NUSANTARA BIOSCIENCE
Vol. 6, No. 2, pp. 173-185
November 2014

ISSN: 2087-3948
E-ISSN: 2087-3956
DOI: 10.13057/nusbiosci/n060211

Mushroom refinement endeavor auspicate non green revolution in the offing

SHAUKET AHMED PALA[1,♥], ABDUL HAMID WANI[1], ROUF HAMZA BODA[1], BILAL AHMAD WANI[2]
[1]Section of Mycology and Plant pathology, Department of Botany University of Kashmir, Hazratbal Srinagar-190006, Jammu and Kashmir, India.
Tel: +91-9858709043; ♥email: sapala29@gmail.com.
[2]Centre of Research for Development, University of Kashmir, Hazratbal Srinagar-190006, Jammu and Kashmir, India.

Manuscript received: 22 August 2014. Revision accepted: 2 October 2014.

Abstract. *Pala SA, Wani AH, Boda RH, Wani BA. 2014. Mushroom refinement endeavor auspicate non green revolution in the offing. Nusantara Bioscience 6: 173-185.* Mushroom can serve as food, tonic, and as medicine thus make people healthier, fitter and happier. They have a cracking potential for generating great socioeconomic impact in human welfare at local, national and international level. With the help of allied mushroom farming we can easily tackle the problem of food for growing world population; reduce environmental pollution by bioconversion of huge organic wastes into mushrooms; recycle huge quantity of organic wastes to mushroom crops, biofertilizers, and biogas; restore damaged environment by mushroom mycelia through mycoforestry, mycoremediation, mycofiltration and mycopesticides in a zero emission fashion. They can be used to degrade radioactive industrial biocide wastes in an eco-friendly fashion. Since mushroom cultivation is an indoor agribusiness, it could have great economic impact by generating employment, income and functional food requirements for rural people especially in developing countries. How far mushroom cultivation can meet the functional food requirements; address the domestic food challenges, rising food prices and crisis vis a vis environmental sustainability will be thrust areas of this communication.

Keywords: Medicinal value, mushroom cultivation, non green revolution, production.

INTRODUCTION

Prior to touching the multitude affairs of mushrooms for human welfare on this biosphere we need their proper introduction. The word 'mushroom' is a loosely-used term that actually refers to the macroscopic fruiting body of fungus. The fruiting bodies are extremely diverse in form; some look amorphous globs of jelly, while others are umbrella like, reminiscent of coral, egg like, birds nest like, starfish shaped etc. One of the most widely accepted definition regarding mushrooms is stated by Chang and Miles "Mushroom is regarded as a macrofungus with a distinctive fruiting body, that can be either epigeous or hypogeous and large enough to be seen with naked eye and to be picked by hand" (Chang and Miles 1992). They mostly belong to class basidiomycetes and ascomycetes of Kingdom fungi. Current studies estimate that out of 1.5 million species of existing fungi, 14,000-15,000 species produce fruiting bodies of sufficient size and suitable structure to be considered as mushrooms (Hawksworth 2001). Of these, about 7000 species are considered to possess varying degree of edibility, and more than 3000 species from 31 genera are regarded as prime edible mushrooms and some 2000 species have medicinal attributes. Contrary to this vast diversity only a handful of species have been exploited by mankind for human welfare and there are about 100 of them grown experimentally, 50 economically cultivated, around 30 commercially cultivated, and only about 6 have reached to industrial scale of production (Chang and Miles 2004). Though this diversity is fouled by some poisonous mushrooms which are clumsy but their number is relatively small (approximately 10%), of these some 30 species are considered to be lethal.

MUSHROOMS OFFER A RAINBOW OF PRODUCTS AND SERVICES

Mushrooms offer a range of food products, medicines and ecological services. Their medicinal and food value is an intermingling area of functional food products. Mushrooms act as a balanced food for all ages. In health sector mushrooms have proved their worth by warding off simple to severe diseases. Mushroom derived medicines have potential to increase immunity of our body thus reducing chances of disease susceptibility. Ecologically mushrooms play role of biofilters and biofertilizers. Mushrooms are important constituents of minor forest produce (secondary produce) and grow on the most abundant biomolecule of this biosphere known as cellulose. They can degrade, neutralize or accumulate pollutants of different kinds. They add to the fertility of soil without damaging it. A bird's eye view of these lineaments is as under.

Nutritional value of mushrooms

Mushrooms as food were used by man when he was still a food gatherer and hunter on the chronology of cultural evolution (Rojas and Mansur 1995; Kumari et al. 2013; Thatoi and Singdevsachan 2014). Edible mushrooms once called the "food of the gods" are still used to garnish the dishes and serve as functional food. Mushrooms are important source of quality protein, minerals and various novel compounds of medicinal value. They are rich sources

of protein (20-30%) with good digestibility and rank below animal meats, but well above most other foods (vegetables and fruit), including milk, thus aptly called mycomeat or vegetable meat (Wang et al. 2014). Mushrooms are also the source of energy foods—carbohydrates and fats; accessory food factors-vitamins; and inorganic compounds which are indispensable to good human health. Mushrooms are one of the best sources of vitamins being rich in thiamine (B1), riboflavin (B2), niacin, biotin and ascorbic acid (Ayaz et al. 2011). Due to low starch content and absence of cholesterol, they suit diabetic and heart patients. Mushrooms are rich in minerals like potassium, sodium and phosphorous. High potassium: sodium (K: Na) ratio in mushrooms; makes them ideally suited for hypertension patients (Chang and Miles 2004; Agrahar and Subbulakshmi 2004)). The moisture content of fresh and dried mushrooms varies from 70 - 95% (depending upon the harvest time and environmental conditions), and 10 - 13% respectively (Kansci et al. 2003). They are rich in dietary fibers that have various beneficial health effects to humans. In addition to nutritional value, mushrooms have some unique color, taste, aroma, and texture characteristics, which attract their consumption by humans. The Nutrient Value of some widely cultivated mushroom (Per 100 grams dried mushroom) is as (Table 1).

Medicinal value of mushrooms

The relationship between diet and disease summarized by father of medicine Hippocrates "Let food be your medicine and medicine be your food" suits good to mushrooms because of their marvelous nutraceutical value. Mushrooms have been found effective against cancer, cholesterol reduction, stress, insomnia, asthma, allergies and diabetes effectively (Waseer 2010, 2011). There are also increasing experimentally based evidence to support centuries of observations regarding the nutritional and medicinal benefits of mushrooms. The value of mushroom products has recently been raised up for encouraging results generated from trials conducted for HIV/AIDS patients (Nanba 1993; King 1993; Pala and Wani 2012). Edible wild or cultivated mushrooms possess commendable immunomodulatory nutriceuticals and dietary supplements to increase the natural immunity. The recent upsurges of interest in traditional remedies for various physiological disorders by the compounds and products from the mushrooms have led to the coining of the term "mushroom nutriceuticals" (Chang and Buswell 1996). From medicinal mushrooms the extractable products are designed to supplement the human diet not as regular food, but as the enhancer of health and fitness. A regular intake may enhance the immune responses of the human body, thereby increasing resistance to disease and or cause regression of an ailment (Chang and Buswell 2008).

Several biologically active compounds like high molecular weight polysaccharides that assign them immune enhancing and tumor retarding effects have been obtained from the cell wall of several medicinal mushrooms. It has been reported that the anti-tumor and anti-cancer effects of the mushroom polysaccharides are based on the enhancement of the body's immune system, like by activating macrophages, natural killer cells, cytotoxic T cells, and their secretory products, such as the tumor necrosis factor, reactive nitrogen and oxygen intermediates, and interleukins, rather than direct cytocidal effects (Smith et al. 2002; Israilides et al. 2008; Mallick et al. 2010; Camargo and Kaneno 2011). Triterpenoids, steroid-like compounds from *Ganoderma* spp. have been reported to conduce cytotoxic, hepatoprotective, and hypolipidmic influence on platelet aggregation, inhibition of angiotensine-converting enzyme, and inhibition of histamine release (Camargo and Kaneno 2011). Lectins (proteins or glycoproteins) exemplify another group of mushroom bioactive compounds with specific binding sites for sugars that own anti-tumour and immunomodulatory activities. Mushrooms are not known to affect the concentration of serum high density lipoprotein (HDL) cholesterol, but the reduction of serum total cholesterol by the mushroom diets is believed to be attributable to the fall in low density lipoprotein (LDL) cholesterol (Lohani 2012).

