भाकृ अनुप
ICAR

Vision 2050

iisr

Indian Institute of Spices Research
Kozhikode, Kerala-673012.
www.spices.res.in

शरद पवार
SHARAD PAWAR

सत्यमेव जयते

कृषि एवं खाद्य प्रसंस्करण उद्योग मंत्री
भारत सरकार
MINISTER OF AGRICULTURE &
FOOD PROCESSING INDUSTRIES
GOVERNMENT OF INDIA

MESSAGE

The scientific and technological inputs have been major drivers of growth and development in agriculture and allied sectors that have enabled us to achieve self reliant food security with a reasonable degree of resilience even in times of natural calamities, in recent years. In the present times, agricultural development is faced with several challenges relating to state of natural resources, climate change, fragmentation and diversion of agricultural land to non-agricultural uses, factor productivity, global trade and IPR regime. Some of these developments are taking place at much faster pace than ever before. In order to address these changes impacting agriculture and to remain globally competent, it is essential that our R&D institutions are able to foresee the challenges and formulate prioritised research programmes so that our agriculture is not constrained for want of technological interventions.

It is a pleasure to see that Indian Institute of Spices Research (IISR), Calicut, a constituent institution of the Indian Council of Agricultural Research (ICAR) has prepared Vision-2050 document. The document embodies a pragmatic assessment of the agricultural production and food demand scenario by the year 2050. Taking due cognizance of the rapidly evolving national and international agriculture, the institute, has drawn up its Strategic Framework, clearly identifying Goals and Approach.

I wish IISR all success in realisation of the Vision-2050.

(SHARAD PAWAR)

Office : Room No. 120, Krishi Bhawan, New Delhi-110 001 Tel.: 23383370, 23782691 Fax : 23384129
Resi. : 6, Janpath, New Delhi-110 011 (India) Tel. : 011-23018870, 23018619 Fax : 011-23018609
E-mail : sharadpawar.sp@gmail.com

डा. एस. अय्यप्पन
सचिव एवं महानिदेशक
Dr. S. AYYAPPAN
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि मंत्रालय, कृषि भवन, नई दिल्ली 110 114

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE, KRISHI BHAVAN, NEW DELHI 110 114
Tel.: 23382629; 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

FOREWORD

The Indian Council of Agricultural Research, since inception in the year 1929, is spearheading science and technology led development in agriculture in the country. This is being accomplished through agricultural research, higher education and frontline extension undertaken by a network of research institutes, agricultural universities and Krishi Vigyan Kendras. Besides developing and disseminating new technologies, ICAR has also been developing competent human resources to address the present and future requirements of agriculture in the country. Committed and dedicated efforts of ICAR have led to appreciable enhancement in productivity and production of different crops and commodities, which has enabled the country to raise food production at a faster rate than the growth in demand. This has enabled the country to become self-sufficient in food and emerge as a net food exporter. However, agriculture is now facing several challenges that are expected to become even more diverse and stiffer. Natural resources (both physical and biological) are deteriorating and getting depleted; risks associated with climate change are rising, new forms of biotic and abiotic stress are emerging, production is becoming more energy intensive, and biosafety concerns are growing. Intellectual property rights and trade regulations impacting technology acquisition and transfer, declining preference for farm work, shrinking farm size and changes in dietary preferences are formidable challenges.

These challenges call for a paradigm shift in our research approach to harness the potential of modern science, innovations in technology generation and delivery, and enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy efficiency, agri-incubators 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.

It is an opportune time that the formulation of 'Vision-2050' by ICAR institutions coincides with the launch of the national 12th Five Year Plan. In this Plan period, the ICAR has proposed to take several new initiatives in research, education and frontline extension. These include creation of consortia research platforms in key areas, wherein besides the ICAR institutions, other science and development organizations would be participating; short term and focused research project through scheme of extramural grants; Agri-Innovation fund; Agri-incubation fund and Agri-tech Foresight Centres (ATFC) for research and technology generation. The innovative programme of the Council, 'Farmer FIRST' (Farmer's farm, Innovations, Resources, Science and Technology) will focus on enriching knowledge and integrating technologies in the farmer's conditions through enhanced farmer-scientist interface. The 'Student READY' (Rural Entrepreneurship and Awareness Development Yojana) and 'ARYA' (Attracting and Retaining Youth in Agriculture) are aimed to make agricultural education comprehensive for enhanced entrepreneurial skills of the agricultural graduates.

I am happy to note that the Vision-2050 document of **Indian Institute of Spices Research, Calicut** has been prepared, based on the assessment of present situation, trends in various factors and changes in operating environment around agriculture to visualize the agricultural scenario about 40 years hence and chalk out a demand-driven research agenda for science-led development of agriculture for food, nutrition, livelihood and environmental security, with a human touch.

I am sure that the 'Vision-2050' would be valuable in guiding our efforts in agricultural R&D to provide food and nutritional security to the billion plus population of the country for all times to come.

(S. Ayyappan)

Dated the 24th June, 2013
New Delhi

PREFACE

The Indian Institute of Spices Research (IISR) started as a Regional Station of Central Plantation Crops Research Institute in 1975, has now grown into a full-fledged institute of international importance. The institute during its existence for over three decades has developed an array of varieties and suitable technologies for the spice farmers of India. The IISR also is the headquarters for the All India Coordinated Research Project on Spices being operated in 19 centers all over the country. I have great pleasure in presenting the Vision 2050 of this Institute. For the second time, IISR bagged the Sardar Patel Award for the Best ICAR Institute in 2010. The institute is concentrating on black pepper, ginger, turmeric, cardamom and tree spices such as nutmeg, cinnamon, garcinia and cassia. The Vision document is prepared with the objective of developing a road map for obtaining high productivity of quality spices. Being the world's top class spice research institute under the ICAR, we contemplate to see IISR as the torch bearer for spice growers around the world.

The consumption of spices is growing in the country with increase in purchasing power. It is envisaged that everyone in India would be consuming one spice or the other with a high per capita consumption. It is estimated that we may have a population of about 1.69 billion people during 2050 and approximately the per capita consumption of black pepper, cardamom, turmeric, and ginger is expected to be about 148 g, 54 g, 1.6 kg and 1.2 kg, respectively.

Our mission is to produce spices without increasing the area under the crop. The objective is also to have a 20% increase in spice export. If this is the case, the productivity in black pepper must increase from the present level of 260 kg to 943 kg ha^{-1}. Similarly the cardamom, turmeric, and ginger should yield 0.98, 10.0, 9.3 t ha^{-1} respectively.

I would like to place on record my grateful appreciation to all my colleagues presently working at IISR and those who have retired from this institute after meritorious service. Everyone in IISR has contributed tremendously for preparation of this document. I would like to thank my fellow editors Drs. V. Srinivasan, R. Dinesh, K. S. Krishnamurthy and S. Devasahayam for bringing out this document. The endless editing, corrections and suggestions we received from Dr. S Ayyappan, the Director General, ICAR and Secretary (DARE), Dr. NK Krishnakumar, Deputy Director General (Hort.) is placed on record with gratitude. The untiring support we received from Dr. S. K. Malhothra, the ADG (Hort.II) for the successful preparation of this document is gratefully acknowledged.

(M. ANANDARAJ)

DIRECTOR

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1. CONTEXT

India has been known from prehistoric times as the land of spices. This led to the landing of the Portuguese navigator, Vasco da Gamma at Kozhikode in 1498. Until the 1970s, India had a virtual dominance in the international spices trade. India still continues to be the largest producer, consumer, and exporter of spices in the world. During the crop year 2010-11 the country produced about 5350.47 thousand tons from 2940.39 thousand hectares of area under spices. About 10% of this is exported annually.

Indian spices flavour foods in over 130 countries and their intrinsic values make them distinctly superior in terms of taste, colour and fragrance. The USA, Canada, Germany, Japan, Saudi Arabia, Kuwait, Bahrain and Israel are the main markets for Indian spices. North America (USA and Canada) and Western Europe are the most important regions having the import demand for many of the spices. Mexico continues to be the major importer of cinnamon and cassia while Saudi Arabia, Bahrain, Kuwait and Israel are the major markets for green cardamom, black pepper, ginger and turmeric. We have near monopoly in spice oils and oleoresins and Indian spices have obtained geographical indicators such as Malabar pepper, Alleppey Green Cardamom, Coorg Green Cardamom and Naga chilli. The estimated growth rate for spices demand in the world is around 3.19%, which is a shade above the population growth rate.

