हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch

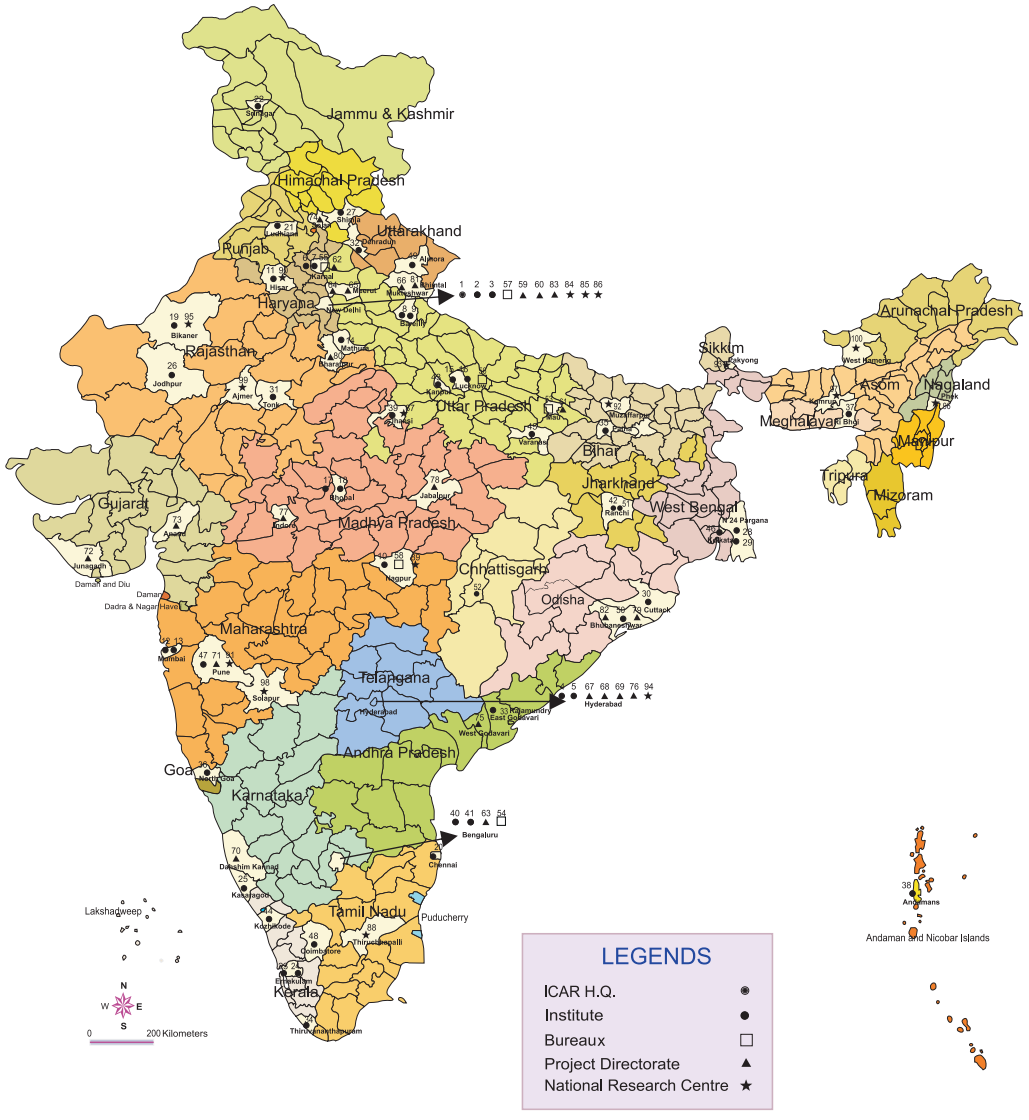
Vision 2050

Directorate of Mushroom Research

Indian Council of Agricultural Research

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Institutes, Bureaux, Directorates and National Research Centres



● 64 Research Institutes ● 6 Bureaux ● 15 National Research Centres ● 15 Project Directorates

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Agricultural Universities

Vision 2050

Directorate of Mushroom Research
(Indian Council of Agricultural Research)
Chambaghat,
Solan (HP) 173 213

www.nrcmushroom.org

Printed : July 2015

संदेश

भारतीय सभ्यता कृषि विकास की एक आधार रही है और आज भी हमारे देश में एक सुदृढ़ कृषि व्यवस्था मौजूद है जिसका राष्ट्रीय सकल घरेलू उत्पाद और रोजगार में प्रमुख योगदान है। ग्रामीण युवाओं का बड़े पैमाने पर, विशेष रूप से शहरी क्षेत्रों में प्रवास होने के बावजूद, देश की लगभग दो-तिहाई आबादी के लिए आजीविका के साधन के रूप में, प्रत्यक्ष या अप्रत्यक्ष, कृषि की भूमिका में कोई बदलाव होने की उम्मीद नहीं की जाती है। अतः खाद्य, पोषण, पर्यावरण, आजीविका सुरक्षा के लिए तथा समावेशी विकास हासिल करने के लिए कृषि क्षेत्र में स्थायी विकास बहुत जरूरी है।

पिछले 50 वर्षों के दौरान हमारे कृषि अनुसंधान द्वारा सृजित की गई प्रौद्योगिकियों से भारतीय कृषि में बदलाव आया है। तथापि, भौतिक रूप से (मृदा, जल, जलवायु), बायोलोजिकल रूप से (जैव विविधता, हॉस्ट-परजीवी संबंध), अनुसंधान एवं शिक्षा में बदलाव के चलते तथा सूचना, ज्ञान और नीति एवं निवेश (जो कृषि उत्पादन को प्रभावित करने वाले कारक हैं) आज भी एक चुनौती बने हुए हैं। उत्पादन के परिवेश में बदलाव हमेशा ही होते आए हैं, परन्तु जिस गति से यह हो रहे हैं, वह एक चिंता का विषय है जो उपयुक्त प्रौद्योगिकी विकल्पों के आधार पर कृषि प्रणाली को और अधिक मजबूत करने की मांग करते हैं।

पिछली प्रवृत्तियों से सबक लेते हुए हम निश्चित रूप से भावी बेहतर कृषि परिदृश्य की कल्पना कर सकते हैं, जिसके लिए हमें विभिन्न तकनीकों और आकलनों के मॉडलों का उपयोग करना होगा तथा भविष्य के लिए एक ब्लूप्रिंट तैयार करना होगा। इसमें कोई संदेह नहीं है कि विज्ञान, प्रौद्योगिकी, सूचना, ज्ञान-जानकारी, सक्षम मानव संसाधन और निवेशों का बढ़ता प्रयोग भावी वृद्धि और विकास के प्रमुख निर्धारक होंगे।

इस संदर्भ में, भारतीय कृषि अनुसंधान परिषद के संस्थानों के लिए विजन-2050 की रूपरेखा तैयार की गई है। यह आशा की जाती है कि वर्तमान और उभरते परिदृश्य का बेहतर रूप से किया गया मूल्यांकन, मौजूदा नए अवसर और कृषि क्षेत्र की स्थायी वृद्धि और विकास के लिए आगामी दशकों हेतु प्रासंगिक अनुसंधान संबंधी मुद्दे तथा कार्यनीतिक फ्रेमवर्क काफी उपयोगी साबित होंगे।

(राधा मोहन सिंह)

केन्द्रीय कृषि मंत्री, भारत सरकार

Foreword

Indian Council of Agricultural Research, since inception in the year 1929, is spearheading national programmes on agricultural research, higher education and frontline extension through a network of Research Institutes, Agricultural Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras to develop and demonstrate new technologies, as also to develop competent human resource for strengthening agriculture in all its dimensions, in the country. The science and technology-led development in agriculture has resulted in manifold enhancement in productivity and production of different crops and commodities to match the pace of growth in food demand.