Ecological services of mushrooms

Ecologically mushrooms play an important role on this biosphere by breaking down plant and animal matter and solublizing the structurally complex compounds into the constituent elements of utmost importance and usage. They extend the nutritional zone of plants through mycorrhizal associations and restore the aspects of soil congenial for survival of bioentities (Stamets 2005). Their relationship with plants is manifested in three forms, viz. those that act on living plants called parasites and those that recycle dead plant materials called saprophytes (vegetable vultures) and finally those which are in symbiosis with their host plants are called mycorrhizal mushrooms. Mycorrhizal mushrooms

Table 1. Nutritional attributes of some wildly cultivated mushrooms (Crisan and Sand 1978; Chang and Miles 2004; Bernas et al. 2006; Suman and Sharma 2007; Barrosa etal. 2007; Boda 2009).

Name of mushroom	Carbohydrate (g)	Fiber (g)	Protein (g)	Fat (g)	Ash (g)	Energy (kcal)
Agaricus bisporus	46.17	20.90	33.48	3.10	5.70	499
Pleurotus sajor-caju	63.40	48.60	19.23	2.70	6.32	412
Lentinula edodes	47.60	28.80	32.93	3.73	5.20	387
Pleurotus ostreatus	57.60	8.70	30.40	2.20	9.80	265
Volvariella volvacea	54.80	5.50	37.50	2.60	1.10	305
Calocybe indica	64.26	3.40	17.69	4.10	7.43	391
Flammulina velutipes	73.10	3.70	17.60	1.90	7.40	378
Auricularia auricula	82.80	19.80	4.20	8.30	4.70	351

donate fertilizers like nitrogen and phosphorus to partner plant thereby allowing them to colonize poor soils and pull otherwise unavailable nutrients from the soil. Mycorrhizal mushrooms can help in reforestation program to a great extent and ecologists have now admitted that a forest's health is directly related to the presence, abundance, and variety of mycorrhizal associations (Perry et al. 1987; Dell 2002). Saprophytic mushrooms that grow on waste particularly of agricultural origin can convert lignocellulosic wastes into the value added products such as food, medicine, feed fuel and fertilizer and recycle the wastes elements. The spent mushroom substrate (SMS) left after final crop harvest has many positive attributes still left for its potential uses. The material has been found to be a good nutrient source for field and horticultural crops because of its nutrient-status. Besides, it has a high cation exchange capacity (a measure of the amount of nutrients a medium can hold) and has a slow mineralization rate that held in retaining its quality as an organic matter.

The use of fungi/mushroom mycelia acts as tools for healing soil and help in protecting and regenerating the environment what Stamets (2005) called "mycorestoration", which is the use of fungi/mushrooms to repair or restore the weakened or damaged biosystems of environment. The processes of mycorestoration include the selective use of mushrooms for mycofiltration, to filter water; mycoforestry, to enact ecoforestry policy; mycoremediation, to denature toxic wastes; and mycopesticides, to control insect pests. Mycorestoration recognizes the primary role fungi/mushrooms can play in determining the balance of biological populations. Mushrooms via bioconversion processes ensue reutilization of spent substrates and transform the polluting substances into valuable foodstuffs (Beyer 2005; Noble 2005).They can accumulate and filter pollutants and act as one of the most promising and effective biosorbent of toxic heavy metals from radioactive nuclear fallout polluting water and soil, thereby act as neutralizers of pollutants (Das 2005; Kulshreshtha 2014). They are voracious decomposers of waste material due to the presence of extra cellular enzymes, thus utilized as mycofilters to degrade pollutants. The mushroom mycelia have the ability to degrade carcinogenic radioactive pollutants released into the environment as a consequence of human activity. Mushrooms can degrade lot of structurally different compounds like D.D.T and Lindane (Bampus and Aust 1987). Mecellia of mushrooms have been shown to biomeneralize uranium oxides, suggesting they may have applications in the bioremediation of radioactively polluted sites (Fomina et al. 2005).

MUSHROOM CULTIVATION

In the present world though science and technology has revolutionized every aspect of life but the diverse challenges and constraints faced in the form of global food crisis, population explosion, climate change damaging farming practices and shortage of land exposes the humans to extreme risk. The 20th century began with a world populated by 1.6 billion people and ended with 6 billion inhabitants- with most of the growth occurring in the developing countries. The growing world population is increasing by about 80 million people per year. At the present, about 800 million people in the world are living in poverty and facing quality food crisis. On the other hand, it has been observed that over 70 % of agricultural and of forest products has not been put to total productivity, and have been wasted in processing. The emerging scenarios demand a paradigm shift and cutting edge initiatives in formulating and implementing the novel an innovative agricultural research programs. Integrating mushroom farming in the existing farming systems will not only supplement the income of the farmers but can contribute in achieving food security, nutritional and social security. Since the mushroom cultivation do not compete for land and have very high productivity per unit area and time, thus can occupy a prominent place to address the void of quality food requirements, health and environmental sustainability. Mushroom cultivation offers an added advantage to recycle agro-waste as carbon pool into good quality protein, much of which otherwise is burnt in the field. Mushroom being an indoor crop, utilizing vertical space offers solution to shrinking land and better waste utility. Commercial production of edible mushrooms represents unique exploitation of the microbial technology for the large scale bioconversion of the agricultural, industrial, forestry and household wastes into nutritious and valuable products. The present century is going to be a century of functional foods free from synthetic chemicals. Mushroom cultivation fits very well into this category and is going to be an important secondary agricultural vocation. To face the global challenges all available expertise and resources need to be utilized to make mushroom Industry competitive in the world market. In this direction stronger research and production linkages with research organizations, industries, progressive farmers and other organizations will be needed. Interactions between research institutions and the mushroom farmers/industry need to be strengthened for realizing the full potential of the frontier sciences. There is a need for genetic enhancement of cultivated mushrooms to develop better strains and scan the new wild new species through systematic exploitation of the germplasm. Development of technologies to prolong the viability, shelf life and ease in bulk transport of the ready-to-use spawn is also required. While introducing high yielding strains of mushrooms, their susceptibility/ resistance to pests and diseases needs to be evaluated before they are released for general cultivation by the growers.

The applied aspect of this scientific endeavour integrates various disciplines of science as well as the associated technological processes to secure maximum benefits from this artful effort (Mabuza 2014). The recent advances in the mushroom science comply with zero emission principle (Lohani 2012). The modern tools and techniques in the field of biotechnology aim to lead the production of new strains of mushrooms having high biological efficiency, wide ecological adaptability, long shelf life, least vulnerable to pathogenic attack and high nutraceutical value (Kamal 2011).

People have harvested mushrooms from the wild for thousands of years for food and medicines but commercial cultivation of mushrooms dates 50-60 years back only (Kaul and Dhar 2007). Mushroom cultivation will serve as means of generating employment, particularly for rural women and youths in order to raise their social status. During off season it can provide additional avenues to the farmers that will definitely improve the economic standards of the people, thus considered as important cash crop. It is hoped that mushroom farming will become a very important cottage industry activity in the integrated rural development program, which will lead to the economic betterment of not only small farmers but also of landless laborers and other weak sections of communities. Round-the year cultivation of different mushrooms in rotation under the seasonal conditions is going to play a major role in increasing as well as diversifying the mushroom production. Their cultivation under controlled conditions in comparison to other crop, abundance of raw material forecasts the possibility of being a major crop in coming years.

Mushroom production in world and differences in production pattern

Since mushroom consumption is popular all over the world, commercial cultivation is therefore equally important. Although mushroom cultivation science is centuries erstwhile, but their cultivation at commercial scale based on scientific principles is recent and dated few decades back. So far only a handful of species are cultivated widely on commercial scale. During the past 30 years the increase in production was exponential with *Agaricus bisporus* playing the centric role. There are around more than 60 countries known for cultivated mushrooms with Asian countries continuing to dominate world production and consumption (Chang 1998) however, consumption in the United States has increased sharply in recent years, providing potential opportunities for mushroom growers. In 2008 it has been estimated that an output of 3,497,290 tons of mushrooms were produced by different countries of the world among which the major players were China, USA, Netherlands, Poland, Spain, India, Italy, Canada, Ireland and Japan which produced 1,608,219, 363,560, 240,000, 180,000, 50,450, 131,974, 100,000, 86,946, 75,000 and 67,000 tons respectively and the percentage of some major countries to the total world output is shown in Figure 1, indicating that China is the leading mushroom producer followed by USA (UNFAOSTAT 2011).

