resource which creates a necessity to find an alternative yet cheap, ready and ideal productive source of suitable substrate for oyster mushroom cultivation in a more feasible and cheap way. Therefore, the availability and the cost of substrates are the two important criteria for cultivation of oyster mushroom.

Other crop wastes such as soybean straw, cotton stalks, pigeon pea stalks and sugarcanediscards have also been found feasible for oyster mushroom cultivation
(Klibansky et al., 1993; Mane et al., 2009). Besides agricultural wastes, various wild plants have been reported as suitable substrate material for cultivation of oyster mushroom, such as water hyacinth (Murugesan et al., 1995), umbrella plant (Cyperus spp.) (Ohga and Royse, 2004), Torpedo grass (Panicum repens), Elephant grass (Pennisetum purpureum) and weed plants (Das and Mukherjee, 2007). It appears that some other plants have also the potential to be used as substrates for oyster mushroom cultivation for bioconversion of lignocellulosic wastes or other materials into food and dietary supplements (Thomas et al., 1998; Philippoussis et al., 2001). However, the type of the substrates used in each region depends upon its availability which may be various agricultural wastes, and other suitable agro-forest wastes (Cohen et al., 2002). This is an effective, innovative step towards conversion of abundant, low valued plant materials into high quality food product in the form of mushroom, especially in and around the regions where the primary substrate material such as paddy straw and saw dusts are scarce (Zhanzi and Zhanhua, 1997).

The cultivation of oyster mushrooms involves five basic steps, viz. pure culture maintenance and spawn preparation, substrate selection and substrate preparation, substrate supplementation, spawning of substrates and crop management (Kapoor, 1989; Upadhyay, 1998; Kapoor, 1999; Upadhyay, 2007; Upadhyay, 2011a). Cultivation technique can be practiced in both indoor and outdoor mushroom shed.

One of the most important steps for a successful cultivation of oyster mushroom is the preparation of the lignocellulosic substrate materials to ward-off saprophytic fungi which compete with the mushroom mycelia during mycelial run as well as cropping and causes various diseases resulting into less yields or sometimes, crop failure. Suppression of potential antagonists in the substrate can be accomplished through various techniques (Geml et al., 2001).
Among the various methods used for substrate preparation, steam pasteurization or hot water treatment and chemical sterilization techniques are the most effective methods widely adopted. Hot water dip at 65±5°C for 60 minutes was recommended by Bano et al., (1978) for preparation of different cereal straw. Hot water treatment at 80°C for 30-60 minutes for better result was suggested by Singh and Dwivedi (1991). Thermal treatment of substrates by autoclaving is also done for substrate preparation. However, sterilization by autoclaving is expensive and tedious process and the sterilized substrates favour development of competitor moulds of mushroom, if contamination occurs during the subsequent stages of cultivation process. Various steam and hot water pasteurization methods have been proposed and these are all efficient by significantly reducing the level of competitor moulds although bacterial pathogens still remain in the substrates, especially sporulating bacteria which may contribute to the selectivity of the pathogens towards the sterilization method (Velaquez-Cedeno et al., 2004).

Chemical sterilization technique is the most effective method in use (Vijay and Sohi, 1987; Yildiz et al., 1998; Upadhyay, 2007) in which dried and chopped, 5-10 cm pieces of substrates are soaked in a solution of 75 ppm Bavistin (carbendazim 50% w/p) and 500 ppm formaldehyde solution (formalin 37-40 % v/v) for a period of 16 to 18 hours or an overnight. This method is now widely adopted to check weed moulds and also for higher mushroom yield and biological efficiency. Apart from these methods, sterile technique (Till Method) or fermentation method or even composting methods have also been suggested for substrate preparation (Philippoussis et al., 2001).