Agricultural production environment, being a dynamic entity, has kept evolving continuously. The present phase of changes being encountered by the agricultural sector, such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new pest and diseases, fragmentation of farms, rural-urban migration, coupled with new IPRs and trade regulations, are some of the new challenges.

These changes impacting agriculture call for a paradigm shift in our research approach. We have to harness the potential of modern science, encourage innovations in technology generation, and provide for an enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy, and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive. Our institutions of agricultural research and education must attain the highest levels of excellence in development of technologies and competent human resource to effectively deal with the changing scenario of Directorate of Mushroom Research (DMR), Solan (HP).

Vision-2050 document of ICAR-Directorate of Mushroom Research (ICAR-DMR), Solan has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

We are hopeful that in the years ahead, Vision-2050 would prove to be valuable in guiding our efforts in agricultural R&D and also for the young scientists who would shoulder the responsibility to generate farm technologies in future for food, nutrition, livelihood and environmental security of the billion plus population of the country, for all times to come.

(S. AYYAPPAN)
Secretary, Department of Agricultural Research & Education (DARE)
and Director-General, Indian Council of Agricultural Research (ICAR)
Krishi Bhavan, Dr Rajendra Prasad Road,
New Delhi 110 001

Preface

In the coming days, in addition to food security there will be emphasis on health foods and mushrooms will be an important component of food basket. India has achieved food security and produced over 250 million tonnes of food grains in 2014-15. However, our struggle for nutritional security is still on. During coming decades, the increasing population, depleting agricultural land, deterioting environment, water shortage and demand for quality food are going to be the vital issues. To meet these challenges, it is important to diversify agricultural activities. Mushroom cultivation recycles agro-residues, much of which is otherwise burnt in the field. In changing agricultural scenario, secondary agriculture is going to play a pivotal role and mushroom fits very well in this category. Our country can emerge as a major player in mushroom production utilizing available abundant agricultural residues. Mushroom being an indoor crop, utilizes vertical space and requires only 25-30 litre water for production of one kg mushroom, thus offering a solution to shrinking agricultural land and water. The modern technologies like bioinformatics, proteomics, functional genomics, etc., will help us in cataloguing, understanding and exploiting our genetic resources. The present document includes the present scenario and future roadmap for harnessing science to promote this important commodity.

The cultivation of mushrooms is relatively a new phenomenon and has picked up across the globe only during last century. The annual world production of button mushroom has reached 6.5 million tonnes and that of all types of mushrooms is estimated to be over 27 million tonnes. Our country has registered twenty-fold increase in production of mushrooms in the last four decades and still our production is only 1.2 lakh tonnes. Button mushroom continues to occupy a prominent place and contributes about 80% of the total mushroom production of our country. Majority of contribution is by environment controlled units and about 15% button mushroom is produced by seasonal growers.

With rapid urbanization and increased production of agro-residues along with increased food production, there will be a need to radically change the way we look at agriculture. High-tech agriculture including mechanized mushroom cultivation under controlled conditions is going to gain importance in coming decades. Mushroom production in the world has increased rapidly in the last few decades and the trend is

likely to pickup in our country as well. Continuous skill-upgradation of human resources will be indispensable to keep pace and to move ahead in R&D. There is need for awareness generation and it is important to establish farm models in value chain format and communication models for generating awareness about mushrooms.

ICAR-Directorate of Mushroom Research initially named as National Centre for Mushroom Research and Training (NCMRT) was established in 1983 under the aegis of Indian Council of Agricultural Research. This Directorate is the only institute exclusively dedicated to mushroom research and development in the country. The Directorate has developed array of technologies for cultivation of different mushrooms suited to various agro-climatic regions of the country. The Directorate is also the headquarter of All India Coordinated Research Project (AICRP) on Mushroom with 24 Coordinating and 7 Cooperating Centres located in 22 states and 1 union territory.

The Vision 2050 has been prepared with the objective of promoting mushroom cultivation as an agro-industry as well as a component of farming system for addressing the issues like nutritional security, unemployment, environmental sustainability, total recycling of agri-residues, etc. The document deals with likely challenges and strategies to meet these objectives.

I would like to thank Dr. S. Ayyappan, Secretary (DARE) & DG (ICAR) for envisioning the preparation of this document in present form and guiding from time to time. I would like to place on record our gratitude for the encouragement received from Dr. N. K. Krishna Kumar, DDG (Hort.). I would like to thank all my colleagues presently working at ICAR-DMR and those who have been transferred/retired from the Directorate after extending their meritorious services for their contributions.

Director
ICAR-DMR, Solan

Contents

Context

The agriculture by 2050 will be an industry requiring precise information and specific protocols. The tomorrow's agriculture will require complete recycling of nutrients, water and agro-wastes. The increasing population, decreasing per capita arable land, urbanization and industrialization, changes in climate, demand for quality and functional foods, etc. will necessitate us to focus on secondary agriculture and novel crops like mushroom.

Diversification in any farming system imparts sustainability and mushrooms are one such component. Commercial production of edible mushrooms represents unique exploitation of the microbial technology for the bioconversion of the agricultural, industrial, forestry and horticultural wastes into nutritious food. India produces around 700 million tonnes crop residues, a good proportion of that can profitably be utilized for mushroom cultivation. Currently, we are using only 0.03% of these residues for producing around 1.2 lakh tonnes of mushrooms resulting in less than 1% of the total world mushroom production. Even if by 2050 we use 2% of the total agro-residues for mushroom production coupled with enhanced productivity, we can produce around 15.0 million tonnes of fresh mushroom, which will be more than double of the current global button mushroom production.

China cultivates around 60 different types of mushrooms and

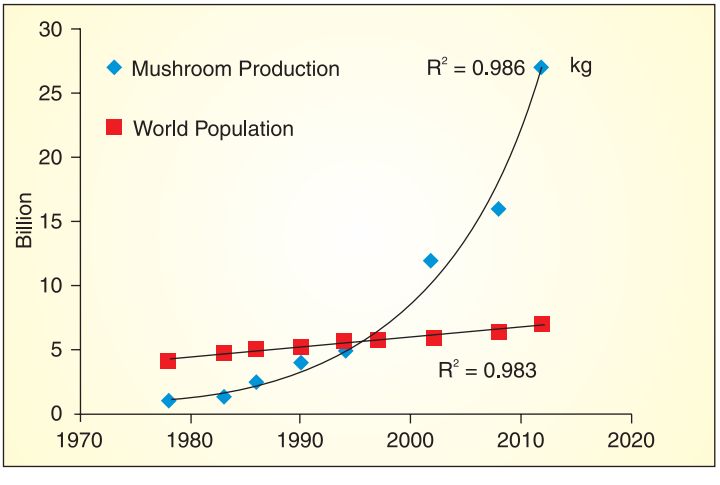


Fig. 1 Mushroom production trend of the World

accounts for 80% of the total world mushroom production (Mushroom Science, XVIII, 2012). There has been exponential increase in mushroom production in last 2-3 decades (Fig. 1). In addition to edible mushroom, the medicinal mushrooms have also gained importance (Fig. 2). Contrary to that, in India we cultivate only four mushrooms on commercial scale. At global level 6 mushrooms contribute 90% of world mushroom production (Fig. 3). Of these we cultivate only three viz., Button, oyster and *Volvariella*. The fourth mushroom under cultivation is milky mushroom.