Mushroom farming is a beneficial agricultural practice that guarantee handsome return with least investment, but the route is yet at infancy. It has been estimated that over 70% of agricultural and of forest products have not been put to total productivity, and have been discarded as waste. If we exemplify India which produces about 600 million tons of agricultural byproducts, using 0.04% of these residues for mushroom has produced around 1.2 lakh tons of mushrooms. 1% use of these residues for mushroom production from this single country which does not figure significantly in international mushroom market can produce 3.0 million tons of mushrooms, which will be almost equal to current global button mushroom production-current world production as per FAO is 3.4 million tons (Directorate of Mushroom Research India 2011).

When we retrospect the mushroom farming figures excluding china and USA most of the countries do not figure significantly as is evident from the Table 2. Though the statistics depicts dramatic increases in the total world production of farmed mushrooms during the period 1961-2011, but booting out China and USA most of the countries are still lagging to touch the significant position in the mushroom production plausibly not because of the absence of raw material but largely due to inadequacy of understanding the vital roles mushrooms can offer in agricultural economy and conjuring up human health when used as dietary food supplements, lack of reliable sources of good quality mushroom spawn for supporting the efforts of local mushroom growers, lack of venture capital to support mushroom farming entrepreneurs, and absence of systematic government support towards promoting mushroom farming as a valuable non-traditional new food and cash crop.

When we examine the Table 2, it is quite evident that there is about sixteen fold increase in world production of farmed mushrooms but the growth is not uniform and positive in all countries. If we take the example of Austria the growth in production is not positive as the production in 1961, 1971, 1981, 1991, 2001 and 2011 has been calculated to be 3,000, 3,000, 4,100, 2,700, 300 and 1,600 metric tons, same is the case with some other countries. Also proportion of increase in production is not in correlation with the increase in population growth thereby can't meet the demand. The production of mushrooms (metric tons) in different countries and continents from 1991-2011 (UNFAOSTAT 2011) is shown in Table 3.

The following statistics (Table 3) serve to illustrate disproportionate production of farmed mushrooms by different countries and continents. In 2011, Asia contributed 68.67% of the total world mushroom tonnage, Europe, 24.23%, Americas 6.0%, Australia 0.77% and Africa only 0.22% by producing 5301160, 1871076, 469832, 59580 and 17716 metric tons. In 2011China alone contributes the 64.88% of the world and 94.48% of Asian mushroom farm production.

It is a positive sign that there is constant virtual increase in the area utilized for mushroom harvesting and the mushroom production figures from 1991-2011, but when we examine the data (Figure 2 and Figure 3) it is quite evident that there is nearly about 3.5 fold increase in both area harvested for farming and total production, which indicates that there is not any significant growth in production efficiency (production per unit area). It is therefore inevitable to bring the fact on the path of research and point out the missing links and bridge the gap.

Though there are some 60 species of mushrooms cultivated in different countries of the World, but notable among them are *Agaricus bisporus, Auricularia auricula, Calocybe indica, Flammulina velutipes, Ganoderma lucidum, Lentinula edodes, Pleurotus ostreatus, Pleurotus sajor-caju,* and *Volvariella volvacea* (Figure 4). However, it

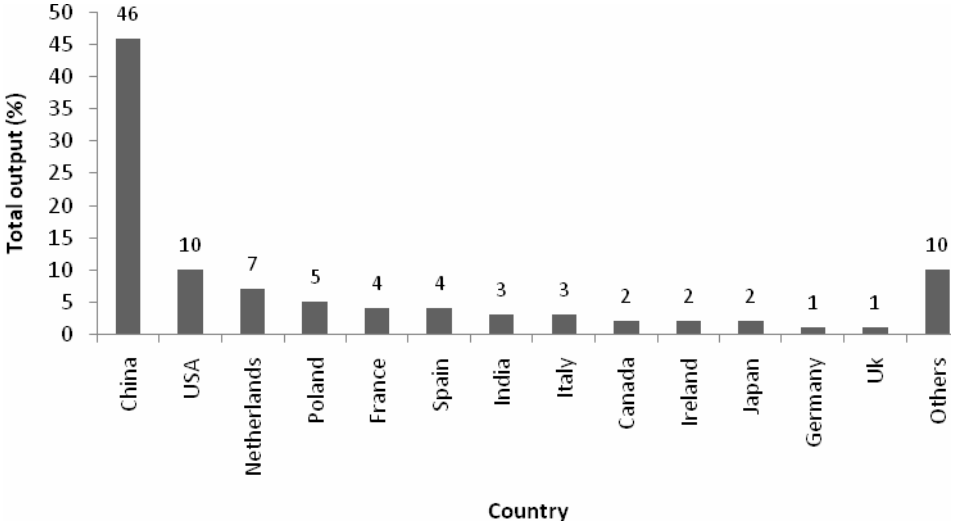

Figure 1. Comparative mushroom production chart of World (UNFAOSTAT 2011).

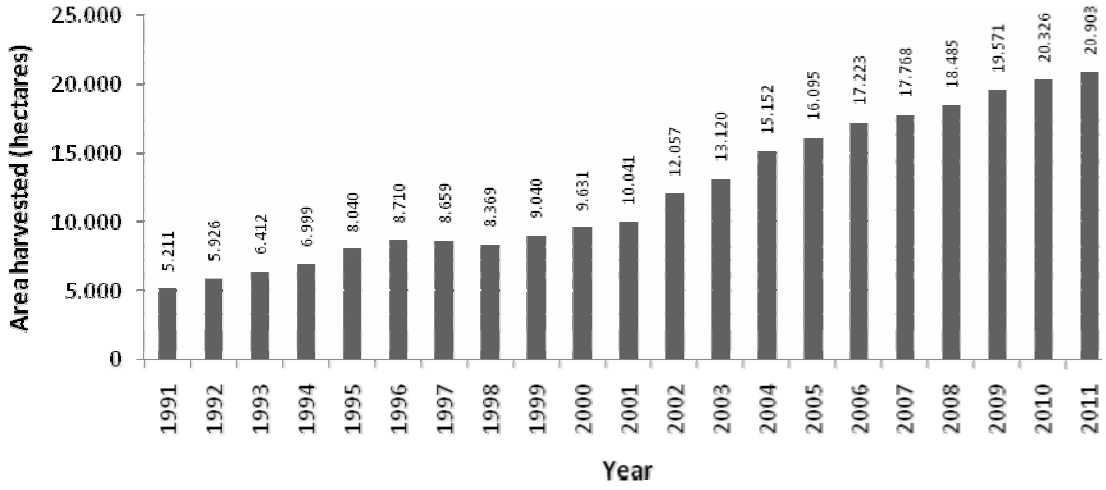

Figure 2. World mushroom production from 1991-2011 (metric tons) (UNFAOSTAT 2011).

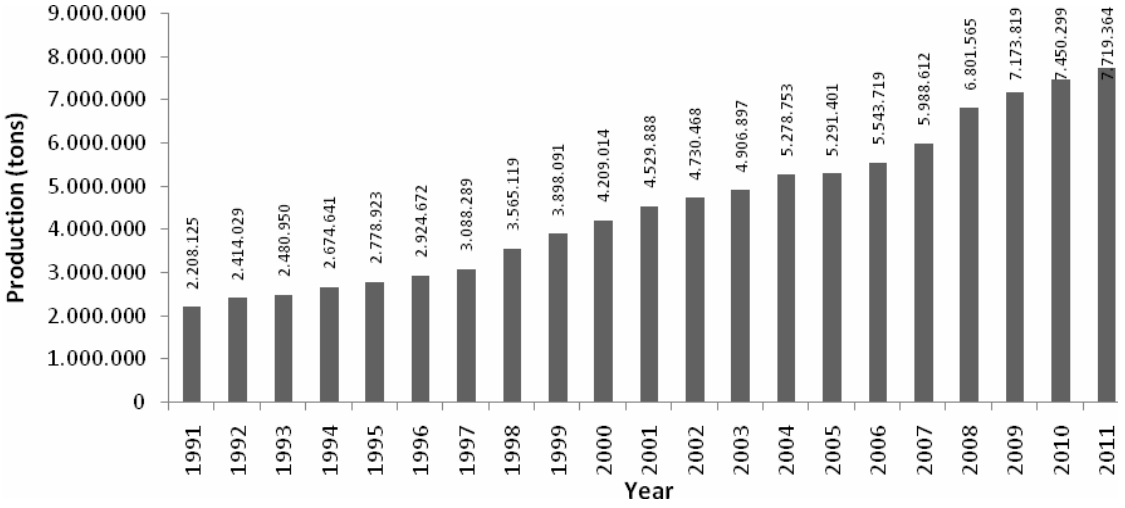

Figure 3. Area harvested for mushroom farming in World from 1991-2011 (hectares) (UNFAOSTAT 2011).

should be noted that *A. bisporus* is only edible fungicultivated globally. In UK and in some other Western countries the mushroom industry is often overwhelmingly focused on one mushroom species i,e. *A. bisporus*. These industries are nearly 100% dominated by *A. bisporus* (Fletcher and Gaze 2008). In the US, it accounts for about 98% of its mushroom industry, *Lentinula edodes* for 1% and *Pleurotus* spp. for only about 0.5% (Table 4). Note: share of total US mushroom production is in brackets.