Our growth in spices export is remarkable though not spectacular considering the historical importance of India as a land of spices. The demand for organic products is steadily increasing in the western markets at 20-25% every year and that of organic spices is about 2%. The medicinal value of spices is getting attention. Value added spices like encapsulated spices; oils and oleoresin are assuming significance in view of convenience. With the reported use of spices oils and oleoresins in soft drinks, food and medicines demand for Indian spice oils and oleoresins is bound to shoot up.

India possesses many innate advantages over other spice producing countries - its large genetic base, varied soil and climatic conditions, and skilled human power. However, in many of the spice crops productivity is low in India. Yields in black pepper (283 kg ha^{-1}), small cardamom (181 kg ha^{-1}), are low compared to Malaysia (2925 kg ha^{-1} in black pepper) and Guatemala (250 kg ha^{-1} in small cardamom). Poor soil fertility, use of low level of inputs like manures, fertilizers and crop protection measures, high labour cost and crop loss due to diseases, lack of resistant varieties and post harvest losses are the major reasons for the low productivity. The biggest handicaps that Indian spices face in the international market are the high cost of the product and high level of microbial contaminants including mycotoxin in the finished product. We need to make concerted efforts for producing clean spices at competitive prices. India can withstand the competition only by increasing productivity and reducing cost of cultivation leading to low cost per unit of production. Considerable efforts will have to be made to improve the present post harvest processing and storage systems and in educating the farmers and traders in handling/process the produce hygienically and promotion of spices in consumer packs, ethnic foods or ethnic medicine would boost up production.

1.1 ***WHY 2050?***

Higher productivity, clean spices through improved post harvest techniques and reasonable threshold price affordable to food industry are the keys to future spice trade. Future trading is going to be tough in view of stringent regulations imposed by ASTA, FDA, USDA and EPA. Though the pace in spice production has slowed down, a revolution in spices production technologies is imminent. While there is a great deal of path-breaking efforts to be made, stale or technologies that may not hold as much promise of profit-making need to be slashed. This would transform the existing fatigue in spices production into a vibrant and competitive profit making sector. Apparently, there is a need for bold initiatives that would often cross state boundaries and bring together unprecedented success.

The forecasted population increase is up to 1619 millions in 2050 with increased GDP and per capita food spending. As spices are of high value with nutraceuticals compounds, its per capita demand may increase many fold by 2050. The projected per capita demand for major spices like black pepper, cardamom, ginger and turmeric is estimated to be about 148 g, 53 g, 1.22 kg and 1.63 kg respectively. With this increase, production levels to meet the local and global demand are estimated to be increased by 2.7 - 5.7 folds from the present levels.

At the Indian Institute of Spices Research we continuously strive to harness the power of intellectual minds and challenge conventional thinking by pushing the boundaries of science to increase spices productivity by enhancing input use efficiency, and reducing post harvest losses with an eye on reducing the cost of production. We also try to discover effective solutions to emerging problems through conventional and modern science techniques thereby producing spices that will improve the quality of life.

Locating resistance sources and evolving high yielding and disease resistant lines through selection, mutation, polyploidy breeding and biotechnological methods are among the important programmes for spices improvement. Multi location testing of varieties for adaptation and quality, evaluation of lines suited to organic production, scaling up the production of nucleus planting material of elite lines through soil less medium/ aero/ hydro phonics will enable the production of disease free planting units that are the basic for development of spices productivity. Studies may be oriented towards identification of varieties which can adapt to climate change and also management strategies to mitigate the ill effects of climate change. The recent advances in technologies such as satellite imagery, use of GPS and modern mapping techniques using GIS have greatly improved the understanding of the land use planning. Spices like ginger, turmeric and most of the tree spices like nutmeg, cinnamon, cassia and garcinia can be exploited for intensive agriculture under mixed farming systems along with other horticultural crops.

As the international trade barriers are steadily coming down, India will have to develop very competitive edge in all respects, if it has to retain and increase its present position in the international trade of spices. The Vision 2050 contemplates realization of the above objectives by giving thrust on conservation of genetic resources, research in frontier areas of science, secondary agriculture, bio risk management, mechanization, Eco-spices etc. so as to realize the set goals.

1.2 *SPICES SCENARIO*

Spices are high value and low volume commodities of commerce in the world market. All over the world, the fast growing food industry depends largely on spices as taste and flavour makers. Health conscious consumers in developed countries prefer natural colours and flavours of plant origin to cheap synthetic ones. Thus, spices are the basic building blocks of flavour in food preparations. The estimated growth rate for spices demand in the world is around 3.19%, which is just above the population growth rate. Almost all States in the country produce one or other spices. Of the total production, nearly 10% was exported. Share of export in total production varied from a mere 0.2% in large cardamom to about 42% in chilli. During 2010-11, export in terms of value was all time high at US $ 1.5 billion.

1.2.1 Trends in growth

Area and Production

During the crop year 2010-11 the country produced about 5350.47 thousand tons from 2940.39 thousand hectares of area under spices (Table 1). During the last three decades the production has become nearly three times due to area expansion and higher productivity. Area and production of total spices have increased by 46.8% and 182.4%, respectively from 1991-92 to 2010-11 period (Fig 1). Value of spices exports from the country has experienced a 5-fold increase during the same period.

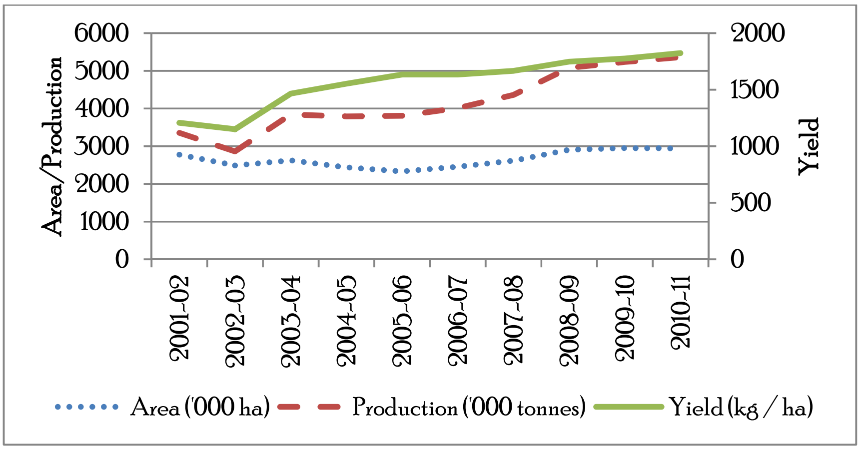

Fig 1. Area, production and productivity trends in spices

Table 1. India: Production and productivity of certain spices

Crop	Production (2010-11)		
	Area ('000 ha)	Production ('000 MT)	Productivity (kg ha^{-1})
Black Pepper	183.77	51.99	283
Ginger	149.11	701.98	4708
Turmeric	195.07	992.94	5090
Cardamom	86.70	15.71	181
Clove	2.42	1.16	480
Nutmeg	16.13	11.42	708
Cinnamon	0.51	0.04	73
Tejpat	2.44	4.98	2044

Source: DASD & Spices Board, Govt. of India.

Black Pepper

There is an increasing production trend in the past decade with increased productivity. Area under pepper has crossed 2.33 lakh ha during the crop year 2003-04 and during 2010-11 the area is 1.83 lakh ha with a production of 51.9 thousand tonnes and productivity of 283 kg ha^{-1}. Pepper productivity in India is one of the lowest in the world. The average productivity of pepper $vine^{-1}$ is highest in Karnataka (ca. 1 kg) and lowest in Kerala (ca. 0.6 kg). The estimated yield $vine^{-1}$ in tea estates is, however, markedly higher (ca. 3.3 kg). Since there is a vast difference between the recorded yield and present level of national productivity, there is enough potential to increase productivity. The reason for low production per unit area in India is due to the system of cultivation, compared to mono cropping followed in Vietnam, Brazil etc with a population ranging from 1100 to 2000 vines ha^{-1}. In India it is grown in mixed or homestead conditions with the population of vines being significantly lower (ca. 200-250 ha^{-1}).

Cardamom

During 1990s, India's production had been showing a consistently increasing trend from 4250 tonnes in 1992-93 to 7900 tonnes in 1995-96, but declined to 6625 tonnes during the subsequent crop year with a lower rate of decline. The increasing trend in production from the crop year 1997-98 is being maintained till date with 13,650 t in 2007-08 and 15,710 in 2010-11 from 86,704 ha. The productivity level has improved from 60 kg ha^{-1} in 1990s and reached 181 kg ha^{-1} during 2010-11. This is due to favourable climate, improved technologies, planned developmental programs and remunerative price.