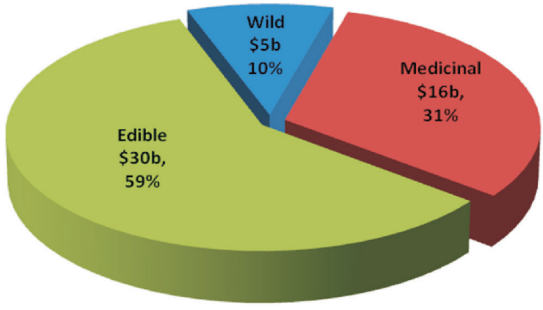


Fig. 2 World Mushroom Industry ($51 Billion USD)

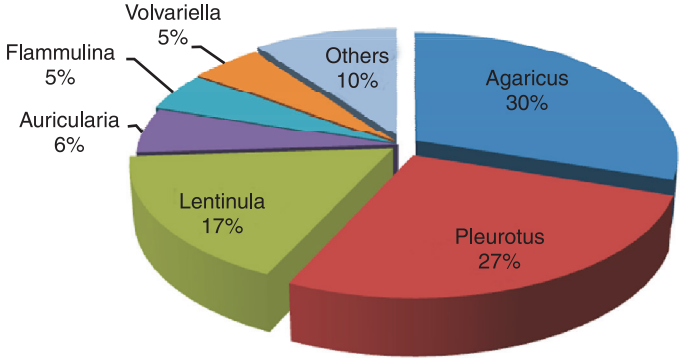
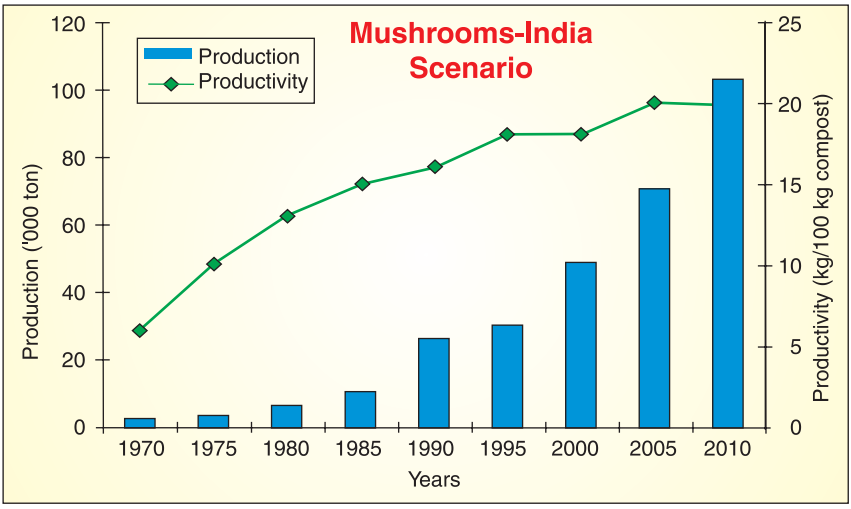


Fig. 3 Share of different mushroom in global production

Mushrooms are considered to be the highest producer of protein per unit area and time. Water requirement for mushroom cultivation is far less (25 litres per kg fresh mushrooms) than field crops as they are cultivated indoors. This implies that mushroom has the potential of being a major crop in coming years.



Button Mushroom production and productivity in the country

Button	Oyester	Milky	Paddy Straw, etc	Total Production
1,00,700	6,400	900	10,300	1,18,300

Total Mushroom Production in the Country

Fig. 4 Mushroom production in India

Button mushroom production in the country started in the 70s and growth rate, both in terms of productivity as well as production was slow in initial years, but has become exponential in last few years (Fig. 4). In seventies and eighties, button mushroom was grown as a seasonal crop in hills, but with the development of the technologies for environment control and increased understanding of the cropping systems, button mushroom production has shot up from 5000 tonnes in seventies to the current production of over one lakh tonnes. In India, the mushroom production systems are of two type i.e. both seasonal as well as high-tech cultivation. Many small and medium scale units have come up in Punjab, Maharashtra, Gujarat, Tamil Nadu, Andhra Pradesh, Uttarakhand, Goa, Haryana and other parts of the country that contribute about 85% of button mushroom production. The remaining 15% is contributed by seasonal growers.

Oyster, milky and paddy straw mushroom have simple cultivation technology and are being cultivated mostly seasonally in different regions of the country. These mushrooms do not require much infrastructure and can be cultivated using varied agro-residues. The cultivation methods

for temperate/sub-tropical/tropical mushrooms and others like *Macrocybe, Lentinula, Flammulina, Auricularia, Agrocybe, Stropharia, Hericium, Ganoderma*, etc. have been developed by the Directorate and can be adopted at commercial level. Integrating mushroom cultivation in the existing farming systems will supplement the income of the farmers and promote proper recycling of agro-residues. The use of spent mushroom substrate as organic manure will improve soil health and promote organic agriculture. Besides, mushrooms can contribute in achieving nutritional and social security in the country.

Marketing of mushrooms in India is not well organized; the export-oriented units have devised their own individual arrangement for marketing. To enable this commodity to become globally competitive, a long-term strategy has to be evolved to lower the production cost and cultivation following globally accepted good agricultural practices, together with higher productivity and processing facility for marketing. As India itself is a big market, vigorous extension activities are required to make the people aware of benefits of mushrooms, which will help in developing market within the country. Greater emphasis in coming decades will be required on market intelligence and information, genetic resource conservation and strain development, basic studies on molecular mechanism of lignocelluloses conversion, role in ecosystem balancing, role in carbon credit management post harvest management and value addition, mushroom quality and safety standards, capacity building, gender equity and environment safety.

The availability of labour component is becoming crucial in mushroom industry. Mechanization can play a major role in sustainability of the industry. Presently, most of the commercial units are depending on European countries for mechanization as indigenous machineries are not available. To sustain the Indian mushroom industry there is an urgent need to focus on mechanization in mushroom industry for button, oyster and other mushrooms.

The loss of mushroom biodiversity due to rapid deforestation, overexploitation, urbanization and other changes across the globe is a major concern. Inappropriate disposal of agro-wastes like burning of paddy straw in many parts of the country is counter productive from environmental, ecological and economic point of view (in Punjab out of 23 MT paddy straw generated in 2012, over 20 million tonnes was burnt just to clear the fields for in time sowing of next crop).

Mushroom cultivation is a promising vocation to address these challenges and hence there is a need for concerted efforts on recycling of agro-wastes with a major emphasis on mushroom cultivation. The

material left after cultivating mushrooms can be ploughed back in to the soil that can play an important role in improving the soil health and crop productivity. The basic research on use of agri-residues to produce biofuels, production of novel compounds with various applications, production of nanoparticles using macrofungi, commercial production of enzymes, systematic degradation of agri-residues for various agricultural and commercial applications are some of the associated sectors that are likely to grow along with mushrooms.