On the other hand, mushroom industry in Asia especially in East Asian countries are relatively less homogenized by *A. bisporus* as shown in Table 5 (shares of total mushroom production are in brackets). *Agaricus* accounted for 12.8%, 11.6% and 0% of total mushroom production in China, S. Korea and Japan respectively (in 2003). *Agaricus, Lentinula* and *Pleurotus* are the three important mushrooms that dominate the mushroom industry in Asian countries (Chang 2006; Cui 2004; Ho and Peng 2006).

World mushroom market

Mushroom farming is a business which necessitates practical experience, scientific knowledge, proper planning and support. The world market for the mushroom industry in 2001 was valued at over US$40 billion. Production of mushrooms worldwide has been steadily increasing possible due to participation of developing countries, after realizing its efficiency in terms of agriculture returns per unit land, labor and money. The world market for the mushroom industry in 2005 was valued at over $45 billion (Chang 2006). The 1999 US market for dietary supplements based mainly on mushrooms was estimated to be US$35 million. From last few decades growth rate, both in terms of productivity as well as production has been phenomenal. The gross production value acquired by mushroom farming from 1991-2011 in different countries and continents is summarized in Table 6.

Figure 4. The world most notable cultivated mushrooms. A. *Agaricus bisporus,* B. *Auricularia auricula,* C. *Calocybe indica,* D. *Flammulina velutipes,* E. *Ganoderma lucidum,* F. *Lentinula edodes,* G. *Pleurotus ostreatus,* H. *Pleurotus sajor-caju,* and I. *Volvariella volvacea.* (photo from many sources)

Table 2. World mushroom production (metric tons) (UNFAOSTAT 2011).

Country	1961	1971	1981	1991	2001	2011
Albania	-	-	-	-	101	123
Algeria	-	-	-	100	120	220
Australia	-	-	8,265	24,394	39,394	49,696
Austria	3,000	3,000	4,100	2,700	300	1,600
Azerbaijan	-	-	-	-	-	1,700
Belarus	-	-	-	-	8,000	6,500
Belgium	-	-	-	-	40,500	41,,556
Belgium-Luxembourg	-	4,500	12,408	20,592	-	-
Bosnia and Herzegovina	-	-	-	-	800	994
Brunei Darussalam	-	-	-	3	8	11
Bulgaria	200	3,200	4,200	5,200	10,000	2,171
Canada	7,800	14,622	32,709	53,020	86,357	78,930
China	3,02,784	4,22,422	4,01,947	7,95,013	26,69,841	50,08,850
Cyprus	120	220	325	1,350	1,470	730
Czech Republic	-	-	-	-	500	361
Denmark	4,000	6,738	7,582	8,200	8,686	10,304
Estonia	-	-	-	-	100	125
Finland	100	100	100	800	1,465	1,668
France	32,342	78,777	1,61,800	1,98,500	1,96,254	1,15,669
Germany	10,530	26,682	47,794	56,000	63,000	62,000
Greece	-	-	300	500	495	3,255
Hungary	500	500	500	5,000	18,414	14,249
Iceland	-	-	-	-	450	583
India	500	1,000	1,400	4,000	23,000	40,600
Indonesia	-	-	500	8,000	25,500	45,851
Iran, Islamic Republic of	-	-	-	6,387	19,000	37,664
Ireland	5,000	3,000	8,000	39,000	68,000	67,063
Israel	-	-	-	1,080	7,500	10,001
Italy	6,464	20,423	47,607	79,536	72,900	7,61,858
Japan	35,000	50,000	78,400	78,000	66,100	60,180
Jordan	-	-	-	250	600	1,123
Kazakhstan	-	-	-	-	500	558
Korea, Democratic People's Republic of	-	-	-	5,500	5,932	5,700
Korea, Republic of	100	10,173	18,910	8,992	21,251	30,574
Kyrgyzstan	-	-	-	-	1,606	201
Latvia	-	-	-	-	534	517
Lithuania	-	-	-	-	2,900	12,700
Luxembourg	-	-	-	-	15	5
Macedonia, The former Yugoslav Republic of	-	-	-	-	2,400	2,784
Madagascar	-	-	-	800	1,067	2,087
Malta	-	-	-	-	781	947
Moldova, Republic of	-	-	-	-	400	475
Mongolia	-	-	-	-	12	278
Morocco	300	600	620	1,500	1,973	2,045
Netherlands	4,000	35,000	68,000	1,65,000	2,75,000	3,04,000
New Zealand	300	1,073	2,936	3,000	8,500	9,884
Philippines	-	-	-	460	565	571
Poland	5,087	4,802	23,000	1,01,500	1,10,000	1,98,235
Portugal	-	-	-	1,046	1,311	1,240
Réunion	-	-	-	70	48	61
Romania	-	-	-	5,608	6,000	7,661
Russian Federation	-	-	-	-	6,000	4,200
Serbia	-	-	-	-	-	4,851
Serbia and Montenegro	-	-	-	-	13,000	-
Singapore	-	-	-	-	-	101
Slovakia	-	-	-	-	500	1,898
Slovenia	-	-	-	-	1,305	1,060
South Africa	-	-	-	4,833	7,019	12,568
Spain	3,000	6,414	35,528	29,693	1,09,605	1,48,000
Switzerland	1,600	2,900	4,200	6,374	7,000	8,524
Thailand	100	200	400	9,404	9,800	6,,791
Tunisia	-	-	-	70	79	122
Turkey	-	-	-	1,300	1,100	2,7058
Ukraine	-	-	-	-	3,400	14,000
United Kingdom	20,000	50,193	64,600	1,23,300	92,600	69,300
United States of America	50,000	1,04,948	2,12,990	3,38,760	3,76,980	3,90,902
Uzbekistan	-	-	-	-	300	661
Viet Nam	1,000	2,500	4,000	9,000	16,000	21,957
Yugoslav SFR	1,300	4,000	4,400	3,900	-	-
Zimbabwe	-	-	-	390	250	613
World	4,95,127	8,57,987	12,57,521	22,08,125	45,14,588	77,19,364

Table 3. World mushroom production (metric tons) of different countries and continents (1991-2011) (UNFAOSTAT 2011).