Ginger

Indian production has been showing a steady increasing trend from 29.59 thousand tonnes in 1970-71 to 701.99 thousand tonnes during 2010-11. This is due to the improvement in both area and productivity. While Meghalaya, Arunachal Pradesh, Sikkim and other NE states together accounted for more than 52% of total production with 26% of area, the region comprising Kerala, Karnataka, Orissa and Tamil Nadu accounted for the rest of the production with 72% area during 2007-08. The yield level of ginger in the country has increased over the years from 1371 kg ha^{-1} during 1970-71 to 4708 kg ha^{-1} during 2010-11. The increase in production during the period was largely due to increase in area and productivity.

Turmeric

The turmeric producing states have shown fluctuations in their production level due to changes in the rate of productivity and area of cultivation. The market price has also played an important role in annual production. India produced 992.9 thousand tonnes from an area of 195 thousand ha with the productivity of 5.09 t ha^{-1} during 2010-11. Andhra Pradesh occupies first position both in terms of average area and production of turmeric, but in terms of productivity, it occupies the third position.

Tree Spices

Tree spices constitute a group of diverse crops where the product of commerce is predominantly used as spice. Clove, nutmeg, cinnamon, comboge, kokum, tamarind etc are the predominant tree spices cultivated in India. The production of clove in India during 2009-10 was 1160 t from an area of 2600 ha. Nutmeg is cultivated in an area of 15,500 ha with the production of 8000 t.

Export

On a global scale, the annual growth rate in spices consumption is estimated at around 10%. At this rate, the India's demand by 2050 will be around 16.6 million tonnes. During the past few years, turmeric, ginger, seed spices and curry powder have registered substantial increase in export earnings.

World trade in spices has shown a consistently upward trend over the past 25 years. The Indian spice export was 2.25 lakh tonnes valued at Rs. 1213 crores during 1996-97. But it crossed the billion US $ mark during 2007-08 with 4.44 lakh tonnes valued at Rs. 4435 crores. The spices export has continued its growth and during 2010-11 recorded 5.25 lakh tonnes worth Rs. 6840.71 crores, an all time high both in terms of volume and value of spices export from India. Apparently, the export has shown an increase of 23% in value and 4.5% in quantity compared to 2009-10.

Among the export of different spices, maximum share was from Chilli (42%) followed by seed spices (21%), turmeric (14%), black pepper (5%), ginger (4%) and other spices (7%) during 2011-12 (Fig 2). However in terms of value, mint products and spice oil & oleoresins contributed 36% of the total export earnings. During 2010-11, the export of chilli, ginger, tamarind and value added products like spice oils, oleoresins and curry powders increased both in volume and value. However, in case of pepper, cardamom, turmeric, nutmeg and mace the export increase was in terms of value (up to 22%) only (Table 2).

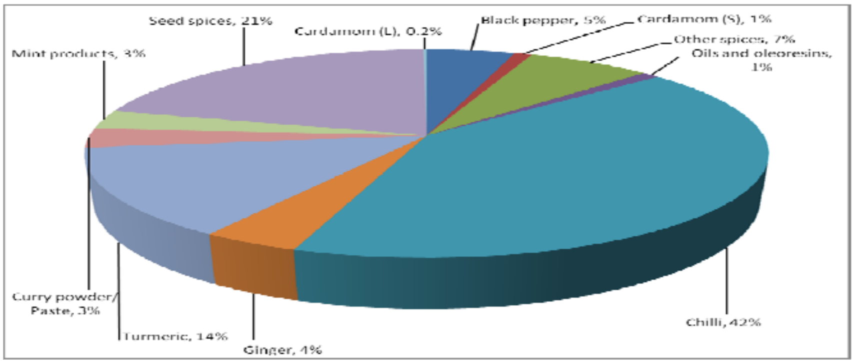

Fig 2. Share of spices and spice products in terms of volume exported in 2010-11

Indian pepper fetches premium price because of its high intrinsic qualities over that of other competing countries. In 2010-11, India exported about 18,850 t valued at Rs. 383.2 crores, with a reduction in volume over 2007-08. USA is the major importer of pepper in the world market with an average of about 60,000 t per annum and in 2008-09 USA imported 10,050 t of pepper accounting for 40% of our total pepper export. India exported 1175 t of cardamom valued at Rs. 132.2 crores in 2010-12 recording a decrease of -40% in volume and -20% in value as compared to 2009-10. Saudi Arabia is the major importer with 1117 t (56%) of our total cardamom export. Other major buyers are UAE (15%), Kuwait and Egypt.

Table 2. Export of certain spices and products from India
(Quantity in MT, Value in Rs. Lakhs)

Crop	**2009–10**		**2010-11**		**% change in 2010-11**	
	Qty	**Value**	**Qty**	**Value**	**Qty.**	**Value**
Black Pepper	19750	31392	18,850	38319	-4.6	22.1
Cardamom (small)	1975	16570	1,175	13216	-40.5	-20.2
Ginger	5500	4675	15,750	12131	186.4	159.5
Turmeric	50750	38123	49,250	70285	-3.0	84.4
Nutmeg & mace	3275	9186	2,100	9777	-35.9	6.4
Vanilla	200	2251	175	1875	-12.5	-16.7
Curry powder	14300	18918	15,250	21051	6.6	11.3
Mint products	19000	118972	17,450	169679	-8.2	42.6
Spice Oleoresins & oils	6750	70875	7,600	91062	12.6	28.5

Source: DASD & Spices Board, Govt. of India.

India exported 15750 t of ginger valued at Rs. 121.3 crores in 2010-11 recording an increase of 186% in volume and 159% in value as compared to 2009-10. Maximum export of ginger is in the dry and powder forms and fresh ginger export which accounts for about 2230 t mainly from the NE states to Bangladesh. India exported a record high 49250 t of turmeric valued Rs. 702.8 crores in 2010-11 with a decrease of -3% in volume but 84% increase in value as compared to 2009-10. India is the major supplier of turmeric in the world market with competition from Vietnam, Indonesia and Myanmar. UAE is the major importer with 6719 t of our total export. About 3275 t of nutmeg and mace is exported to other countries with an earning of Rs. 91.8 crores and the major importers are UAE, Vietnam, Singapore and USA. Cinnamon is commercially cultivated in Kerala, Karnataka and Andaman & Nicobar Islands with production of 1670 t from an area of 1000 ha.

Value added products including spice oils and oleoresins, mint products, curry powder/paste/condiments, and spice powders contributed around 58% in value towards the total export earnings by spices from India. During 2010-11, 15250 t of curry powder blends valued at Rs. 210.2 crores has been exported to UK, Saudi, UAE and USA. Export of spice oils and oleoresins has recorded an all time high of 7600 t valued at Rs. 910.7 crores in 2010-11. Major spice oils exported are pepper oil, nutmeg oil, mustard seed oil, clove oil, celery seed oil and ginger oil and in case of oleoresins, paprika oleoresin followed by capsicum, pepper, garcinia and turmeric oleoresins are exported. USA is the major importer of spice extracts followed by Germany, UK, South Korea and China. Mint products account for 21% of the total spice export mainly to USA, China, Singapore, Germany, UK, Netherlands and Brazil.

India exports its spices to more than 120 countries in the world. But, few countries dominate the importers list for Indian spices by virtue of the quantity imported. From the region-wise export data for various periods, it can be seen that the Asian zone is fast emerging as the major destination for Indian spices with 66% in quantity and 48% in value followed by American zone and European Union countries.

Imports

The total import of spices in India during 2008-09 is about 86775 t valued Rs. 1175.5 crores. The import value has increased by 7% as compared to previous years. The major spices imported are pepper, poppy seed, clove, cardamom, ginger fresh and cassia. Out of the total import of pepper (16100 t), more than 60% is light (immature) pepper for oleoresin extraction and re-export. Fresh ginger is imported mainly from Nepal (30% of import volume) for domestic consumption. Poppy seed, cassia, clove and star anise are also imported to meet the domestic consumption as the production of theses spices are less in India.

Over the years, India's share in world spices market has not appreciated much and its monopoly as a supplier of spices is threatened by countries like China, Brazil, Vietnam, Pakistan, Egypt, Turkey and other African and Caribbean countries. India also faces shortage of exportable surplus because of increasing domestic demand. Sharp fluctuations in the quantum and value of exports and in the unit value realization have characterized the spices trade in recent years.

2. CHALLENGES

The productivity level in India is believed to be low compared to other countries. However, the collection of data is far from being scientific. Many competing countries are in the spices trade with the opening of international market (Table 3). A major effort is needed to bridge this gap in productivity. In India, even the gap between national average and the realizable yield is very wide (Table 4). In pepper, it is around 2445 kg/ha, in cardamom 1625 kg/ha (national average is 290 kg/ha and 120 kg/ha respectively). Bridging this gap is sufficient to increase country's production many fold. Hence the strategic planning need to focus natural, biological, environmental, sustainability, research, value addition and development factors.