❑

Challenges

Conserving Biodiversity

Biodiversity is depleting fast due to deforestation, urbanization, climate change, natural hazards and extensive unsystematic exploitation through collection of wild mushrooms for food and trade. Some species, particularly the mycorrhizal and medicinally important mushrooms are facing extinction. Hence, there is an urgent need to collect and conserve this biodiversity.

Characterizing Biodiversity

Periodic collections of indigenous mushroom diversity from various climatic zones of the country and their genetic characterization for wider gene pool and novelty will be necessary for genetic improvement of cultivated mushrooms and future exploitation of industrially/medicinally important compounds. With increasing number of duplicates, loss in vigour due to repeated sub-culturing, narrow genetic base in some species, it is a challenge to characterize the available collections and develop strategies for maintenance and enhancement.

Understanding Biodiversity

Mycelial mats for specific compounds – multiplication in fermenters can help in commercializing mushroom products

Mushroom fruit body formation is induced by specific changes in environmental conditions like temperature, carbon dioxide, relative humidity, pH, light, nutrient balance, etc. But the conditions required differ with different mushroom species depending upon their pattern of life cycle and sexuality. Inadequate understanding of the biology of mushrooms is the greatest limitation not only in improving the yield of the commercial types but also in domesticating the newer ones.

Exploiting Biodiversity

There are number of edible fungi that are still being collected from the forest for human consumption and research is required to domesticate new species. There is a need for developing superior strains of cultivated mushrooms using available germplasm. Alternatively systems have to

be developed for commercial/industrial scale mycelia multiplication for extracting industrial/medicinal important metabolites/compounds.

Mushroom diversification

India is largely a tropical country and we mainly cultivate temperate mushroom (*Agaricus bisporus*). The tropical and sub-tropical mushrooms like oyster (*Pleurotus* spp.), paddy straw (*Volvariella* spp.), milky (*Calocybe* sp.), wood ear (*Auricularia* spp.), etc. are not cultivated on a larger scale. Round the year cultivation of different mushrooms depending on their temperature requirements assumes significance especially for rural livelihood security and women empowerment through crop diversification.

Commercializing Technologies

Button mushroom: In view of the fast rate of growth in the mushroom industry, a rapid technological change is also envisaged. For environment controlled growing, a fully automated mushroom farm controlled and monitored from a central point may become a reality in near future. Forecasting of crop-yield in advance will enable the monitoring unit to employ corrective measures in advance. Also, the post-harvest handling of the produce needs to be done automatically without human interference. All these automations will drastically curtail the requirement of manpower.

Oyster mushroom: Cultivation of oyster mushroom in the tropical and sub-tropical regions has tremendous potential, which is yet to be fully harnessed. Research support to improve the cultivation technology for sustainable yield of quality produce is very much needed. Diversification also has great scope in this mushroom, as species vary in their temperature and substrate requirements for growth and quality of fruit bodies. New species like king oyster, *Pleurotus nebrodensis* have shown a sharp increase in production in last few years. Mechanized models for commercial cultivation of oyster are available. In near future changes in such units as per our needs may lead to large scale production of this genera.

Paddy straw mushroom: Potential of this mushroom remains under exploited despite abundant availability of paddy straw and highly suited environmental conditions in eastern and southern India especially in the coastal region. Adopting indoor cultivation technology using alternative

Cultivation of mushrooms like *Morchella, Cordyceps, Podaxis, Tuber, Phellorina* mushroom is a challenge and requires modern techniques including balanced nutrition through hydroponics or similar systems

agro-residues is the need of the time to scale up its production at industrial level. Post harvest processing is another issue which needs immediate attention of the researchers as well as the policy makers.

Propagating Quality Planting Material (Spawn)

Development of spawn standards, commercial production and availability in all parts is a pre-requisite for growth of mushroom cultivation

Spawn, which acts as the `starter' or seed, is the most crucial input for successful cultivation of mushrooms. Therefore, its genetic and physical purity and quality needs to be maintained to the highest level. During the last century a number of substrates and containers have been tried for production of spawn of different kinds of mushrooms. The technology has already assumed the standard of a full-fledged industry in several countries, where spawn is produced in large quantities under completely aseptic conditions, packed in contamination free sealed packets with micro-filters and transported throughout the world. However, in India, the spawn industry is an un-organized venture and needs research support in the years to come so that it may attain quality standards and competitiveness comparable to multi-national companies. Also, there should be collaborations between the research institutes and the upcoming spawn industry so that the much needed genetic purity and quality of spawn is ensured.

Utilizing Spent Mushroom Substrate

Need for innovative utilization methods to make mushroom a zero waste industry

Mushroom growing is an eco-friendly activity as it utilizes the byproducts from agriculture, poultry, brewery, etc. and in turn produces a quality food with excellent and unique nutritional as well as medicinal attributes. The spent mushroom substrate (SMS) left after final crop harvest is a matter of concern as it creates various environmental problems including ground water contamination and nuisance if not handled properly. As mushroom production is increasing, so is the SMS generation, which calls for its efficient management and use as manure for horticulture and field crops, land filling, bioremediation and source of fuel and feed.

Integrated Pest Management

Diseases caused by biotic and abiotic agents are quite common in seasonal farms especially those using unpasteurized compost. However, the incidence of diseases and competitors is relatively less in environment controlled units.

Bio-sensors for detecting pathogenic microbes, hygiene standards and bio-control agents may play more important role in IPM of tomorrow

Postharvest Technology

Increased productivity demands proper post harvest infrastructure to enhance shelf life and marketability. Mushrooms are delicate and highly perishable in nature. Short shelf life of mushroom poses unique problems in packaging, marketing and preservation. In developed countries, `state of the art' technology is in practice like modified atmosphere packaging (MAP) or controlled atmosphere packaging (CAP). However, in our country, the retail packaging for fresh marketing is highly crude and is done in hand sealed polypropylene bags or punnets. Similarly, canning for button mushroom and sun drying for other mushrooms are the most common methods of preservation employed in India.

In coming days we may require Mushroom flavours, Designer mushrooms for meeting the need of health basket and novel compounds from mushrooms

Transfer of Technology - Utilizing Information Technology

Use of Information technology in various sectors including mushroom information technology is well validated. It will prove an effective tool for transfer of technology. The challenge is to synchronize the available information with the common needs of entrepreneurs. This will require greater understanding of the needs of farmers, entrepreneurs and industrialists involved in supply of raw materials, machinery, mushroom production, value addition, processing, marketing, etc.