Country	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Albania	-	-	-	-	-	100	94	98	92	96	101	104	114	118	101	100	99	105	107	100	123
Algeria	100	107	116	110	122	116	115	125	110	97	120	123	130	150	170	200	197	191	229	220	220
Australia	24,394	25,502	27,575	38,889	33,337	34,945	35,485	38,895	37,568	36,000	39,394	43,412	39,288	46,265	47,992	43,641	42,739	47,102	43,416	41,295	49,696
Austria	2,700	2,500	2,485	2,080	1,255	800	300	100	100	100	300	500	800	900	900	900	900	900	1,100	1,300	1,600
Belarus	-	-	-	-	-	-	-	4,500	4,200	5,000	8,000	5,000	7,000	7,117	7,018	8,000	6,800	7,000	7,037	7,000	6,500
Belgium	-	-	-	-	-	-	-	-	-	46,300	40,500	42,500	43,000	44,526	41,608	41,712	43,361	40,000	42,266	41,728	41,556
Bosnia and Herzegovina	-	300	263	400	300	400	700	800	900	1,200	800	1,000	829	1,500	2,000	1,000	1,000	956	943	1,200	994
Bulgaria	5,200	4,435	5,000	9,000	8,000	12,000	13,000	11,000	10,200	11,500	10,000	8,961	9,341	11,000	3,000	1,894	1,716	1,438	1,725	1,619	2,171
Canada	53,020	53,700	54,670	56,610	62,690	59,410	68,020	72,880	69,280	80,241	86,357	75,075	87,937	84,682	80,071	87,631	73,260	79,990	65,550	72,930	78,930
China	7,95,013	8,85,254	9,61,955	10,89,991	12,08,672	13,11,027	14,62,196	18,95,691	21,83,006	24,08,234	26,69,841	28,59,806	30,09,469	33,60,513	34,09,686	36,84,342	40,68,518	47,10,574	46,80,720	48,33,725	50,08,850
Cyprus	1,350	1,800	2,300	2,150	1,650	1,500	2,170	2,300	2,000	1,730	1,470	1,270	1,200	1,101	1,014	828	1,213	1,013	793	790	730
Czech Republic			100	300	500	200	300	100	200	1,000	500	800	800	350	350	350	313	400	311	261	361
Korea	5,500	4,500	4,370	4,800	4,000	4,252	4,319	5,000	6,000	5,867	5,932	6,200	6,263	6,300	6,262	6,000	6,500	6,377	6,335	6,540	5,700
Denmark	8,200	9,371	9,000	8,391	10,000	10,000	8,766	8,314	8,300	8,686	8,686	8,686	8,180	10,946	10,946	10,946	11,000	10,000	9,500	9,541	10,304
Finland	800	1,150	1,155	1,107	1,171	1,443	1,242	1,364	1,623	1,536	1,465	1,756	2,020	2,230	1,996	2,054	2,016	1,971	1,812	1,645	1,668
France	1,98,500	1,96,600	1,84,039	1,71,692	1,64,154	1,89,213	1,73,000	1,51,564	1,51,889	2,03,811	1,96,254	1,75,288	1,65,647	1,65,466	1,38,541	1,15,846	1,62,450	29,936	1,13,851	1,19,346	1,15,669
Germany	56,000	60,000	58,000	58,000	57,000	59,000	60,000	60,000	60,000	62,000	63,000	62,000	50,000	50,000	50,000	59,000	55,000	57,000	52,200	60,000	62,000
Greece	500	454	476	485	482	492	485	504	1,200	500	495	500	2,500	2,516	2,262	2,474	3,500	3,334	3,565	3,181	3,255
Hungary	5,000	5,904	6,916	6,802	7,651	10,761	13,559	14,425	15,901	16,926	18,414	20,257	22,396	18,303	19,734	21,208	21,637	23,906	21,950	14,026	14,249
Iceland	-	210	221	220	251	259	293	377	379	447	450	450	465	461	438	488	575	526	553	579	583
India	4,000	10,000	12,000	16,000	18,000	16,000	9,000	13,500	14,000	24,000	30,000	40,000	40,000	40,000	40,000	35,000	37,000	37,000	37,000	40,600	40,600
Indonesia	8,000	21,000	19,000	25,500	22,000	22,000	19,000	8,000	24,000	28,000	25,500	18,300	31,233	10,544	30,854	23,559	48,247	43,047	38,465	61,376	45,851
Iran	6,387	8,454	7,619	6,732	7,108	9,223	8,962	10,434	13,000	16,000	19,000	21,000	22,000	25,000	27,908	28,000	28,000	23,405	26,726	29,009	37,664
Ireland	39,000	40,700	45,000	49,000	49,000	54,000	57,800	62,000	64,800	59,800	68,000	69,000	69,000	65,000	62,000	75,000	81,000	90,000	60,000	65,000	67,063
Israel	1,080	1,032	1,010	1,040	860	1,160	1,260	1,000	1,000	7,500	7,500	7,800	8,600	9,000	9,500	9,500	9,500	9,500	9,500	9,500	10,001
Italy	79,536	87,210	67,383	68,221	65,285	65,894	57,646	59,343	61,623	72,492	72,900	72,700	96,090	94,152	88,361	1,00,100	85,911	3,42,000	7,20,100	8,00,000	7,61,858
Japan	78,000	76,800	77,400	74,300	74,495	75,157	74,782	74,217	70,511	67,224	66,100	64,400	65,400	66,200	66,000	65,000	67,000	67,500	63,084	59,550	60,180
Jordan	250	500	355	450	500	500	500	750	600	500	600	700	675	764	795	832	852	840	910	1,030	1,123
Kyrgyzstan	-	5	500	512	615	736	930	1,077	1,397	1,451	1,606	1,662	300	300	200	209	225	234	235	200	201
Latvia	-	200	300	400	500	400	367	500	500	500	534	500	600	550	500	550	500	420	560	463	517
Lithuania	-	2,000	3,000	2,000	3,000	2,500	2,398	5,300	2,500	6,000	2,900	2,900	2,503	3,871	4,087	5,175	6,688	8,150	14,056	10,400	12,700
Luxembourg	-	-	-	-	-	-	-	-	-	16	15	15	15	15	5	5	5	5	5	5	5
Madagascar	800	888	796	869	1,000	1,013	1,100	1,166	1,225	1,000	1,067	1,054	1,252	1,304	1,192	1,493	1,651	1,592	1,901	2,217	2,087
Malta	-	-	-	-	-	-	-	900	863	849	781	644	698	980	989	950	1,093	1,130	1,188	1,088	947
Mongolia	-	-	-	-	-	-	-	-	-	-	12	30	110	250	200	200	217	220	221	235	278
Morocco	1,500	1,700	1,600	1,700	1,373	1,700	1,662	1,750	1,656	1,800	1,973	1,850	2,007	1,900	1,688	2,077	1,878	1,883	1,887	1,943	2,045
Netherlands	1,65,000	1,90,000	1,90,000	2,20,000	2,30,000	2,37,000	2,40,000	2,46,000	2,50,000	2,65,000	2,75,000	2,70,000	2,63,000	2,60,000	2,45,000	2,35,000	2,40,000	2,55,000	2,30,000	2,66,000	3,04,000
New Zealand	3,000	3,500	4,300	6,000	5,500	6,300	7,500	8,400	8,150	8,500	8,500	8,500	8,500	8,840	8,600	10,042	8,500	9,368	8,635	8,213	9,884
Philippines	460	455	501	482	481	737	762	568	563	569	565	560	570	544	508	551	565	564	557	526	571
Poland	1,01,500	1,00,000	1,18,172	1,03,419	1,14,235	1,04,501	1,01,786	1,02,570	1,06,483	1,13,479	1,10,000	1,20,000	1,30,196	1,50,000	1,60,000	1,53,497	1,80,000	1,85,000	1,99,148	1,73,448	1,98,235
Portugal	1,046	854	1,060	1,151	1,175	1,275	1,160	1,448	1,430	1,251	1,311	1,143	1,173	1,575	1,423	1,289	1,050	1,070	1,100	1,400	1,240
Republic of Korea	8,992	10,000	11,183	10,037	9,582	12,418	13,181	16,000	19,774	20,659	21,251	24,688	24,957	27,781	28,375	27,404	28,764	28,361	27,033	26,250	30,574
Republic of Moldova	-	500	400	307	314	207	193	500	498	300	400	349	355	300	400	450	400	438	499	463	475
Réunion	70	79	82	88	85	80	70	62	54	61	48	38	47	55	54	49	43	53	56	65	61
Romania	5,608	6,173	8,000	9,000	8,000	5,000	4,000	3,000	4,000	5,000	6,000	9,000	80	7,050	563	2,559	1,083	1,664	7,317	9,973	7,661
Russian Federation	-	200	400	750	1,500	1,500	1,500	3,500	3,600	6,000	6,000	7,000	5,700	6,000	5,000	6,000	5,700	6,000	6,200	5,500	4,200
Serbia and Montenegro	-	3,000	1,500	2,000	1,500	7,000	8,000	8,325	10,000	12,000	13,000	15,605	13,163	12,000	11,421	-	-	-	-	-	-
Slovakia	-	-	600	700	700	800	700	600	800	600	900	800	900	1,000	1,100	1,300	1,500	1,800	2,000	2,335	1,898