Table 3. Competing countries with India in production and export of major spices

Spice	Competing country
Black pepper	Indonesia, Brazil, Malaysia, Thailand, Sri Lanka, Vietnam, China (P.R), Madagascar, Mexico
Cardamom	Guatemala, El Salvador, Indonesia, Malaysia, Papua, New Guinea, Sri Lanka
Ginger	China (P.R), Thailand, Japan, Bangladesh, South Korea, Malaysia, Fiji, Philippians, Jamaica, Nigeria, Sierra Leone
Turmeric	China (P.R), Pakistan, Bangladesh, Thailand, Peru, Jamaica, Spain
Clove	Brazil, Indonesia, Madagascar, Malaysia, Papua, New Guinea, Sri Lanka
Nutmeg and Mace	Grenada, Guatemala, Mexico, Nicaragua, Sri Lanka
Cassia	China, Indonesia, Madagascar, Malaysia, Vietnam, Sri Lanka
Cinnamon	Madagascar, Papua, New Guinea, Seychelles

Considerable efforts will have to go to improve the present post harvest processing and storage systems and in educating the farmers and traders in handling/process the produce hygienically. The envisaged increase in share of value added products in the export basket of spices needs strengthening of processing facilities both on farm and outside.

The major risk factors involved in spices production are,

- Emergence and epidemics of pests and diseases
- Vagaries of monsoon resulting in drought
- Emergence of other major spice producing countries which compete with India in the International market.
- Shifting of interests of growers to more profitable/less risky crops.
- Adulteration of spices
- Cyclic market fluctuations at international and national level
- Lack of awareness about pesticide residues and mycotoxin contaminants in the products and lack of MRL and ADI standards in some of the pesticides used in spices

The research programmes of the future would be geared to meet the challenges that can arise from these risk factors.

3. OPERATING ENVIRONMENT

3.1 About IISR

A major step in initiation of sustained research on spices was the launching of All India Coordinated Spices and Cashew Improvement Project (AICSCIP) at Central Plantation Crops Research Institute (CPCRI) at Kasaragod, Kerala, during 1971 by Indian Council of Agricultural Research (ICAR). Later the ICAR felt the need for intensifying research on spices and established a Regional Station of CPCRI at Kozhikode, Kerala during 1975, exclusively for conducting research on spices by the ICAR. The Regional Station was upgraded as National Research Centre for Spices (NRCS) in 1986 by merging with the Cardamom Research Centre of CPCRI at Appangala, Karnataka. The NRCS was further elevated to the present Indian Institute of Spices Research (IISR) during 1995.

The laboratories and administrative offices of the institute are located at Chelavoor (50m above MSL), 11 km from Kozhikode, Kozhikode District, Kerala on the Kozhikode -Kollegal road (NH 212), in an area of 14.3 ha. The research farm is located 51 km northeast of Kozhikode at Peruvannamuzhi (50 m above MSL) on the Peruvannamuzhi-Poozhithode road in Kozhikode district, in an area of 94.08 ha. Cardamom Research Centre, Appangala (920 m above MSL) is located at Appangala, Kodagu district, Karnataka on the Madikeri-Baghamandala road, 8 km from Madikeri, in an area of 17.4 ha. Large scale improvement is also being made in the development of infrastructure facilities at Research centre, Appangala and Research Farm, Peruvannamuzhi. Modern facilities for both applied and basic research, with specialized facilities for molecular biology, biotechnology, biocontrol, post harvest technologies are available. The institute hosts various other facilities such as ATIC, Bioinformatics center, ARIS and NIC for Spices. The institute functions as the head quarters of the AICRP on Spices (which coordinated the research on spice crops being conducted at 21 centers all over the country), Outreach research project on PHYTOFURA (with 19 centres all over the country) and Indian Society for Spices (ISS).

3.2 Mandate

- To extend services and technologies to conserve genetic resources of spices as well as soil and water of spices agro ecosystems.
- To develop high yielding and high quality spice varieties and sustainable production and protection systems using traditional and novel biotechnological approaches.

- To develop post harvest technologies of spices with emphasis on product development and diversification for domestic and export purposes.
- To act as a centre for training and technology upgradation of spices and to coordinate national research projects.
- To monitor the adoption of new and existing technologies to make sure that research is targeted to the needs of the farming community.
- To serve as a national centre for storage, retrieval and dissemination of technological information on spices.

3.3 Mandate crops

The crops on which research is being conducted at the institute include black pepper (*Piper nigrum),* cardamom (*Elettaria cardamomum),* ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), cinnamon (*Cinnamomum verum*), cassia (*Cinnamomum cassia*), clove (*Syzygium aromaticum*), nutmeg (*Myristica fragrans*), allspice (*Pimenta dioica*), garcinia (*Garcinia gummi-gutta* and *Garcinia indica*), vanilla (*Vanilla planifolia*) and paprika (*Capsicum annuum*).

3.4 Objectives

- To conserve genetic resources of spices, develop high yielding and high quality varieties
- To develop sustainable production systems, post harvest technologies of spices with emphasis on product development and diversification
- To disseminate technologies by imparting training, impact assessment and technology commercialization

3.5 Significant Achievements

- The institute holds the world's largest germplasm collection of spices that are being characterized for various traits. The collections include 2300 black pepper accessions besides 1400 hybrids, 439 cardamom, 700 ginger, 924 turmeric, 484 nutmeg, 225 clove, 408 cinnamon, 116 garcinia and 79 vanilla accessions.

- Improved varieties with high yield, quality and resistance to pests and pathogens were developed. These include Sreekara, Subhakara, Pournami, Panchami, IISR Thevam, IISR Girimunda, IISR Malabar Excel and IISR Shakthi in black pepper; IISR Suvasini, IISR Avinash, and IISR Vijetha in cardamom; IISR Varada, IISR Rejatha and IISR Mahima in ginger and Suvarna, Sudarsana, Suguna, IISR Prabha, IISR Pratibha, IISR Alleppey Supreme and IISR Kedaram in turmeric; IISR Navashree and IISR Nithyashree in cinnamon and IISR Viswashree in nutmeg.
- Protocols for micro-propagation of several spice crops and improved vegetative propagation methods were standardized in black pepper, cardamom, clove, nutmeg, cinnamon and cassia that are being utilized for multiplication of planting materials.
- The optimum spacing, nutrient and water requirements for black pepper, cardamom, ginger and turmeric were standardized. Mixed cropping and intercropping systems were developed in black pepper and cardamom for increasing productivity from unit area of land.
- Targeted yield equations for predicting site specific nutrient requirements for fixed yield targets and organic production packages were standardized for black pepper, ginger and turmeric. The micronutrient requirement for major spice crops was also standardized and developed spice and soil pH specific nutrient mixtures for alleviating the deficiencies.
- Whole genome sequencing and annotation of *Phytophthora capsici* infesting black pepper was completed.
- Eco-friendly integrated strategies involving cultural methods, biocontrol agents, plant products, resistant varieties and need-based application of pesticides were developed for management of pests and diseases of spice crops that resulted in pesticide-free produce.

- Protocols for real-time quantitative PCR (qPCR) for detection of PYMoV and CMV infecting black pepper and Banana bract mosaic virus (BBrMV) and Cardamom mosaic virus (CdMV) infecting cardamom and loop-mediated isothermal amplification (LAMP) for detection of CMV, PYMoV and BBrMV were developed and used to produce and certify virus-free planting.
- Post harvest technologies for processing and value addition of black pepper, cardamom, ginger, turmeric, nutmeg, mace, clove, cinnamon and cassia were developed.
- The institute has developed and implemented 'ARISoft', novel office automation software which is a fully integrated system that automates the multifarious functions and day-to-day operations in an research institute.
- Institute has successfully demonstrated the technologies on integrated management of black pepper and cardamom in more than 15,000 ha in Kerala and Karnataka which helped to improve the productivity and kept the disease incidence below 5%.