Models for awareness generation are necessary to promote consumption along with farm models in value chain format to enhance production

Operating Environment

Mushroom research in India started in 60s in the states of Himachal Pradesh and J&K and remained confined to these states with focus on white button mushroom only. Later, a National Seminar on research, production, processing and marketing of mushrooms was organized by the ICAR on January 21-22, 1979, which was inaugurated by the then Prime Minister Sh. Morarji Desai and presided over by Sh. Surjit Singh Barnala, Union Minister of Agriculture & Irrigation. During this seminar it was recommended to establish a National Research Centre on Mushroom and to strengthen mushroom research under coordinated programmes. As a result National Centre for Mushroom Research & Training as well as All India Coordinated Mushroom Improvement Project was sanctioned in VI Five Year Plan. NCMRT became operational at Chambaghat, Solan in June, 1983. It was renamed as National Research Centre for Mushroom in 1997 and upgraded to Directorate of Mushroom Research in December 2008. In last few decades both production and productivity has increased, diversification in mushroom has taken place and mushroom cultivation has spread throughout the country. Let us have a look at the current environment and future scenario in our biological and human resources, energy, etc.:

1. **Natural resources:** Due to industrialization, urbanization and population growth, there will be shrinkage of arable land and availability of natural resources will be a limiting factor. Mushrooms do not compete for arable land and can utilize vertical space, hence this commodity is required to be promoted among the masses. Moreover, the water requirement of this crop is meager in comparison to field crops. Being an indoor crop the effects of global warming may be lesser on mushroom production as well as productivity. We foresee a sea change in mushroom growth in the coming decades that will generate employment opportunities in addition to providing quality food.
2. **Raw material:** In the coming decades, agricultural residues are bound to increase and need to be recycled /utilized judiciously. Burning of residues or their *in situ* decomposition is not the right strategy as it is creating environmental hazards leading to deterioration of human and soil health. Utilization of agro-residues for mushroom production will not only help to reduce the environmental pollution

but will profitably recycle them into quality food, besides improving soil health due to recycling of spent mushroom substrate.

3. **Labour:** Mushroom cultivation is a labour intensive activity and will provide ample employment opportunity in the coming decades. The future decades will however, see a shift towards use of machinery both by the industry and seasonal growers.
4. **Energy:** In the coming decades, energy may be a limiting factor for various vocations including mushrooms. Hence round the year seasonal cultivation of different mushrooms based upon the prevailing environmental conditions in different regions of the country needs to be popularized. To ensure sustainable production, these activities can be linked with limited use of energy, solar based gadgets and other novel approaches to maximize the use of available energy. This Directorate foresees that alternative sources of energy like solar, wind or SMS based energy will play a major role in meeting the growing demand of energy in environment controlled mushroom cultivation units. Chilling stations based on these alternative sources of energy will have to be developed and popularized.
5. **Human resource:** To meet the challenges posed by advanced countries including China, human resource may remain a constraint. Constant and upgraded research is required at various facets of mushrooms to increase their productivity and quality. The competitive market, brain drain, need for precise technology, food standards, export restrictions, etc. are some of the issues that need attention.
6. **Depleting biodiversity:** Increasing deforestation and unplanned collection of wild mushrooms like *Morchella*, *Cordyceps*, etc. is leading to rapid depletion of mushroom diversity and in extreme cases may lead to their extinction in the decades to come. Proper publication and scientific approaches are needed to check this loss.
7. **Food habits:** As mushrooms are rich source of proteins, minerals, nutraceuticals, vitamins, etc. these can help in meeting the protein gap. FAO has also recommended mushrooms as an alternative protein source next to meat and vegetables.

❑

Opportunities

To face the global challenges, all available expertise and resources in the country as well as outside need to be tapped to make Indian mushroom industry competitive in the world market. In this direction strong research and production linkages between research organizations, industries, progressive farmers and other organizations will be needed.

International collaboration can pave the way needed to achieve the objectives set in the programme.

a) Research
b) Policies
c) Development
d) Working environment
e) Infrastructure
f) Labour
g) Raw material/climatic conditions etc.

To keep pace with the advancement in spawn production technology, we may have to develop linkages with some multi-national spawn producing companies like Sylvan Spawn Laboratory, USA; Amycel, US; Campbell's Fresh, Canada, etc. Similar linkages with companies in China, Korea, etc. may be required for liquid spawn technology and machinery for various tropical mushroom.

Besides the discipline-oriented programmes, inter-disciplinary research will be the hall-mark of the future research. The growth of mushroom sector will imply that basic and strategic research will be the main responsibility of the Directorate whereas private sector may play an important role in applied research and commercialization of technologies. So far as the assessment of location specific technologies are concerned, the AICRP may continue to play its role; with possibilities of private sector as collaborators. It is expected that mushroom growing will spread far and wide in the country.

❑

Goals and Targets

To achieve the Vision of Mushroom revolution for economic growth, ecological sustainability and nutritional security, and also models for total recycling of agriculture and other product from the waste, it is important:

- To collect and conserve mushroom biodiversity as bio-resource for food, feed, fuel, afforestation, medicine and novel compounds
- To promote mushroom cultivation in the country including integrating mushroom farming with traditional farming systems and also promoting mushroom as an industrial activity
- To recycle agro-residues through mushroom production and use of spent mushroom substrate in re-growing of mushrooms, as organic manure for field crops, plant diseases management, animal feed, fuel and environment management
- To generate technologies for novel application of macrofungi to produce enzymes, novel compounds, nanoparticles, etc. and also for ameliorating poverty through self-employment and to ensure socio-economic as well as nutritional security

The share of the button mushroom is bound to decline with more and more specialty mushrooms becoming available for seasonal or industrial scale cultivation. With the increased production, an organized mushroom marketing channel is bound to get established. A significant quantity of mushroom is likely to be utilized for production and consumption of the value-added products.

Mushroom cultivation system will be designed and directed towards complete recycling of the agro-residues for production of food (mushroom), medicines, novel compounds, feed (cattle feed), fuel (biogas, bioethanol), fertilizer (organic manure) and environment management. With the proposed thrusts directed towards research on the development of the genetically improved strains and the production technologies, we do visualize lesser dependence on the imported strains and technologies. In fact, we may be able to lead and help Africa and other underdeveloped countries.

A sustained growth in mushroom productivity will depend on regular genetic improvement and management of biotic and abiotic stresses. India has diverse agro-climatic regions and is rich in mushroom diversity. Bio-prospecting will lay the foundation for effective allele

mining. The vast gene pool available needs to be explored and utilized for genetic enhancement of cultivated mushrooms and for identifying as well as mass production of industrial/medicinally important components. Hi-tech mushroom cultivation and processing will require higher degree of mechanization in the wake of increased labour and raw material costs. 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, yielding real gainful employment throughout the year to the poorest of the poor.

Undoubtedly, it will require tremendous efforts on all aspects of the research as well as developmental policies and programmes like improvement in the strains, production technology including the IPM, vigorous efforts on the transfer of technology, deployment of greater financial and human resources with policy for their skill up-gradation. Such efforts shall not only be capital- and knowledge-intensive, but also shall warrant strong Public-Public and Public-Private Partnerships. Interactions between research institutions and the mushroom farmers/ industry need to be strengthened for realizing the full potential of the frontier sciences.