Slovenia	-	1,500	1,732	1,621	1,786	1,881	1,833	1,701	1,970	1,683	1,305	1,505	1,376	1,100	1,200	1,080	894	1,043	1,150	823	1,060
South Africa	4,833	4,142	4,735	6,200	7,824	7,048	7,406	6,507	7,617	7,278	7,019	7,021	8,610	8,415	8,385	8,477	10,320	11,351	11,744	12,217	12,568
Spain	29,693	67,077	67,116	70,814	75,968	71,529	81,304	80,000	93,600	63,254	1,09,605	1,34,669	1,29,205	1,38,782	1,37,764	1,35,419	1,31,974	1,33,548	1,31,000	1,33,000	1,48,000
Switzerland	6,374	7,365	7,300	7,614	8,083	7,666	7,239	7,800	7,100	7,350	7,000	7,400	6,800	7,451	7,440	7,440	7,440	7,500	7,905	8,465	8,524
Thailand	9,404	8,161	9,000	10,838	9,200	9,168	9,000	9,200	9,455	9,500	9,800	9,035	8,503	10,000	9,123	6,964	6,394	6,366	6,933	6,925	6,791
Macedonia	-	3,000	1,500	1,596	2,000	1,900	1,600	1,836	1,800	2,000	2,400	3,000	2,000	2,500	3,000	3,166	2,500	2,606	2,870	2,900	2,784
Tunisia	70	71	60	62	57	73	67	75	69	72	79	88	96	103	99	100	107	114	120	126	122
Turkey	1,300	1,000	964	1,022	1,138	2,000	1,200	3,000	5,000	7,000	9,000	11,000	13,000	15,000	17,000	21,833	23,426	26,526	19,501	21,559	27,058
Ukraine	-	-	-	-	-	-	2,000	2,500	3,000	3,500	3,400	3,500	4,000	5,000	6,000	8,500	7,200	6,300	8,500	11,000	14,000
UK	1,23,300	1,20,613	1,22,327	1,33,842	1,01,671	1,06,555	1,07,359	1,09,500	1,04,700	89,900	92,600	84,700	81,000	74,000	74,000	68,000	71,500	70,200	69,400	69,300	69,300
USA	3,38,760	3,52,150	3,40,560	3,54,250	3,52,836	3,52,300	3,66,810	3,84,540	3,87,550	3,83,830	3,76,980	3,77,080	3,87,601	3,87,601	3,86,984	3,82,541	3,59,630	3,68,591	3,71,844	3,59,469	3,90,902
Uzbekistan		300	251	244	220	204	400	500	400	387	300	316	359	360	382	464	509	573	626	600	661
Viet Nam	9,000	9,500	10,000	10,500	11,443	10,000	10,339	12,000	14,000	20,500	16,000	16,299	16,819	18,000	18,229	18,646	18,818	19,514	20,808	21,213	21,957
Zimbabwe	390	433	388	424	406	411	426	220	240	230	250	320	380	396	350	438	484	467	558	651	613
European Union	8,43,525	9,19,219	9,16,872	9,42,900	9,30,626	9,67,656	9,62,173	9,68,922	9,89,890	10,34,113	10,83,035	10,90,194	10,81,820	11,05,509	10,47,441	10,37,256	11,06,404	12,61,019	16,86,197	17,86,777	18,28,172
World	22,08,125	24,14,029	24,80,950	26,74,641	27,78,923	29,24,672	30,88,289	35,65,119	38,98,091	42,09,014	45,29,888	47,30,468	49,06,897	52,78,753	52,91,401	55,43,719	59,88,612	68,01,565	71,73,819	74,50,299	77,19,364
Africa	7,763	7,420	7,777	9,453	10,867	10,441	10,846	9,905	10,971	10,538	10,556	10,494	12,522	12,323	11,938	12,834	14,680	15,651	16,495	17,439	17,716
Americas	3,91,780	4,05,850	3,95,230	4,10,860	4,15,526	4,11,710	4,34,830	4,57,420	4,56,830	4,64,071	4,63,337	4,52,155	4,75,538	4,72,283	4,67,055	4,70,172	4,32,890	4,48,581	4,37,394	4,32,399	4,69,832
Asia	9,28,739	10,38,763	11,18,412	12,54,602	13,69,969	14,76,088	16,18,006	20,53,641	23,65,113	26,19,629	28,84,985	30,83,575	32,50,003	35,92,187	36,66,571	39,30,858	43,47,798	49,83,826	49,42,145	51,22,159	53,01,160
Europe	8,52,449	9,32,994	9,27,656	9,54,837	9,43,724	9,85,188	9,81,622	9,96,858	10,19,459	10,70,276	11,23,116	11,32,332	11,21,046	11,46,855	10,89,245	10,76,172	11,42,005	12,97,037	17,25,734	18,28,794	18,71,076
Australia	27,394	29,002	31,875	44,889	38,837	41,245	42,985	47,295	45,718	44,500	47,894	51,912	47,788	55,105	56,592	53,683	51,239	56,470	52,051	49,508	59,580

The mushroom industry is based on two aspects which complement each other (sometimes called two legs of the mushroom industry) viz. mushroom science concerned with mushroom production and mushroom biotechnology concerned mushroom products. In the past, the focus was mainly on the production of fresh, canned and dried mushrooms. This means the industry had only one leg thus can't go long way in most efficacious manner, but at present, the focus on second leg has strengthened the mushroom industry to establish and spread its roots

The paradigm shift resulted generation of large income from mushroom products, e.g. in 1987, the value of pharmaceuticals developed from three mushrooms: *Coriolus versicolor*, *Lentinula edodes* and *Schizophyllum commune* was reported to be 769 million dollars annually in Japan alone (Chang and Buswell 1993). There are several other mushroom products e.g. those from *Ganoderma* manufactured and used in China, Korea and Taiwan that are also worthy many millions of dollars. Table 7. evinces the income generated by Japan and USA by the sale of raw anticancer drugs as early as 1987. The monetary returns from medicinal mushrooms and their derivative dietary supplements worldwide was estimated about US$1.2 billion in 1991, US$3.6 billion in 1994 and US$6.0 billion in 1999 (Chang 1996; Wasser et al. 2000). In 2001, the figure of US$9-10 billion was cited as representing the value of medicinal mushroom products, including tonics and medicines. The market value of *Ganoderma*-based nutriceuticals alone in 1995 was estimated US$1.6 billion (Chang and Buswell 1999). A lot of mushrooms are traded in china for diverse medicinal uses (Wasser 2010). The corresponding monetary values will touch new heights if the medicinal potential of other medicinal mushrooms is fully exploited.

International efforts to publicize the science

The mushroom industry seems to be one of the fastest growing investment sectors in the world, yet lot is to be done to watch full phase of the moon. Prior to practice the practice it is important to know how and to what extent the benefits of both mushroom production and mushroom products can be maximized. We need to increase mushroom production through the improvement of mushroom biotechnology and make greater leaps and advancements in the mushroom industry which in turn contribute more to the welfare in mankind. To achieve the goals of mushroom industry it is essential that there is cooperation in the exchange of information and technology concerning mushroom production and mushroom products among research scientists, industry, regulatory agencies, government and the public.

Theoretically three segments could be identified in mushroom industry with each received international recognition as important inter-related components and

Table 4. The US mushroom industry is dominated by *Agaricus bisporus* (NASS 2005).

Mushroom production (t)	2002-2003	2003-2004	2004-2005
Agaricus	379318.8 (98.6%)	381479.4 (98.4%)	380083.0 (98.2%)
Lentinula	3390.5 (0.9%)	3506.1 (0.9%)	4118.4 (1.1%)
Pleurotus	1812.6 (0.5%)	2008.2 (0.5%)	2453.0 (0.6%)
Sub-total	384521.9 (99.9%)	386993.7 (99.9%)	386654.4 (99.9%)
Others	197.3 (0.01%)	541.0 (0.01%)	253.5 (0.01%)
Grand total	384719.2 (100%)	387534.7 (100%)	386907.9 (100%)

Table 5. Asia's mushroom industry is more diverse (2003 data) (Chang 2006; Cui 2004; Ho and Peng 2006).