Composting when applied properly, in general, requires no further thermal treatments (Stamets and Chilton, 1983; Laborde et al., 1993; Villa-Cruz et al., 1999;
Contreras et al., 2004). Alternatively, soaking in alkaline water to obtain an initial pH of 8 has also been proposed (Contreras et al., 2004), but in this method, bacterial pathogens persist and remain active causing damages to colonizing mushroom mycelia during spawn run and cause various diseases to the crop. For most of the species, the optimum range of substrate pH is between 5 to 6 which is also one of the important factors for mycelial growth and development (Srivastava and Bano, 1970; Jandaik and Kapoor, 1975).

The variation in the mushroom yield on different substrates is attributed to the difference in nutrient content, C:N ratio, phenolic compounds and the nature of the ligno-cellulosic complex (Thomas and Rajagopal, 2003). The nitrogen content of mushroom mycelia ranges between 3 to 6% and gets depleted at the time of fructification when most of the nitrogen contents in the substrate becomes inadequate and becomes a limiting factor for mushroom yield (Rangaswami et al., 1975; Nallathambi and Marimuthu, 1993; Isikhuemhen and Okhuoya, 1998). Hence, a C:N ratio of 1:50 is considered essential both for mycelial growth and fruit body production (Zadrzil, 1978) and the nature and the concentration of nitrogen sources in the substrate regulate the production of ligninolytic enzyme (Mikiashvili et al., 2004).

Since the nitrogen content in most of the substrates ranges between 0.5 to 0.8% (Upadhyay et al., 2002), addition of inorganic or organic nitrogen to the substrate to enhance the mushroom yield as well to hasten the entire production process in oyster mushroom cultivation has been suggested by various workers (Zadrzil, 1980; Bano and Rajarathnam, 1982; Goswamy et al., 1987; Royse and Schisler, 1987a; Royse and Bahler, 1988; Azizi et al., 1990; Royse, 2002; Royse, 2003; Royse et al., 2004; Mamiro and Mamiro, 2011). Addition of supplements,
mostly rich in C:N ratio, gives better nitrogen and carbohydrate influx that generally affects the sporophore formation and thus enhances mushroom yield (Jandaik and Kapoor, 1976a; Rai and Mohatarum, 2002).

The fruit body yield of *Pleurotus* spp. has been found to increase due to supplementation of substrate with inorganic nitrogen source such as ammonium nitrate which increases the yield by about 30% (Zadrazil, 1980). Supplementing the substrate with controlled liberation of urea and Mn (II) shortens the crop period of *Pleurotus* spp. and also increases mushroom productivity (Lelley and Jan Ben, 1993; Curvetto et al., 2002). Organic nitrogen sources like alfalfa, soybean meal, spent agro-residues, wheat bran and millet grains (Royse, 1992), rice bran, cotton seed cake, gram flour, mustard cake and groundnuts have also been recommended as better supplementing materials (Ralph and Kurtzman, 1994; Upadhyay et al., 2002; Narain et al., 2009). Some aquatic weeds, viz: *Typha angustica* (Typha), *Oryza nigra* (Tina) and *Scirpus lacustris* (Gonn) in different proportions as supplementing materials has also been tried (Mishra and Singh, 2007). In some developing countries, water hyacinth (*Eichhornia crassipes*) has also been utilized (Murugesan et al., 1995; Nageswaran et al., 2003; Anakalo et al., 2008).

The biological efficiency (conversion rate i.e., fresh mushroom production from per 100 g dry substrate) of *Pleurotus* spp. is considered high (upto 100% or even more) that depends on the substrate combination as well as the way in which the substrate has been managed during fruiting season (Martinez- Carrera et al., 1985; Martinez-Carrera, 1989; Singh, 2011). A maximum of five flushes could be harvested from a crop (Sharma and Jandaik, 1981) and the maximum yield can be harvested from first three flushes, the first being the highest and thereafter a gradual reduction in the yield is observed. The richer the substrate and its combination, and the whiter and
denser the mushroom mycelia on the substrate block, the higher will be the mushroom yield and the lesser will be the crop cycle (Royse, 2002). The yield of oyster mushroom may show a drastic reduction after the first flush and there might be a flush break of 10 to 20 days, depending upon the species of Pleurotus and the nature of the substrate material being used. This reduction in the yields can be attributed either to a depletion in the nutrient content of the substrate used or accumulation of toxic substances unfavourable for fruiting (Upadhyay et al., 2002).