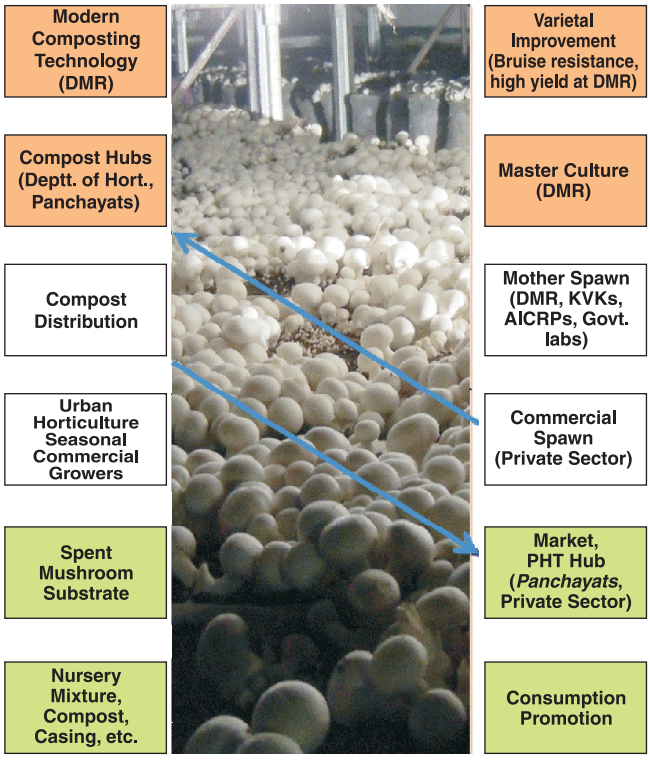
The salient functions of Research organization will be:

- To act as the repository of mushroom germplasm and information
- To work on all aspects of basic and applied research leading to higher productivity, better IPM and post harvest care of different mushrooms
- To coordinate network research on location specific problems to achieve higher productivity
- To promote human resource development and transfer of technology and to provide technical support to the mushroom industry

The goal is not only to increase mushroom production or increase utilization of agrowaste, but the target is to make mushroom as an integral component of food basket. It will require mushroom diversification where we have to exploit medicinal and mycorrhizal mushrooms as well. Holistic mushroom based farming systems will mean employment generation and women empowerment. We see a dominant place for Mushrooms in urban and peri-urban horticulture.

To meet the targets there is need for synchronized efforts by policy makers, researchers, industry and farmers. We need policies for energy availability, marketing, infrastructure development, research in basic sciences, support from industry in applied part and above all farmers. There is need to create compost and spawn production hubs,

develop better strains and technologies and motivate people or farmers organization/self help groups/NGOs one such schematic flowchart given below:



A model for promoting better mushroom production in the country

Way Forward

While research establishments are mandated to provide research and technical inputs, development is an area where other organizations are also required to play their part. Some key developmental programmes, which require due attentions in coming years in our country are the following:

- Monitoring the establishment of spawn units in public and private sectors, and enforcing spawn standards and fair price
- Establishment of compost mother units for supply of quality compost to the small growers in potential areas
- Supply of spawn run substrates in urban and peri-urban areas for kitchen garden cultivation of mushrooms
- Involvement of cooperatives and other marketing organizations for providing the required inputs as well as help in viable marketing of mushrooms
- Ensuring liberal financial support by the government agencies and financial institutions
- Ensuring minimum support-price for mushrooms and provisions for insurance coverage
- Active campaign and awareness programmes to boost the domestic demand for mushrooms through advertisements, articles and films, etc.

In order to meet the challenges, the following activities are envisaged towards profitable and sustainable mushroom farming in India. The strategy will be to:

i) Conserve Biodiversity

- Development of mushroom atlas depicting available mushroom biodiversity of the country with passport data. Integrating information into serial publications `Mushroom Wealth of India'. Preparation of a 'Red-Data List' of endangered mushroom species and their conservation.
- Strengthening facilities in research organizations for safe-deposit and retrieval of cultures, using long term preservation techniques like cryopreservation and lyophilization.

ii) Characterize Biodiversity

- Genetic diversity analysis and characterization of germplasm particularly of edible/commercially important mushrooms using morphological, biochemical and molecular markers.
- Confirmation of accessions for their purity using biotechnological tools
- Cataloguing of the available germplasm into different groups based upon their utility, be it for edible mushroom cultivation, pharmaceutical, waste management, environment management, afforestation, mycorrhizal, etc.
- Developing mushroom biodiversity gardens in forest for *in situ* conservation of mycorrhizic mushrooms for agri-tourism and studies of biology.

iii) Understand Biodiversity

- Understanding sexuality patterns of different mushrooms and identification of mating type genes
- Cloning and sequencing of mating type genes, allele mining, genome sequencing, gene mapping, creation of gene libraries and genetic maps of commercially important mushrooms
- Understanding structural and functional genomics using advanced molecular techniques of cDNA, AFLP, ESTs and microarrays
- Understanding the molecular mechanism of biodegradation of lignocellulosic compounds by different mushrooms
- Identification of markers for poisonous mushrooms spp.

iv) Exploit Biodiversity

Exploitation of mushroom biodiversity is needed for the improvement of commercially available edible mushrooms besides the introduction of new suitable mushrooms from wild. Similar improvement may be needed in medicinal mushroom to enhance output of active compounds. The improvement required in white button mushroom will need:

- Development of high yielding hybrids for controlled environment and partially controlled environment units
- Development of transgenics for improved quality, shelf-life, diseases/ insect pest resistance (like bubble diseases, yellow mould, viruses, etc.) and stress tolerance
- Identification and characterization of bioactive molecules of industrial/medicinal importance
- Development of high temperature tolerant button mushroom variety

- Identification of additional *Agaricus* species for cultivation and their genetic improvement
- Molecular profiling of varieties developed and released by DMR
- Identification of quantitative trait loci (QTLs) for yield and other traits and MAS in mushroom breeding
- Development of high yielding hybrids of *A. bitorquis* resistant to false truffle
- Development of somatic hybrids between *A. bisporus* and other *Agaricus* species by protoplast fusion

In oyster mushroom improvement is required in yield, shelf-life, quality and other nutraceutical properties. It will require research in the following areas:

- Techniques for rapid single spore isolation and inter-mating for inter and intra-specific hybrids
- Protoplast fusion between closely related species to incorporate the desirable traits like fruit body size, colour, flavour and texture into the high yielding types
- Breeding spore deficient/low spore strains/ Lovastatin and vitamin D rich hybrids with better quality and higher yield
- Breeding varieties for disease/pest resistance and amenability to processing

The major breeding objectives of paddy straw mushroom will be:

- Development of strains/hybrids having white colour, high yield, better quality and shelf life
- Protoplast fusion for production of somatic hybrids between closely related species
- Development of low temperature requiring strains for their cultivation during winter season and storage under refrigerated conditions for shelf life improvement
- Breeding varieties deficient of volvotoxin
- Preparation of transgenic varieties with high yield at different temperature regimes with superior shelf life

Breeding work is also required in other mushroom species particularly in *C. indica* for flavour, *L. edodes* for yield and lentinan content, *G. lucidum* for medicinal attributes and other edible and medicinal mushrooms like *Auricularia*, *Flammulina*, *Grifola*, *Hypsizygus*, etc. The main focus shall be on varietal improvement using both conventional and modern approaches involving protoplast fusion and other biotechnological tools.