Production	China (x1000t)	Japan (t)	S. Korea (t)	Taiwan (t)
Agaricus	1330.4 (12.8%)	-	19790 (11.6%)	4276 (4.0%)
Lentinula	2228 (21.5%)	35294 (10.7%)	41876 (24.6%)	36000 (33.4%)
Pleurotus	2488 (24.0%)	5219 (1.6%)	61965 (36.5%)	4540 (4.2%)
Sub-total	6046.4 (58.2%)	40513 (12.3%)	123631 (72.7%)	44816 (41.6%)
Others	4340.5 (41.8%)	290333 (87.8%)	46369 (27.3%)	62984 (58.4%)
Grand total	10386.9 (100%)	330846 (100%)	170000 (100%)	107800 (100%)

Table 6. Gross Production Value of mushrooms in current million US$) (USD) from 1991-2011 (UNFAOSTAT 2011).

Country	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia	74	72	72	113	94	102	100	98	97	86	93	109	125	162	185	184	218	236	198	216	302
Canada	131	122	118	124	140	131	151	152	143	174	177	164	209	218	226	255	230	252	197	240	282
China	702	1749	2195	1323	1386	3448	3386	4417	3697	3790	3287	4971	4944	5844	6199	7362	9282	11885	9218	3013	6160
Denmark	20	23	20	19	26	24	18	19	18	26	24	26	24	35	36	34	30	36	39	37	47
France	235	261	236	239	269	217	165	139	135	159	144	131	146	159	147	112	174	35	138	144	156
Germany	121	134	108	110	131	130	120	122	82	85	119	101	124	129	116	152	154	149	139	151	153
India	4	6	7	14	12	13	7	14	17	17	20	31	31	33	36	32	40	41	41	46	47
Indonesia	5	12	11	16	14	14	11	2	25	24	26	19	36	10	36	33	73	103	97	188	186
Iran	64	152	6	5	9	8	15	26	14	28	50	13	14	25	30	32	34	60	33	61	96
Ireland	89	98	94	105	124	151	154	156	153	124	137	153	177	189	179	218	295	374	230	158	172
Israel		6	5	5	4	4	5	3	3	31	21	20	25	26	28	28	31	35	32	34	72
Italy	174	198	123	121	114	123	101	103	107	110	103	121	190	205	196	220	212	948	1930	1979	2006
Japan	326	199	510	400	385	228	288	408	315	226	231	193	250	301	286	248	242	307	316	361	381
Netherlands	225	252	250	311	334	325	296	310	309	305	394	384	414	440	385	378	449	500	374	427	517
New Zealand	8	8	9	14	13	15	17	16	15	14	13	14	18	21	22	25	26	28	24	27	37
Poland	96	95	124	105	113	102	93	89	81	86	85	92	110	153	180	179	250	293	273	236	289
Republic of Korea	20	29	39	31	29	46	43	29	38	60	55	60	52	52	49	91	101	78	61	73	94
South Africa	13	12	12	15	18	16	15	10	9	11	11	13	18	25	22	22	14	22	14	14	27
Spain	33	81	64	68	83	74	78	79	92	56	96	112	130	182	202	193	207	227	166	170	213
Switzerland	34	34	33	40	53	40	42	35	35	38	29	40	42	49	46	50	51	56	55	78	80
Turkey	2	1	1	1	2	2	1	5	6	10	8	10	18	25	31	42	54	69	42	56	61
United Kingdom	314	284	270	296	240	271	483	251	232	196	181	187	203	190	171	162	159	152	115	129	119
United States of America	646	679	647	715	727	726	760	856	855	855	889	873	906	923	913	886	920	959	959	927	1022
.																					
World + (Total)	3423	4590	5046	4320	4462	6334	6488	7501	6647	6663	6364	8023	8413	9612	9931	11152	13506	17119	14982	9061	12809
Africa + (Total)	17	17	17	18	22	20	19	14	13	15	14	16	23	28	26	26	19	28	21	21	34
Americas + (Total)	777	802	765	839	867	857	911	1009	998	1029	1066	1037	1115	1141	1139	1140	1150	1211	1156	1167	1304
Northern America + (Total)	777	802	765	839	867	857	911	1009	998	1029	1066	1037	1115	1141	1139	1140	1150	1211	1156	1167	1304
Asia + (Total)	1127	2148	2769	1813	1856	3759	3750	4903	4122	4191	3706	5315	5370	6317	6694	7865	9857	12578	9843	3845	7108
Europe + (Total)	1420	1544	1414	1522	1610	1581	1691	1461	1402	1329	1471	1531	1763	1944	1866	1911	2237	3038	3740	3785	4023
-Australia & New Zealand + (Total)	82	79	82	127	107	117	118	114	112	99	105	124	142	182	207	209	243	264	222	243	340

Table 7. The top ten best selling anticancer drugs in Japan and the USA, 1987 (Fukushima 1989).

	Japan			USA		
	Drug	Sales ($ × 10^6)	Market share (%)	Drug	Sales ($ × 10^6)	Market share (%)
1	PS-K	358	25.2	Doxorubicin	86	16.3
2	OK-432	191	13.4	Cisplatin	79	15.0
3	Tegafur uracil	177	12.5	Tamoxifen citrate	68	12.9
4	5-Fluorouracil	104	7.3	Etoposide	52	9.8
5	Tegafur	101	7.1	Cyclophosphamide	31	5.9
6	Tamoxifen citrate	63	4.4	Methotrexate	29	5.5
7	Interferon β	40	2.8	Megestrolacetate	27	5.1
8	Lentinan	31	2.2	Mitomycin C	25	4.7
9	Carmofur	26	1.9	Bleomycin	20	3.8
10	Estramustine phosphate sodium	25	1.8	Vincristine sulphate	18	3.4

deserving its own special patronage and paths of development: (i) cultivated edible mushrooms (mushroom themselves-used directly or indirectly as food); (ii) medicinal mushrooms (mushroom derivatives-used as nutriceutical therapy/dietary supplements); and (iii) wild mushrooms including edible mycorrhizal, symbiotic and poisonous mushrooms (collected, up to now, only from the wild). The three International forums/bodies were developed to boost the mushroom industry all over the world (Chang et al. 1993; Chang 2006): (i) The international movement for edible mushrooms, (ii) The international movement for medicinal mushrooms, (iii) The international movement for wild mushrooms, mainly concerned with edible mycorrhizal mushrooms

CONCLUDING REMARKS

Outrightly, it is now evident and accepted fact that mushroom farming, based on applied scientific and practical knowledge using industrial or lignocellulosic waste materials available in abundance in both developed and developing countries can have positive global impact on long term food production, health, environmental conservation, regeneration of healthy environment, and socio-economic aspects of people all over the world thereby can lead to sustained agriculture and ecosystems. The biggest problem faced by the growing population of world is food scarcity, rising prices, new diseases and finally overexploitation of natural capital and dragon of pollution. In this scenario mushrooms offer a solution to almost every problem of mankind if properly and thoroughly scanned for their hidden potential and properties, thereby mushrooms auspicate non green revolution in the form of food, medicine and healthy environment.

REFERENCES

Agrahar MD, Subbulakshmi G. 2004. Nutritional value of edible wild mushrooms collected from the Khasi hills of Meghalaya. Food Chem 89 (4): 599-603.

Ayaz FA, Torun H, Ozel A, Col M, Duran C, Sesli E, Colak A. 2011. Nutritional value of some wild edible mushrooms from Black Sea region (Turkey).Turk Biyokimya Dergisi 36 (3): 213-221.

Bampus JA, Aust SD. 1987. Biodegradation of environmental pollutants by the white rot fungus, *Phanerochaeta chrysosporium*: Involvement of the lignin degrading system. Bio Essays 6: 166-170.

Barrosa L, Bapista P, Correria DM, Casal S, Ferrira C. 2007. Fatty acids, sugar compositions and nutritional value of five wild edible mushrooms from north east Portugal. Food Chem 105 (1): 140-145

Bernas E, Jaworska G, lisiewska Z. 2006. Edible mushrooms as a source of valuable nutritive constituents. Acta Sci Pol Technol Aliment 5(1): 5-20.

Beyer D. 2005. Spent mushroom substrate (SMS) research in the US. Amer Med Group Assoc J, Summer Issue: 31-32.

Boda RH. 2009. Studies on the mushroom flora of western Kashmir. [Ph.D. Dissertation]. Department of Botany, University of Kashmir, India.

Camargo MR, Kaneno R. 2011. Antitumor properties of *Ganoderma lucidum* polysaccharides and terpenoids. Ann Rev Biomed Sci 13: 1-8.