Nevertheless, supplementation of substrate materials has its own adverse effects on the bed by causing a rise in bed temperature (Royse, 2003). Various organic supplements such as cotton seed meal, soybean meal, groundnut cake, wheat flour, gram flour etc., which are rich sources of organic nitrogen when applied causes a significant rise in the bed temperature by 3 to 5°C encouraging the growth of pathogens such as Coprinus spp. (ink cap fungi) due to ammonia formation (Royse, 2003; Upadhyay, 1998; Upadhyay, 2007). It is therefore, recommended to first treat the organic supplements with 25 ppm carbendazim for about 14-16 hours prior to application. It has been advised to avoid supplements during summer seasons or rainy seasons where the moisture and room temperature is very high, which increases the risk of contamination (Kapoor, 1999).

Spawn is prepared from pure mycelial culture of selected strains mostly on cereal grains, example: wheat, rye or millet (Chang and Hayes, 1978; Chang and Miles, 1989). The success of a mushroom production greatly depends upon the quality of spawn used, which is one of the most important and expensive material involved in the entire cultivation process. Several studies have been done to improve and to develop new techniques for the production of quality spawn (Chu and Wang, 1977; Claxton, 1979; Sarkar and Chakravarty, 1982; Bisht and Harsh, 1984; Abdullah et al.,
1995; Abosriwil and Clancy, 1999; Holtz and McCulloch, 1999; Friel and McLoughlin, 2000; Muthukrishnan et al., 2000). The optimum spawning rate varies from 3 to 5 percent (Royse, 2003; Upadhyay, 2011a). Increase in the rate of inoculum level could increase the mushroom yield, shortens the cropping period (Royse, 2003; Sivaprakasam and Ramaraj, 1991). Filling of spawned substrates are done in different containers through different methods and for incubation; such as gunny bags, earthen pots, bamboo baskets, bamboo shelf, tray, jar, grid frame, wall frame, empty fruit cartoons and various other materials (Stamets, 2000) but the most suitable practices of filling methods are: perforated polythene bags, compact bag method, de-naked plastic bottles and shelf cultivation methods (Bano and Nagarajan, 1976; Bhaskaran et al., 1978; Zadrazil and Kurtzman, 1982; Eswaramoorthy et al., 1983; Choi, 2003). Perforated polythene bags with small holes of 2-5 mm diameter all over the surface of the filled bags are reported to give a maximum yield and an early crop of 4-6 days than the non-perforated ones that accumulates high CO₂ concentrations that delays cropping and lowers yields (Kapoor, 1989; Upadhyay, 2007).

The environmental factors are of much importance in the production of *Pleurotus* spp. through artificial cultivation. The spread of mycelia, of *Pleurotus* spp. greatly depends upon temperature and humidity, which are different among the species. Although the mycelia of *Pleurotus* spp. can grow in a temperature range between 10 to 30°C (Zadrazil, 1975), but beyond 36°C, the mushroom mycelia dies out. The spread of mycelial growth is greatly dependent on temperature and humidity, which however varies from species to species (Zadrazil and Schneidereit, 1972). A temperature range of 20 ± 2°C is considered best for proper mycelial run and complete colonization of the substrate within spawned bags incubated in total
darkness for a period of 10-25 days (Thomas et al., 1998; Kapoor, 1999; Shah et al., 2004; Mandeel et al., 2005).

Once the mycelial run completes, the bags are peeled off and the substrate-mycelia blocks are arranged in racks or shelves at a minimum distance of 30 cm apart from each other in rows for fruit body formation. Environmental factors inside the cropping room are of much importance for pinning and fructification. Maintaining proper humidity (80 to 90%) and a congenial temperature (25 ± 5°C) inside the well ventilated growing room are the two most important factors for getting a good crop (Bano and Srivastava, 1962; Jandaik and Kapoor, 1976b; Chang and Hayes, 1978; Chang and Quimio, 1982; Chang and Miles1989; Kapoor, 1989; Zadrazil, 1998). Too much variation in the room temperature and relative humidity inside cropping room delays the fruiting thus resulting in reduced yield (Purkayastha and Jana, 1983; Kapoor, 1999).