4. OPPORTUNITIES

- Increasing demand for spices and its value added from globally
- Scope for crop improvement especially to develop genotypes resistant to biotic and abiotic stresses and also responsive to low input management through conventional breeding and biotechnological approaches.
- Public - private industry partnership to identify potential problems and workable solutions like large-scale multiplication of quality planting materials of released varieties with strict quality regulation and certification
- Scope for establishment of Advanced Centres for Research on Biotechnology, *Phytophthora* Research, Biocontrol and Biosystematics, high value compounds etc.
- Identification of varieties which can adapt to climate change and also management strategies to mitigate the ill effects of climate change. Popularizing the soil conservation/water management technologies and encouraging organic farming and IPM approaches at community level will help in sustaining the production and productivity of spices.
- Potential for establishment of cooperative movement to regulate production and marketing to increase competitiveness of Indian products in the international market.
- Employment opportunities for trained manpower in spice industry and spice farming.
- There is substantial scope for value addition and diversification in spices. Considerable efforts will have to go to improve the present post harvest processing and storage systems and in educating the farmers and traders in handling/process the produce hygienically.
- The envisaged increase in share of value added products in the export basket of spices needs strengthening of processing facilities.
- Spices are increasingly being noticed for their pharmacological activities and therefore their potential as a functional food has magnified scope. The scientific validation of the medicinal properties of spices using state of the art technology like drug modeling, molecular biology and nanotechnology, holds great promise and will provide greater avenues for medicinal uses of spices.

5. GOALS AND TARGETS

India will have to develop very competitive edge in all respects including competitive production, post harvest and value addition fields, if it has to retain and increase its present position in the international trade of spices. There is a great scope to improve the productivity of major spices as the potential yield realized in the research station and at the progressive farmers plots are very high and well above the national average (Table 4). The realization of this potential yield can be made through dissemination of the developed technologies like promising varieties, high production and pest and disease management strategies.

Table 4. Potential for productivity increase at the national level (kg/ha)

Crop	National	Progressive Farmer	Research station	Abroad
Pepper	283	2000	2445	2925 (Malaysia)
Cardamom	181	1625	450	320 (Guatemala)
Ginger	4880	5500	8250	-
Turmeric	5090	6200	10700	-

The forecasted population increase is up to 1619 millions in 2050 with increased GDP and per capita food spending. As spices are of high value with nutraceuticals compounds, its per capita demand will also increase many fold. The projected per capita demand for major spices like black pepper, cardamom, ginger and turmeric is given in fig 2. With this increase, production levels to meet the local and global demand are estimated to be increased by 2 to 5 folds from the present levels. Table 5 highlights the targeted task to be achieved for major spice crops. These estimates were made taking into account the present level of production, export, import, per capita consumption, expected level of increase in export and population growth etc.

Under the above said background the targeted production need to be achieved with marginal increase in area under the crops potentially utilizing the scientific, technological and traditional strengths for sustainable production. India can withstand the competition only by increasing productivity and reducing cost of cultivation leading to low cost per unit of production.

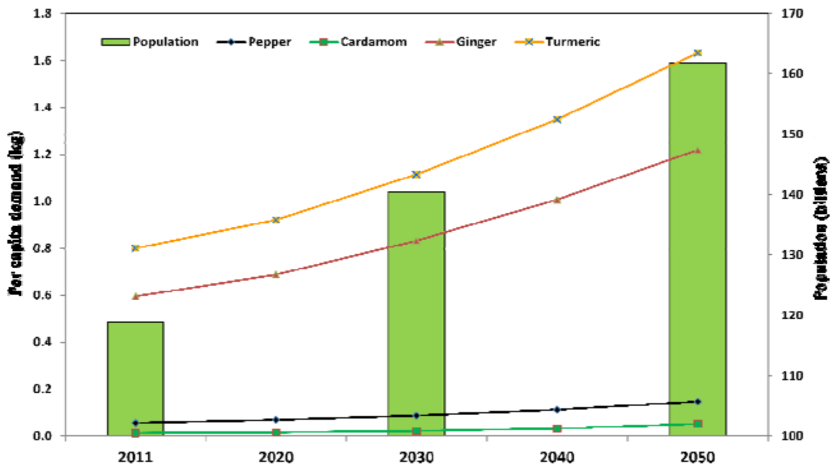

Fig 2. Estimated per capita demand for major spices in 2050

Table 5. Estimated production target for spices in India (Qty. in '000 tons)

Area	Total demand by 2050	Extra to be produced over the present production	Productivity to meet the total demand by 2050 (t/ha)
Black pepper	239.25	197.25	0.94
Cardamom	79.07	63.20	0.99
Ginger	2152.49	1380.30	9.35
Turmeric	2882.15	1819.70	10.03

Considerable efforts will have to go to improve the present post harvest processing and storage systems and in educating the farmers and traders in handling/process the produce hygienically. The envisaged increase in share of value added products in the export basket of spices needs strengthening of processing facilities both on farm and outside.

6. *WAY FORWARD*

6.1 Vision

- Enhancing productivity of spices for meeting growing domestic demand and to be the global leader in spices export

6.2 Mission

- Utilize the scientific, technological and traditional strengths for sustainable spice production

6.3 Strategies for research

The main focuses on researchable areas to accomplish the vision and objectives are,

- Conservation of genetic resources, bar-coding and crop improvement
- Increasing productivity of spices through
  - Quality planting material production and supply
  - Productivity enhancement technologies and systems through better input management
  - Bio risk management
- New market oriented technologies for secondary agriculture and value addition
- Effective transfer of technologies to the target groups

6.3.1 *Conservation of genetic resources, bar-coding of genotypes and crop improvement*

Perspective: To have a complete information on gene pool which is native to India for sustainable utilization and conservation and raise the production to targeted levels by developing improved varieties with high yield, quality traits and disease/ pest resistance

Locating resistance source and evolving high yielding and disease resistant lines through selection, mutation, polyploidy breeding and biotechnological methods are among the important programmes for spices improvement. Advances are made to locate source(s) of resistance/tolerance to biotic and abiotic stresses. Efforts may be oriented towards identification of varieties which can adapt to climate change and also management strategies to mitigate the ill effects of climate change.

6.3.2 *Increasing productivity of spices – Quality planting material production*

Perspective: To raise production levels by using quality planting materials of improved varieties.

Availability of good quality planting material is the key to the success of spice cultivation as it accounts for about 40% of total cost of production in ginger and turmeric and the long standing crop in black pepper and tree spices. Hence selection of quality material for planting and its storage till the planting season is very important. Protocols for micropropagation of several spice crops and improved vegetative propagation methods were standardized in black pepper, cardamom, clove, nutmeg, cinnamon, cassia and allspice for rapid clonal multiplication of spices and it may be supplied at reasonable rates by the government/agencies.

6.3.3 *Productivity enhancement technologies and systems through better input management*

Perspective: Resource budgeting and management of cropping system for efficient use, stable yield, quality and income.

This will include generation of eco-region specific technologies based on maximum productivity of available natural resources, soil fertility and water. With the change in climate, increase in temperature and associated increase in light intensity may reduce the yield of some spices like ginger, in southern states. Studies may be oriented towards varietal responses to climate change, identification of varieties which can adapt to climate change and productive use of water to get enhanced water productivity by increasing the water and nutrient use efficiency. IT based enabling mechanism for technology transfer to provide support for decision.

6.3.4 *Control of pests and diseases*

Perspective: To raise the production levels through IDM/ IPM.

Emphasis should be on identification of new and effective bio-molecules for management of biotic stresses coupled with development of innovative diagnostic techniques for rapid, accurate and cost effective detection of high impact pests and diseases. Integrated management system for emerging diseases and pests will be essential for plant health management to reduce the losses. Holistic approach would be needed for water, nutrient, pest and disease management and adoption of region wise agro-techniques.

6.3.5 *Development of Secondary Agriculture and Value Addition*

Perspective: To increase the acceptability, demand and value of spices and developing new markets

Value addition of spices has great scope considering present International trade scenario. The research programmes should orient for this demand by focusing more attention on better agro techniques in product diversification, varieties suitable for such products and following GAP. Development of post-harvest technologies to improve product quality and minimize environmental impacts coupled with value addition, could be a focus for reducing crop losses and increasing marketability. Wind and solar energy must have to be utilized in mechanization and processing spice based products. Chemo profiling and identification of new flavour compounds, bio active principles for patenting are the new avenues to exploit potentials in value chain.

6.3.6 *Effective TOT to target groups*

Perspective: Effective technology dissemination, adoption and further refinement

There must be participatory approach for effective transfer of technologies, monitoring and evaluation and also feedback for further refinement. Stakeholders may be empowered through trainings and FLDs from ATIC and KVKs on proven technologies, for better adoption at field level. Private and public partnership as producers and distributors of certified planting material and products will help in fulfilling the demand for quality planting materials in spices.