Commercialize Technologies

Button mushroom: Research to improve the seasonal and environmental controlled cultivation of button mushroom for Indian conditions may be required in the following areas during the coming decades.

a) Seasonal farming

- Zero energy passive aeration based improved composting technology for button mushroom
- Microbial stimulants and enzymes for accelerated and improved composting
- Development of compost formulations for different parts of the country keeping in view the cost and availability of raw materials
- Non-chemical methods of pasteurization using physical processes like solarization, sonic bombardments, microwaves, etc
- Development and improvement in the design of low cost growing houses for optimum yields

b) Environment controlled farming

- Shortening composting period by total indoor/single phase composting by use of enzymes and microbial stimulants for unexploited low cost easily available agro-wastes.
- Development of `environment-friendly' composting process – use of biofilters to eliminate emission of undesirable gases; restricted use of chicken manure in dried and odour free form
- Search for newer and improved casing materials, which may be made into ready to use thin sheets or rolls for easy and uniform application
- Better environment management using solar energy for improvements in yield and quality, introduction of cheaper but more efficient and grower-friendly control systems
- Introduction of mechanization and automation, as in the years to come labour will become costlier. Mechanical or robotic harvesting together with single flushing or reduced flushing strains will be common
- Designs for small, medium and large integrated as well as specialized units for composting, processing and spawn production
- The technique for hydroponics for rare edible and medicinal mushroom to be developed.

Sequential degradation of raw materials using different mushrooms will help to utilize wide variety of agrowastes.

- Mechanization and automation at various stages of substrate development, mushroom production and processing.

Oyster mushroom: Cultivation of oyster mushroom in the tropical and sub-tropical regions has tremendous potential, which is yet to be fully harnessed. However, research support to improve the cultivation technology for a sustainable yield of quality produce is very much needed, particularly in the following areas:

- Efficient low-cost region-specific growing systems for seasonal and round-the-year commercial cultivation
- Bringing newer species like king oyster, blue oyster, Kabul dhingri under domestication
- Yield optimization by methods like improved substrate preparation, supplementation, environment control, etc, to increase its profitability
- Promoting oyster mushroom by developing ready-to-use kits/ fully spawn run blocks in urban, peri-urban and unexplored areas; use of liquid spawn technology
- Promotion of mechanized farming with controlled conditions.
- Use of spent straw/substrate for recycling as manure or cattle feed
- IPM in oyster mushroom for stable yields

Paddy straw mushroom: Potential of this mushroom remains under exploited despite abundant availability of paddy straw and highly suited environmental conditions in eastern and southern India especially the coastal region.

- Efforts are needed to improve the existing technology for consistent and higher yields
- Technology for its indoor commercial cultivation under controlled conditions besides small-scale seasonal outdoor cultivation
- Integrated disease and pest management strategy for consistent yield
- Utilization of SMS for white button mushroom casing and vermicomposting
- Developing technology for integrated farming with maize and other tropical crops

Specialty mushrooms

- Commercialization of *L. edodes* (shiitake) and *Auricularia* spp. (wood ear mushroom) in the country
- Promotion of milky mushroom (*Calocybe indica*) in unexplored areas
- Popularization of specialty mushrooms like *Macrocybe giganteum, Stropharia rugoso-annulata* (giant mushroom), *Flammulina velutipes*, *F.fennae* (winter mushroom), *Pholiota nameko, Agrocybe aegerita,*

Macrolepiota procera, etc. with complete package of practices for commercial cultivation

- Identification and characterization of new mycomolecules using sophisticated technologies like LC-MS, GCMS
- Studies on biology and cultivation technology for other prized mushrooms like *Cordyceps, Morchella, Tuber* spp., *Podaxis* spp., *Termitomyces* spp., *Boletus* spp. *Rhizopogon* sp etc
- Promotion of medicinal mushrooms like *G. lucidum* and *Grifola frondosa* (Maitake) is required considering the national/international market
- *Morchella* spp. and *Cordyceps* must be given serious attention for cultivation in India, in view of the wild germplasm available in the country and an established market for Indian morels abroad

Propagate Quality Planting Material (Spawn)

- Development of mushroom spawn standards
- Development of liquid spawn technology for all the cultivated mushrooms
- Development of technologies (carriers and containers) to prolong the viability, shelf life and ease in bulk transport of the ready-to-use spawn
- Private sector to be encouraged for the mass production of quality spawn at local level
- Development of suitable machineries for quality spawn production for seasonal growing and development of technologies for the hi-tech spawn units for controlled environment farming
- Development and enforcement of spawn standards in the country
- Development of alternative spawn substrate sterilization technique for producing quality spawn to lower the cost of spawn preparation

Under rural development programme, emphasis will be given to use polyhouse/green house mushroom cultivation with suitable mechanization to augment the production of tropical and sub-tropical mushrooms. The farmers will be encouraged to form cooperatives at the Panchayat level to promote mushroom cultivation by preparing their own spawn and compost/substrate, processing and marketing as a cottage industry.

Utilize Spent Mushroom Substrate

SMS 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 rates that help in retaining its quality as an organic matter. Efficient utilization of SMS will require:

- Use of microbes and other organisms for converting the spent substrate into casing material, manure or products for bioremediation
- Use of SMS as feed and fuel (briquettes, bio-gas, bio-fuel, etc.)
- Use of decomposed SMS for preparing vermicompost
- Development of technology for use of SMS as carrier for biofertilizers, biocontrol agent and for enzyme extraction
- Development of technology for reuse of SMS for preparing compost for button mushroom and cultivation of other mushrooms
- Reuse of SMS for bioremediation of contaminated soils and water purification

Integrated Pest Management

- Development of area-specific disease maps for various mushrooms and histopathological studies on different mycoparasites
- Epidemiological studies on new competitors and parasitic moulds, bacterial and viral diseases
- Development of molecular diagnostic tools against major diseases and insect-pests
- Integrated pest and disease management packages for major mushrooms
- Investigations on mushroom viruses and development of diagnostics and vaccines against important mushroom viruses
- Use of botanical pesticides, bio-control-agents and virulent strains of pathogens to control diseases and pests of mushrooms
- Residual toxicity of chemicals used by the mushroom industry
- Identification and use of environmentally safe bio-pesticides including chitin synthesis inhibitors, growth regulators, anti-feedants, EPN and *Bacillus thuringiensis* strains to avoid pesticide residues and development of resistant population/strains
- Development of quick diagnostic methods for detection of nematodes infestation
- Use of insect attractants, repellents, chemosterilants, pheromones, kairomones and genetic control
- Development of biosensors for detection of microbial load

Post harvest Technology

- Low cost drying technology for the domestic and state-of-the-art

technology for international market
- Refinement in modified atmosphere packaging (MAP) and controlled atmosphere packaging (CAP) suiting mushrooms for their increased shelf-life
- Use of recyclable and biodegradable packing material.
- Substitution of tin cans with alternative materials and reduction in blanching losses during canning
- Development of low cost freeze-drying and IQF technologies
- Ready-to-cook recipes, value-addition and product diversification to cover pharmaceutical, cosmetic and fast food industries

Utilize Information Technology

- Development of expert system (ES) for mushroom cultivation, marketing, forecasting and management of insect-pests and diseases
- Development of data bases of input suppliers, entrepreneurs, farmers, market channels and financial institutions
- Development of interactive online-website on mushrooms and establishment of teleconferencing facilities
- On-line connectivity of National Mushroom Library for referencing and dissemination of published information

Transfer of Technology

As per the proposed organizational hierarchy most of the technology will be developed/evaluated at select R&D establishments. DMR being at the apex, a 2-tier system for transfer of technology is envisaged. DMR will act primarily as trainers training centre, where R&D workers from various States and Central Organizations including NGOs will be imparted training in the latest technical know-how on mushrooms, who, in turn, will train the prospective growers and entrepreneurs. DMR will also impart training to personnel from big commercial units and international agencies. The Krishi Vigyan Kendras (KVKs), State Agricultural Universities and State development departments will directly train the growers. DMR may also train the managers and senior technicians to be employed in the big mushroom units. The emphasis for TOT programmes will be on the following aspects:

- Publication and distribution of mushroom literature through print and electronic media
- Adoption of a model village as well as commercial unit for transfer of technology
- Close association with KVKs, state developmental agencies, self-help groups and NGOs for active transfer of mushroom production

technology

- Skill development: Every village should have minimum 10 persons trained in spawn production, cultivation process of mushroom.
- Holding of workshops, conferences and `Mushroom Melas' for interaction of the R&D workers with the industry and growers
- Participation of DMR in Trade Fairs and Farmers Fairs, and creation of awareness about mushrooms through mass media
- Preparation of short documentary films and video-clips on mushrooms for dissemination among the rural/urban masses
- Dissemination of information through internet, mobile and other ICT tools
- Creation of spawn and compost hubs at selected KVKs for popularizing mushroom throughout the country
- Each state should have ample supply of mushroom seed and readymade substrate

Fig. 5 Model for community level mushroom processing centre

HRD is an important instrument to improve the efficiency and capabilities of scientific as well as technical manpower. There is an urgent urge to train scientists and technical personnel in emerging frontier

areas of mushroom research. The Directorate plans to give high priority to this aspect and train DMR scientists in emerging frontier areas of mushroom research. To achieve the objectives set in the vision-2050, the first and foremost requirement is to ensure the availability of scientists and technicians with adequate knowledge and experience in the respective field. Exposure of scientists to modern techniques and advances in the basic research will be a prime component of HRD. Similarly the technicians will also need to be exposed to the hi-tech part of the production technology in countries where climate controlled mechanized cultivation of mushrooms has attained greater heights. Training in some other related agrionic areas like computer automation and informatics may also be essential. The approaches for achieving different goals can be summed up as:

Mushroom popularization and diversification

- Integrating mushrooms into existing farming systems
- Promoting region specific mushroom cultivation (variety) suiting to agro-climatic conditions and developing protocols for GAP.
- Deciphering health and medicinal benefits of different mushrooms in the country
- Development of low cost medium scale models with partial environment control and cultivation of different mushrooms in different seasons.
- Development of food safety standards for fresh, dried and processed mushrooms.

Employment generation and nutritional security

- Development of models for higher productivity with efficient use of infrastructure and natural resources including water
- Promoting cold chain marketing, storage and distribution systems
- Technologies suitable for women, rural and unemployed youths
- Promoting Vitamin-D fortified mushrooms (UV exposed mushrooms)
- Promoting mushroom fortified ready to use products.

Conserve mushroom wealth

- Cataloguing and conservation of wild mushroom germplasm collected and consumed by local inhabitants in different regions of the country
- Identifying species threatened by urbanization, deforestation, overexploitation and climate change and their conservation

- Bringing potential wild mushroom species under cultivation
- Bringing out atlas on mushroom wealth of India and study biodiversity changes in different decades on selected sites

Promote integrated organic farming

- Utilizing locally available substrates for construction of cropping rooms and also as substrate for mushroom cultivation
- Utilizing spent mushroom substrate for making manure, vermi compost or using it as feed/fuel and building material
- Developing models for complete recycling of agricultural residues for small, medium and large farms by integrating mushroom cultivation in different farming systems

Transport, value addition and processing

- Development of technologies for prolonged shelf life and safe transport
- Development of indigenous mushroom products
- Market research for understanding trends in demand and supply
- Development of community level processing units

Improved health and risk management

- Addressing abiotic and biotic stresses through improved technologies including suitable varieties
- Developing region specific technologies for predicting and encountering sudden climate variations affecting mushroom production

Human Resource Development

- Use of ICT and web/mobile based expert system for awareness generation and promotion of mushrooms
- Promoting multi-disciplinarity, capacity building by training state officials, KVK staff, NGOs and entrepreneurs for multiplier effect

Linkages

- Integrating industry for focused research and proper utilization of the output.
- Linkages with other national and international agencies like Medical Colleges. To develop holistic information covering physiological aspects of medicinal mushrooms, biomaterials for mushroom houses, need based softwares, biosafety and biosecurity, mycomolecules, nano particles, biofuels, enzymes, etc.
- CSIR Labs and Nutrition Lab.

Goals	Approach	Performance indicator
Collection, characterization and exploiting the Indian mushroom diversity	• State wise/zone wise collection and cataloguing of wild mushrooms • Conservation in DMR gene bank in culture form • Red data list preparation • Domestication of new mushrooms • Utilization of wild mushroom germplasm for the improvement of different edible mushrooms	• State/zone wise mushroom catalogues and maps • Number of mushrooms conserved in DMR gene bank : 15000 or more • State-wise red data list of mushroom • At least twenty five new mushrooms domesticated • To develop designer mushroom. • 25 per cent improvement in the productivity of edible mushrooms through utilizing indigenous germplasm
Production enhancement of quality spawn	• Development of liquid spawn technologies • Development of spawn standards • Development of technologies for zero level contamination and contaminated spawn to be used for cellulose production and for biocontrol agents. • Creation of spawn hubs at selected KVKs and other line departments	• Technology for liquid spawn • Standards for spawn for different edible mushrooms and of different categories • Spawn production technology with zero level contamination • Five to ten spawn hubs will be developed across the country
Production and productivity improvement of mushroom	• Utilization of more and diverse agro-residues for mushroom production • Development of new varieties for higher yield and better quality in different commercial edible mushrooms • Refinement of production technology for better yield • Diversification of mushroom by popularizing indigenous specialty mushrooms	• A minimum utilization of 4% of the total agro residues produced in the country for mushroom production • Minimum of two varieties in major/ commercial edible mushrooms will be developed. • Number of refined production technologies developed for higher yield. • Production technology for minimum of 5-10 indigenous edible/specialty mushroom will be developed and popularize
Control and management of alarming pest and diseases in major edible mushrooms	• Control measures for wet bubble, yellow mould will be developed through integrated disease management protocol • Control of major pests in common edible mushroom cultivation below ETL • Development of molecular diagnostic tools	• Control measures for wet bubble and yellow mould • Control measures for major insect pests in common edible mushrooms • Molecular tools for early detection of diseases in button mushroom
Reduction of post harvest losses and enhancement of shelf life	• Refinement of MAP, CAP and other technologies to extend the shelf life of mushrooms • Development of new value added products	• Refined MAP and CAP technologies for extended mushroom shelf life • New value added products and ready to eat recipes developed
Promotion of mushroom awareness and capacity building	• Utilization of ICT tools for better mushroom information dissemination • Development of utility oriented databases • Mushroom Cultivation be included for vocational studies. • Conducting and participating in training, workshops, melas and seminars/ conference	• Development of expert system as well as decision support system for different needs • Databases for input suppliers, entrepreneurs, farmers, market channels and financial institutions will be developed • Training, workshops, melas and seminars/ conference conducted and participated

NOTES

NOTES

NOTES

Laser typeset at M/s Print-O-World, 2568, Shadipur, New Delhi 110008 and printed at M/s Royal Offset Printers, A-89/1, Naraina Industrial Area, Phase-I, New Delhi 110 028.