Humidity is another important factor affecting mushroom yield (Bano and Rajarathnam, 1982) which is generally maintained inside the cropping room by sprinkling water on floor and walls frequently by misting process for keeping the humidity level between 70-90%. Over wetting of bags and the growing room also inhibits formation of fruiting bodies. However, over wetting of growing room may cause rotting of the substrate inside the bags as well as favouring the growth of inhibitor competitive moulds and pathogens. Excessive humidity, improper ventilation, over heating of substrates during sterilization and excessive moisture contents have been identified as the most common factors leading to occurrence of disease and pests (Kapoor, 1999).

CO₂ concentration also greatly influences the rate of mycelial colonization of the substrate. The tolerance range for CO₂ concentration for colonizing mycelia inside
the bag varies between 15 to 20% (strong range of CO\textsubscript{2} concentration), but above this range, the mycelial growth drastically decreases (Zadrazil, 1975). The CO\textsubscript{2} concentration inside the cropping is also a critical factor determining the initiation of pinning and fruit body formation. Unlike high CO\textsubscript{2} concentration required for spawn running (20-22%), a very less CO\textsubscript{2} concentration of 0.6% is required during cropping (Purkayastha and Jana, 1983; Upadhayay, 2007), therefore, proper ventilation for aeration and circulation of fresh oxygen has been suggested inside the cropping room. High level of CO\textsubscript{2} concentration inside the cropping room results in the formation of deformed fruit bodies with long stipe and small, trumpet shaped weak pileus (Zadrazil, 1973; Royse, 2003).

Light is also very essential for fruit body formation. For primordial formation, the light requirement is 200 lux intensity for 8-12 hours daily (Upadhayay, 2007) which is provided either as natural light by keeping the doors of the cropping room open for few hours or by providing cool, white fluorescent light. Inadequate light conditions give long stipe, small pileus, weak and deformative fruit bodies and poor yields, besides influencing the colour of the pileus. Light intensity of less than 100 lux results in pale, yellowish fruit bodies. During night or during rainy days, fluorescent white light of 300-500 lux is recommended for 2-3 hours @ 2-3 times daily (Puri et al., 1981; Zadrazil and Dube, 1992; Royse, 2003).

During intensive and continual cropping, the growing condition tends to become unfavourable as the growing room temperature rises above 35 °C, coupled with excess moisture in the beds that encourages various pests and diseases to establish frequently (Kapoor, 1999). Various competitor moulds and diseases are known to occur during the cultivation of oyster mushrooms hampering the crop by causing significant yield reduction and sometimes even crop failure (Kapoor, 1999;
Royse; 2003; Upadhyay, 2011a). Most of the competitor moulds and diseases causing insect-pests adversely affect the mycelial run and fruit body formation at various stages of cropping. Excessive amount of nitrogen source supplemented to the substrate also results in the higher rate of fungal infestation (Royse, 2003). At times, there may be complete crop damage, depending upon the stage and intensity of infection, quality of substrate preparation, maintenance of cropping room, prevailing environmental conditions and the nature of handling and management of the materials, tools and objects in use (Sharma and Kumar, 2011).

Most often, the oyster mushroom crop suffers from a variety of diseases mostly fungal, bacterial, insect-pests and even due to improper handling and management of cropping room. The most common fungal competitor moulds reported so far are *Aspergillus* spp., *Botrytis* spp., *Coprinus* spp., *Fusarium* spp., *Monilia* spp., *Mucor* spp., *Penicillium* spp., *Trichoderma* spp., *Trichothecium* spp. (Royse, 2003; Sharma et al., 2007). Green moulds are caused by *Trichoderma* spp., wherein patches of this competitor mould grow all over the substrate surface as green mat causing less or reduced mycelial run which sometimes results into complete crop failure. Ink caps are caused by *Coprinus* spp., another competitor mould of mushroom mycelia that grows all over the substrate surface, thereby damaging the colonizing vegetative mycelia during auto digestion, releasing inky exudates and subsequently causes rotting of the mushroom mycelia as well as the substrate.