6.4 Priority Targets

6.4.1 *Genetic enhancement*

- Collection, conservation and characterization (molecular markers, bar coding) of germplasm and establishment of global gene bank of spices genetic resources
- Complete genome and transcriptome sequencing of spice crops – Identification of resistant genes, their isolation and use in development of resistant varieties.
- Locating sources of resistance for biotic and abiotic stresses using conventional and biotechnological tools and developing varieties with high yield, quality and specific traits
- Developing molecular bar codes for all germplasm accessions, pests and pathogens their natural enemies and molecular profiles of all released varieties
- Molecular farming to identify genes of interest
- Convergent improvement of black pepper for pyramiding multiple resistance genes (Pollu beetle, Phytophthora and nematodes).
- Developing crop ideotypes suited for uniform ripening (black pepper), synchronous flowering (cardamom) and varieties of ginger suited to specific end

products such as ginger candy, ginger shreds, ginger wine as well as turmeric rich in curcuminoids.

- Developing spices varieties for sustainable production under intensive management conditions
- Developing cardamom hybrid lines with bold capsules and high quality (rich in 1, 8 cineole and α-terpinyl acetate).
- Novel nutmeg genotypes (bisexual) with altered mace colour and uniform seed size will assume priority.
- Varietal evaluation of newly developed genotypes to suit specific agro ecological and soil conditions.
- Specific targeted breeding programme for sustainable yield under extreme climate (drought, flooding, high and low temperatures)

6.4.2 *Production systems*

- Development of novel techniques for accelerating production of quality planting material
  and certification systems for planting materials
- Horticultural interventions (high tech horticulture) to maximize productivity of spice based cropping systems
- Development of precision farming for spices to increase productivity especially for ginger and turmeric.
- Vertical farming to make maximum use of space by filling glass houses with plant beds stacked high one above the other in ginger and turmeric.
- Protected cultivation of spices for mitigating climate change
- Alternate cropping systems with spices / farming system approach
- High density planting in black pepper, cardamom and tree spices and including dwarf plant types
- Hydroponic and aeroponic cultivation (for ginger and turmeric)
- Development of varieties suitable for organic farming (through organic plant breeding) and extreme climate situations
- Nutrient sensing for external and internal mineral nutrient concentration and adjusting the growth based on resource availability (transduction network)
- Development of agro-ecosystem based insect pest management strategies using novel selfish gene drive systems, gene silencing and endosymbionts.
- Automated plant protection strategies under protected cultivation of spices

6.4.3 *Climate change resilient research*

- Crop weather soil relation based simulation models for extreme climatic conditions
- Impact of climate change on productivity, emergence of new diseases and pests and adaptation and mitigation studies
- Futuristic research for dry land/ rain fed cropping system for spice crops
- Increasing the water up-take ability through maximizing the root zone characteristics of plant and identification/development of varieties with enhanced water use efficiency
- Drought management studies/moisture conservation studies and water foot print of spice crops
- Designing smart fertilizer and pesticide delivery systems which can respond to environmental changes thereby facilitating controlled release of their cargo (slowly or quickly) in response to different signals e.g. heat, moisture, pH, etc

6.4.4 *Synergies of frontier science – Biotechnology, Nanotechnology, GIS, Bioinformatics*

- Molecular profiling including genome sequencing of important cultivars, varieties and hybrids
- Marker aided selection for desired traits, allele mining and identifying genes controlling superior quality traits, pest and disease resistance
- Molecular mechanisms of host-pathogen interactions in black pepper and ginger
- Genome sequencing of *P. capsici* and comparative transcriptomics/ genomics for identification of species specific markers.
- GIS based spice resource maps for specific agro- ecological situations and land use planning vis-à-vis climate change
- Nanotechnology-enabled devices like stand-alone nano sensors linked into a GPS system for real-time monitoring of soil conditions and crop growth.
- Nano-clay capsule containing nutrients, growth stimulants and biocontrol agents designed for slow release of active ingredients requiring only one application over the entire crop period.
- Development of super sensors for detecting a specific molecule that is associated with the condition of a system - Detection by sensing metabolic products or direct detection of a pathogen in the rhizosphere, rhizoplane and in plant parts.
- Biosensors for detecting spoilage of post harvest spice products by sensing metabolic products of spoilage bacteria or direct detection of spoilage bacteria.

6.4.5 *Managing natural resources*

- Cost effective nutrient budgeting through integrated nutrition management (INM) for targeted production and organic farming strategies
- Development and popularization of cost effective agricultural practices (INM/IPM) for increasing productivity
- Realizing the maximum carrying capacity of available land and water resources (so that there is a possible shift from quantity research to quality research)
- Abiotic stress - Quantification of water use efficiency and water requirement in spices
- Carbon sequestration potential in spice based cropping systems and C foot print

6.4.6 *Secondary agriculture*

- Value addition through microencapsulation, extrusion and other techniques
- Bioprospecting using bioinformatics tools
- Characterization of mode of therapeutic action of spices and their fully or partially
  purified extracts *in vivo*.
- Application of spices extracts or their purified bioactive principles in user-friendly mode for drug delivery, pesticidal and antimicrobial applications.
- Chemical modification, synthesis and appropriate packaging of spice(s) derived phytochemicals at defined dosages in conditions supporting optimum bioavailability,
  minimum toxicity/ break-down and targeted site-specific delivery.
- Encapsulation of spice extracts or their purified compounds, using micro- or nanotechnology, for culinary, nutraceutical, drug, agricultural and other novel applications, with improved physico-chemical properties.
- Development of novel bio-molecules using proteomics and metabolomics as future generation pest management tools.
- Developing electronic devices for monitoring quality and adulteration of spices

6.4.7 *Management of inputs and energy*

- Development of implements/tools for harvesting and processing for value added spice products.

- Developing precision farming models for management of nutrient and water to get optimum production from unit of water and nutrient used
- Development of solar dryers and solar cookers for post harvest processing of spices

6.4.8 ***Bio-risk management***

- Pest risk analysis
- Surveillance, identification and characterization of new invasive pests and pathogens
- Development of rapid and reliable diagnostics against pests and pathogens including invasive species.
- Management of new invasive pests and pathogens

6.4.9 ***Policy issues***

- Commercialization of techniques/ technologies
- Genetic finger printing of germplasm and its registration
- Registration of released varieties
- Patenting technologies related to spices
- Documentation of ITKs
- Conversion of agriculture in to a business venture with maximization of profit

6.4.10 ***Transfer of Technology (TOT)***

- Setting up village level disease detection kiosks
- Establishing 24 x 7 knowledge centres on spices
- Constraint and SPIN (Situation, Problems, Implications and Need) analysis and impact assessment of new technologies
- Large scale demonstration of proven technologies through KVK's as FLDs
- Establishing technology incubation centre
- Participatory Seed Production of major spices
- Use of next generation ICT for knowledge updating of farmers to develop them as technopreneurs.