Chang ST, Buswell JA, Miles PG. 1993. Genetics and Breedings of Edible Mushrooms. Gordon and Breach Science Publisher, Philadelphia. USA.

Chang ST, Buswell JA. 1999. *Ganoderma lucidum* (Curt.: Fr.) P. Karst. (Aphyllophoromycetidease): a mushrooming medicinal mushroom. Int J Med Mush 1: 139-146.

Chang ST, Buswell JA. 2003. Medicinal mushrooms—a prominent source of nutriceuticals for the 21st century. Curr Top Nutraceut Res 1: 257-280.

Chang ST, Buswell JA. 2008. Safety, quality, control and regulational aspects relating to mushroom nutriceuticals. Proc. 6th Intl. Conf. Mushroom Biology and Mushroom Products. GAMU Gmbh, Krefeld, Germany.

Chang ST, Miles PG. 1992. Mushroom biology–a new decipline. Mycologist 6: 64-65.

Chang ST, Miles PG. 2004. Mushrooms: Cultivation, Nutritional Value, Medicinal Effect, and Environmental Impact (2nd ed). CRC Press, New York.

Chang ST. 1996. Mushroom research and development–equality and mutual benefit. In: Royse DJ (ed). Mushroom Biology and Mushroom Products. Penn. State Univ., University Park, Pennsylvania.

Chang ST. 1998. Development of novel agroscience industries based on bioconversion technology. In: Chou CH, Shao KT (ed). Frontiers in Biology: the Challenges of Biodiversity. Academia Sinica, Taipei.

Chang ST. 2006. The world mushroom industry: trends and technological development. Inter J Med Mushr 8 (4): 297-314.

Chang, ST, Buswell JA. 1996. Mushroom nutriceuticals. World J Microbiol Biotechnol 12: 473-476.

Crisan EW, Sands A. 1978. A Nutritional value. In: Chang ST, Hayes WA (eds). The Biology and Cultivation of Edible Mushrooms. Academic Press, New York.

Cui ZH. 2004. The production, import and export of edible mushrooms in S. Korea. The Proceedings of The Coordinative Forum on the Development of Chinese Mushroom Industry, November 2004, Zhejiang, China.

Das N. 2005. Heavy metal biosorption by mushrooms-Review Article. Nat Prod Rad 4 (6): 454-459.

Dell, B. 2002. Role of mycorrhizal fungi in ecosystems. CMU J 1 (1): 47-60.

Directorate of Musroom research .2011. Vission 2030, Indian Council of Agricultural Research, Chambaghat, Solan-173 213, H.P., India.

Fletcher JT, Gaze RH. 2008. Mushroom Pest and Disease Control, A Colour Handbook. Manson Publishing, Boston.

Fomina MA, Alexander IJ, Colpaert JV, Gadd GM. 2005. Solubilization of toxic metal minerals and metal tolerance of mycorrhizal fungi. Soil Biol Biochem 37: 851-866.

Fukushima M. 1989. The overdose of drugs in Japan. Nature 342: 850-851.

Hawksworth DL. 2001. The magnitude of fungal diversity: the 1,5 million species estimate revisited. Mycol Res 105: 1422-1432

Ho MS, Peng JT. 2006. Edible mushroom production in Taiwan. Mushroom International (ISMS Newsletter) April Issue: 6-7.

Israilides C, Kletsas D, Arapoglou D, Philippoussis A, Pratsinis H, Ebringerova A, Hribalova V, Harding SE. 2008. In vitro cytostatic and immunomodulatory properties of the medicinal mushroom *Lentinula edodes*. Phytomedicine 15 (6-7): 512-519.

Kamal S. 2011. Quality Traits in Cultivation Mushrooms and Consumer Acceptability. Mushrooms-Cultivation, Marketing and Consumption (In: Singh M, Vijay B, Kamal S, Wakchure GC ed.). Directorate of Mushroom Research (ICAR) Chambaghat, Solan –173213, H.P., India.

Kansci G, Mossebo DC, Selatsa AB, Fotso M. 2003. Nutrient content of some mushroom species of the genus *Termitomyces* consumed in Cameroon. Die Nahrung 47 (3): 213-216.

Kaul TN, Dhar BL. 2007. Biology and Cultivation of Edible Mushrooms. Westville Publishing House. New Delhi.

King TA. 1993. Mushrooms, the ultimate health food but little research in U.S. to prove it. Mushr News 41: 29-46.

Kulshreshtha S, Mathur N, Bhatnagar P. 2014. Mushroom as a product and their role in mycoremediation (Mini Review. AMB Express 4: 29-36.

Kumari, R, Tapwal A, Pandey S, Borahi RK, Borahi D, Borgohaini J. 2013. Macro-fungal diversity and nutrient content of some edible mushrooms of Nagaland, India. Nusantra Bioscience 5 (1): 1-7.

Lohani H. 2012. Training Manual on Mushroom Cultivation Technology. United Nations-Nations Unies Economic and Social Commission for Asia and the Pacific Asian and Pacific Centre for Agricultural Engineering and Machinery (APCAEM), Beijing-100029, P.R. China.

Mabuza ML, Ortmann G, Wale E. 2014. Effects of transaction costs on mushroom producers' choice of marketing channels: Implications for access to agricultural markets in Swaziland. SAJEMS NS 17 (2): 207-219.

Mallick SK, Maiti S, Bhutia SK, Maiti TK. 2010. Immunostimulatory properties of a polysaccharide Isolated from *Astraeus hygrometricus.* J Med Food 13 (3): 665-672.

Nanba H. 1993. Maitake mushroom- the king mushroom. Mushr News 41: 22-25.

NASS. 2005. 2005 Agricultural Statistic. National Agricultural Statistics Service, USDA-NASS, Washington, DC.

Noble R. 2005. Spent mushroom substrate –an alternative use. Amer Med Group Assoc J, Summer Issue: 33-35.

Pala SA, Wani AH. 2012. Mushrooms: The entities with multifarious medicinal properties. J Pharm Res 3 (12): 4721-4726.

Perry DA, Molina R, Amaranthus MP. 1987. Mycorrhizae, mycorrhizospheres, and reforestation: current knowledge and research needs. Can J For Res 17: 929-940.

Rojas C, Mansur E. 1995. Ecuador: Informaciones generales sobre productos non madereros en Ecuador In: Memoria, Consulta de Expertos Sobre Productos Forestales no Madereros para America Latina y el Caribe. Serie Forestal #1, FAO Regional Office for Latin America and the Caribbean, Santiago, Chile.

Smith J, Rowan N, Sullivan R. 2002. Medicinal Mushrooms. Their Therapeutic Properties and Current Medical Usage with Special Emphasis on Cancer Treatment; Special Report Commissioned by Cancer Research UK. University of Strathclyde, Glasgow.

Stamets P. 2005. Mycelium Running: How Mushroom can Help Save the World. Ten Speed Press, Berkeley.

Suman BC, Sharma VP. 2007. Uses of mushrooms. In: Suman BC, Sharmas VP (eds.). Mushroom Cultivation and Uses. Daya Publishing House, Delhi, India.

Thatoi H, Singdevsachan SK. 2014. Diversity, nutritional composition and medicinal potential of Indian mushrooms: A review. Afr J of Biotech 13(4): 523-545.

UNFAOSTAT. 2011. United Nations, Food and Agriculture Organization Statistics, 2011. http: //faostat.fao.org/default.aspx. [14-01-2014]

Wang XM, Zhang J, Wu LH, Zhao YL, Li T, Li JQ, Wang YZ, Liu HG. 2014. A mini-review of chemical composition and nutritional value of edible wild-grown mushroom from China. Food Chem 151: 279-285.

Waseer SP. 2010. Medicinal mushroom science: History, current status, future trends, and unsolved problems. Int J Med Mush 12 (1): 1-16.

Wasser SP, Nevo E, Sokolov D, Reshetnikov S, Timor-Tismenetsky M. 2000. Dietary supplements from medicinal mushrooms: diversity of types and variety of regulations. Intl J Med Mush 2: 1-19.

Wasser SP, Weis AL. 1999. Medicinal properties of substances occurring in higher Basidiomycetes mushrooms: current perspectives (Review). Int J Med Mush 1: 1-62

Wasser SP. 2011. Current findings, future trends, and unsolved problems in studies of medicinal mushrooms. Appl Microbiol Biotechnol 89 (5): 1323-1332.