The four major diseases caused by fungal pathogens on oyster mushrooms that have been reported from India are white cottony growth caused by *Cladobotrym* spp; green moulds by *Gliocladium virens*, fluffy growth caused by *Arthrobotrys pleuroti* and powdery white growth by *Sibirina fungicola* (Sharma et al., 2007). Bacterial
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blotch disease is caused by *Pseudomonas tolaassii* and yellow blotch disease is caused by *Pseudomonas agarici*.

A variety of small flies, midges and insect-pests have been reported to cause significant crop loss during oyster mushroom cultivation. The insect pest damaging the oyster mushrooms (*Agaricus bisporus*) are responsible for the infestation on button mushrooms most of which are the members of sciarids, phorids, cecids, springtails, and beetles, that damages the fruit bodies (Kumar and Sharma, 2005). Among insect pests, the most prominent ones damaging the crop of oyster mushrooms are *Lycoriella solani* (Sciarids), *Megaselia halterata, Megaselia nigra* (Phorids), *Mycophila speyeri* (Cecids) (Royse, 2003). The larvae of these insect-pest, flies and midges feed on the mature fruit bodies, mostly by boring holes in the gill surface, causing damages to fruiting bodies and proliferating vegetative mycelia (Sharma and Kumar, 2011). To minimize frequent buildup of flies in the mushroom farm, timely disposal of spent straw or spent substrates after mushroom harvest therefore, has been suggested (Royse, 2003).

Occasionally, there are also cases of deformities of the fruit bodies during cropping. Although most causes of the deformed fruit bodies are not known, yet most of these have been attributed due to less aeration, poor ventilation, smoke, chemical vapours, over heated substrate (Royse, 2003). Also, during spawn run, extreme low fruiting temperature ≥ 10°C and insufficient light causes deformed fruit bodies (Royse, 2003; Upadhyay, 2011a).

The cultivation of oyster mushrooms is the most promising economic method of converting lignocellulosic agricultural wastes to consumable, protein rich biomass (Sanchez et al., 2002; Mandeel et al., 2005; Tisdale et al., 2006). The production cost of oyster mushroom under varied climatic conditions is the lowest and cheapest
among all other cultivated edible mushrooms (Jandaik, 1997; Upadhyay, 1998; Upadhyay, 2011a). Being a labour oriented vocation, it is very significant in enhancing the income of resource poor rural families together with a good economic return to the entrepreneurs and common growers (Kaul, 1978; Bhattacharya and Samajpati, 1992; Savitri et al., 1993; Singh and Rai, 1997; Pradeep and Abraham, 1998). As a less expensive, easily manageable, short duration crop requiring less space, oyster mushroom cultivation may establish itself as a promising agri-based technology in North-eastern states of India as the region is bestowed with suitable climate ranging from sub-tropical to temperate and produces a variety of readily available, easily accessible agro-forest wastes suitable for mushroom cultivation (Roy, 1976; Saikia, 1986; Kalita et al., 1997; Singh and Borah, 1998). Literature survey reveals that although a significant number of wild edible Pleurotus spp. has been identified and collected from different parts of Arunachal Pradesh by various workers (Mishra, 2003; Pakam and Singh, 2004), research on oyster mushroom cultivation for developing an easily accessible, cheap, manageable, region specific farm practice has not yet been undertaken so far. Selection of suitable species of Pleurotus keeping in view the local climatic conditions and identification of suitable substrate materials, both biologically and economically is important for developing a low cost technology. As the high investment costs associated with indoor cultivation method can be prohibitive to many farmers and poorer sections of the society, therefore, for formulating a farmers’ friendly farm practice with better results, the outdoor cultivation method which produces relatively lower yields but at the same time is much cheaper and requires less technical monitoring needs to be refined for developing a region specific cultivation technology (Shen et al., 2004).