6.5 ROAD MAP FOR ACTION

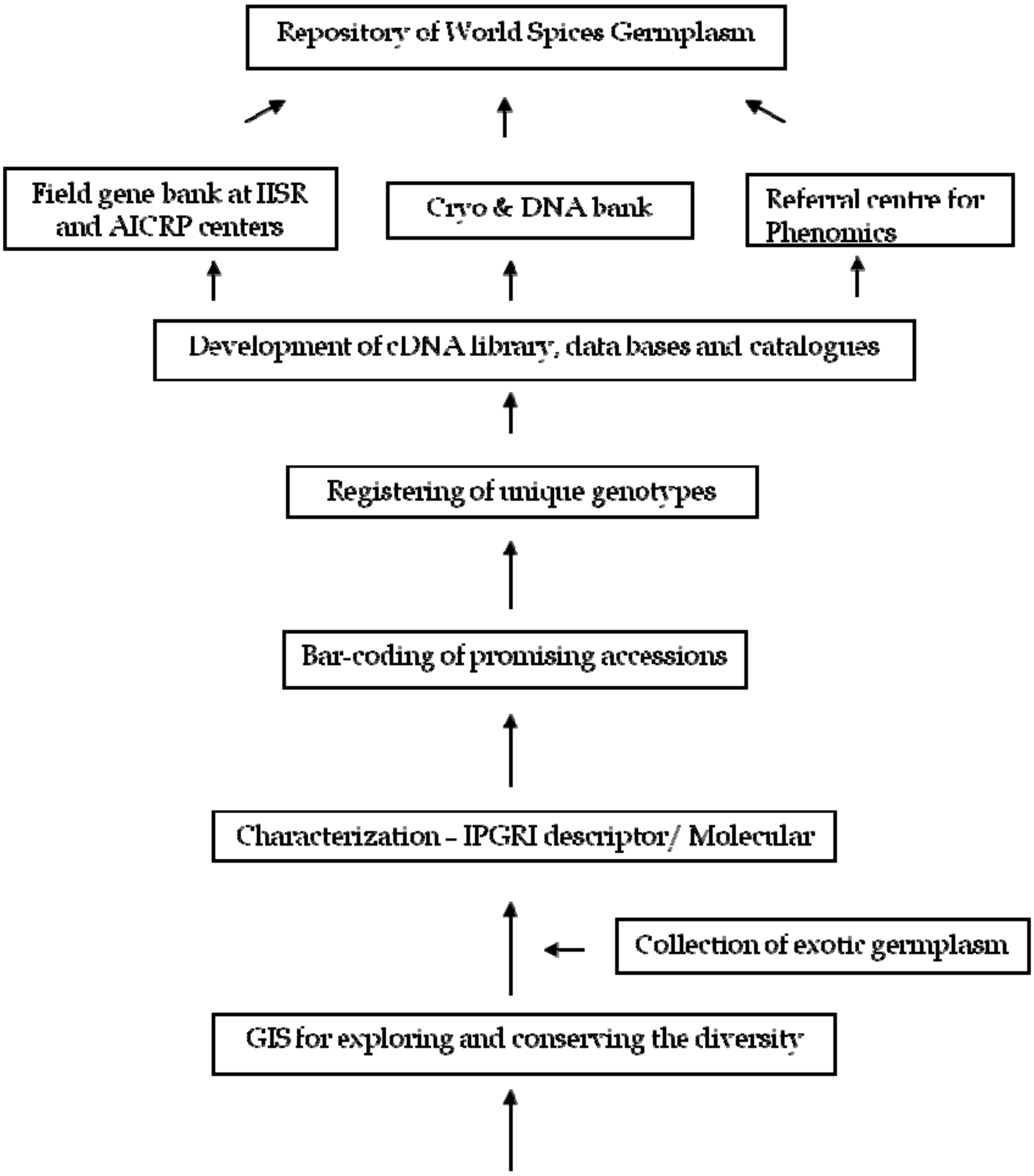

Figure 1: Conservation of genetic resources

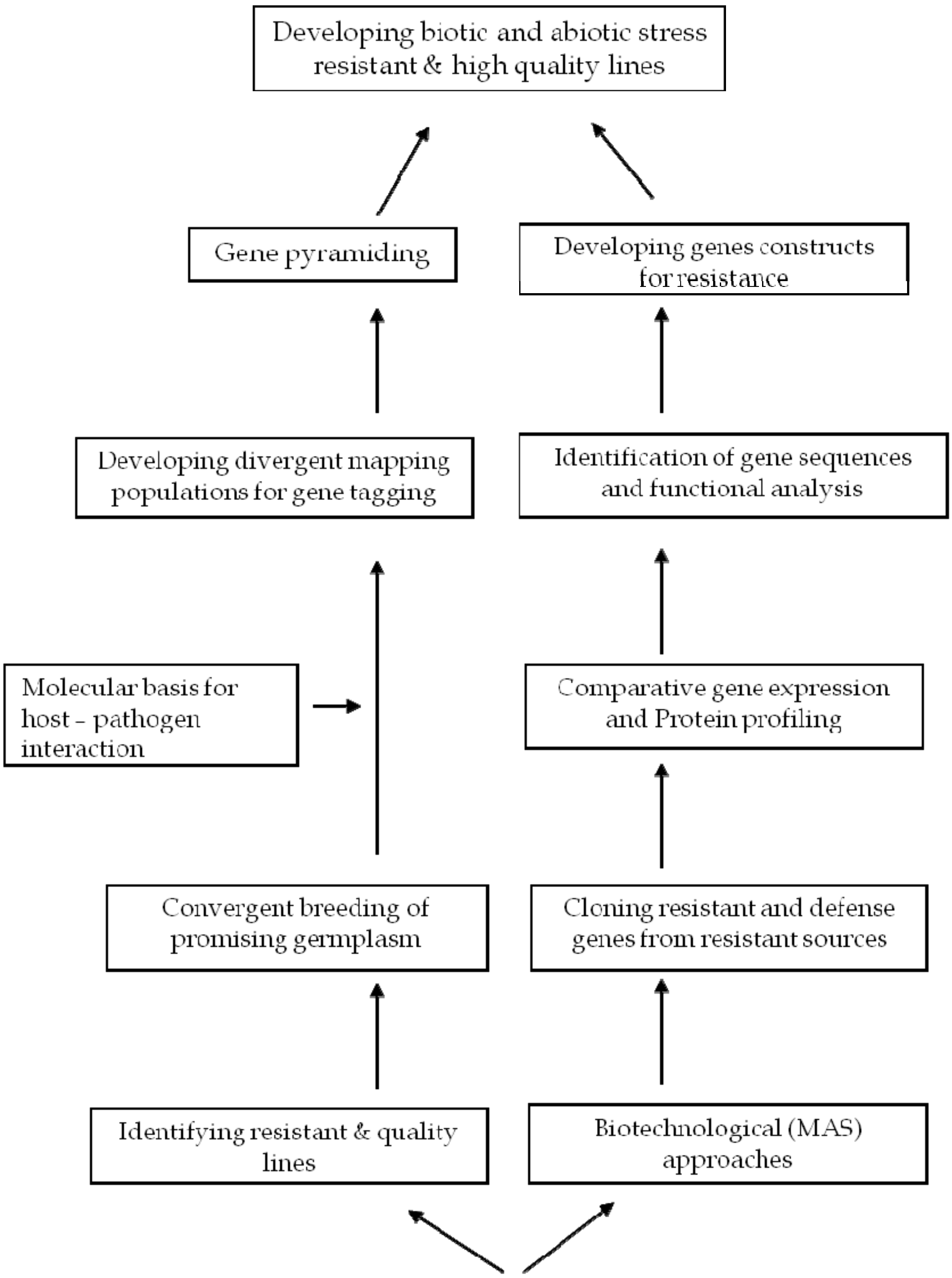

Figure 2: Improved varieties with resistance to biotic/ abiotic stresses

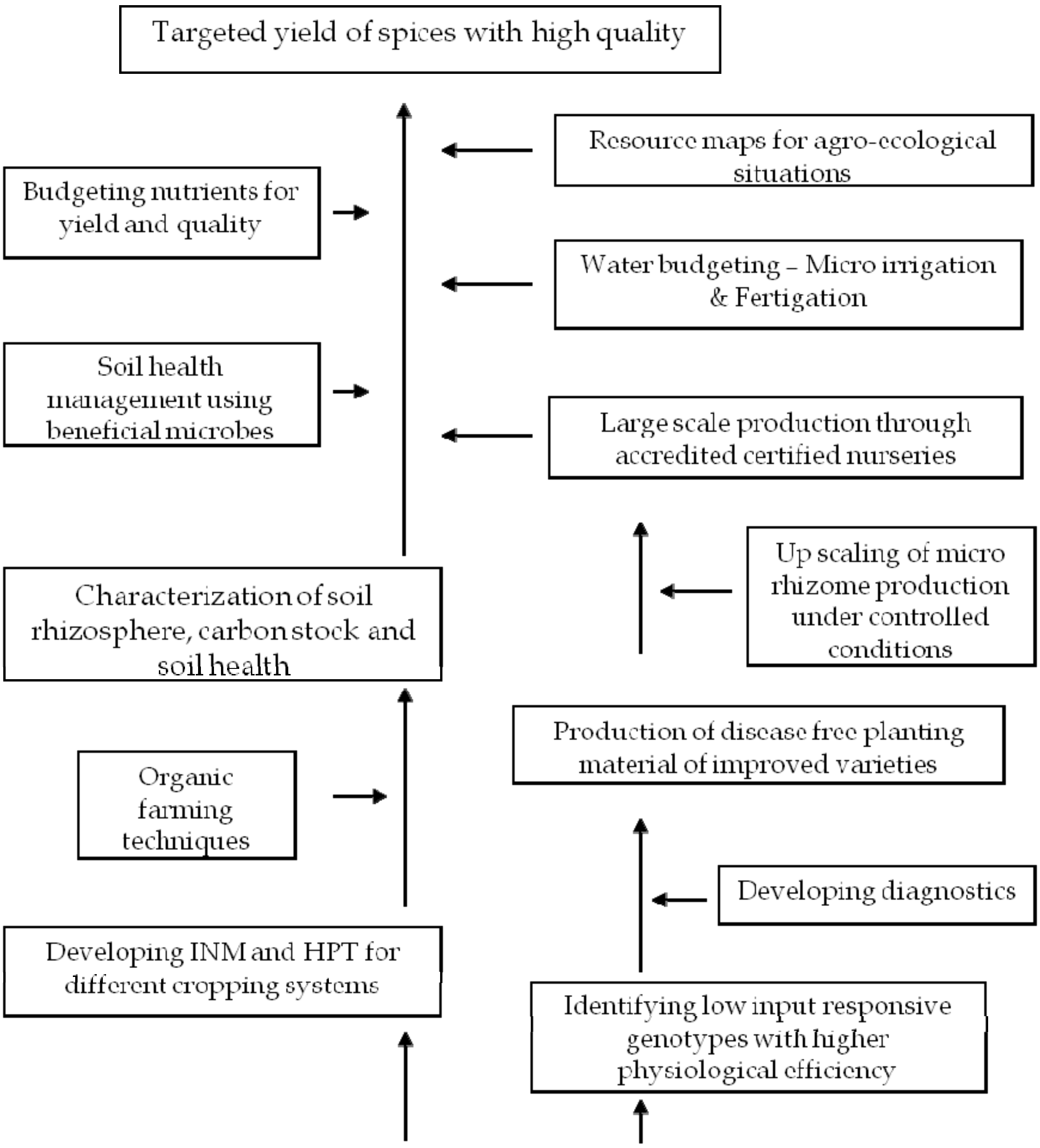

Figure 3: Resource budgeting and cropping system management

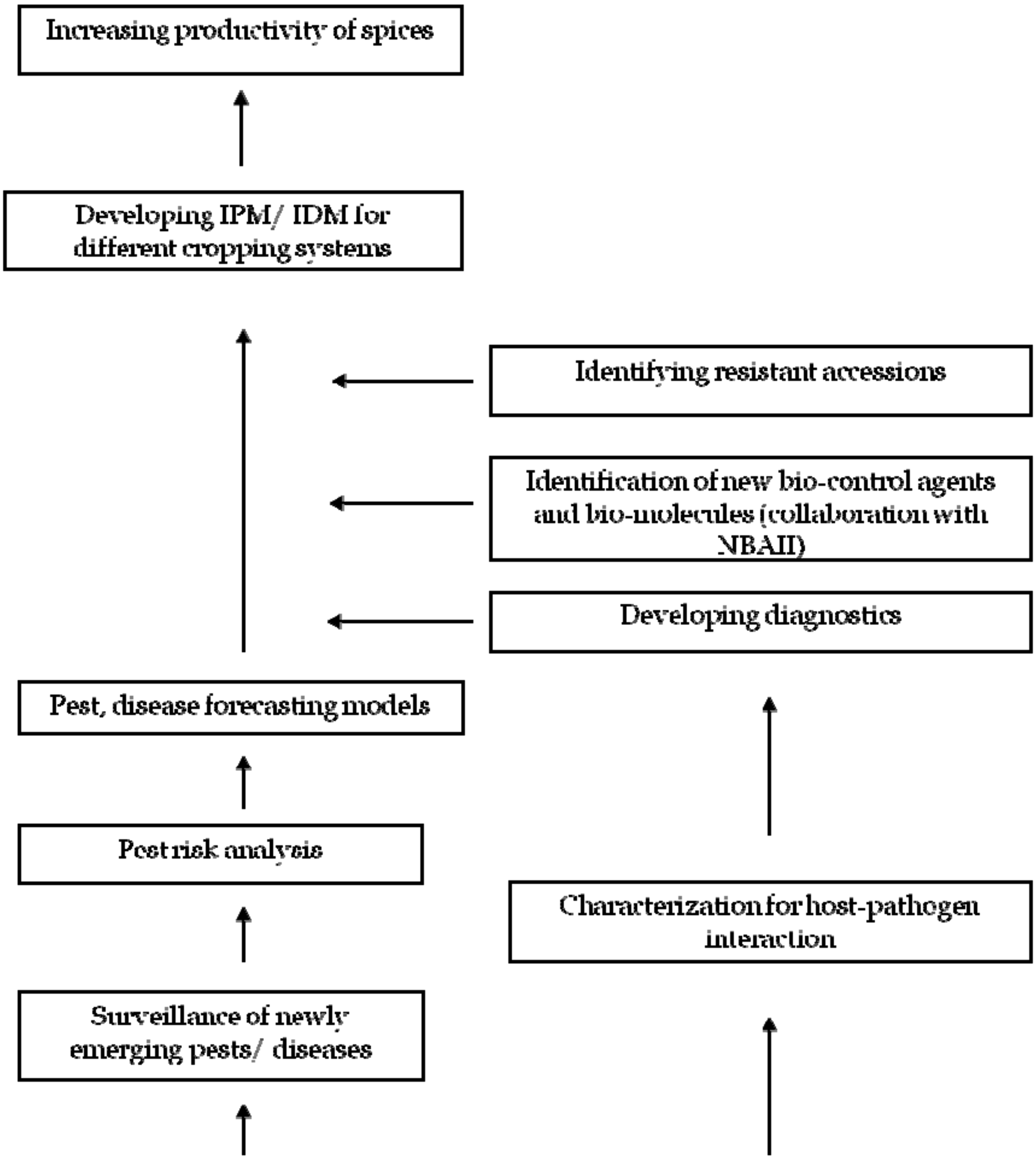

Figure 4: Bio-Risk Management

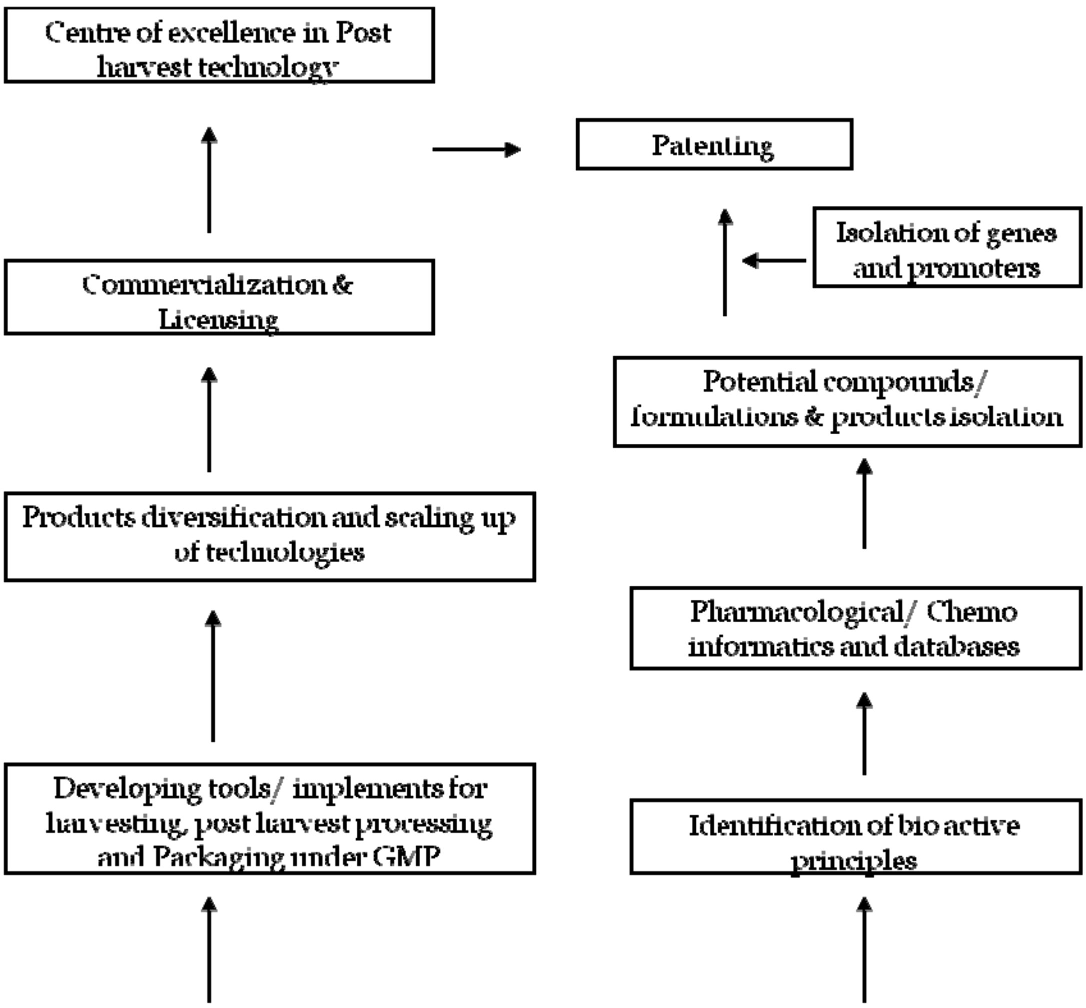

Figure 5: Secondary Agriculture

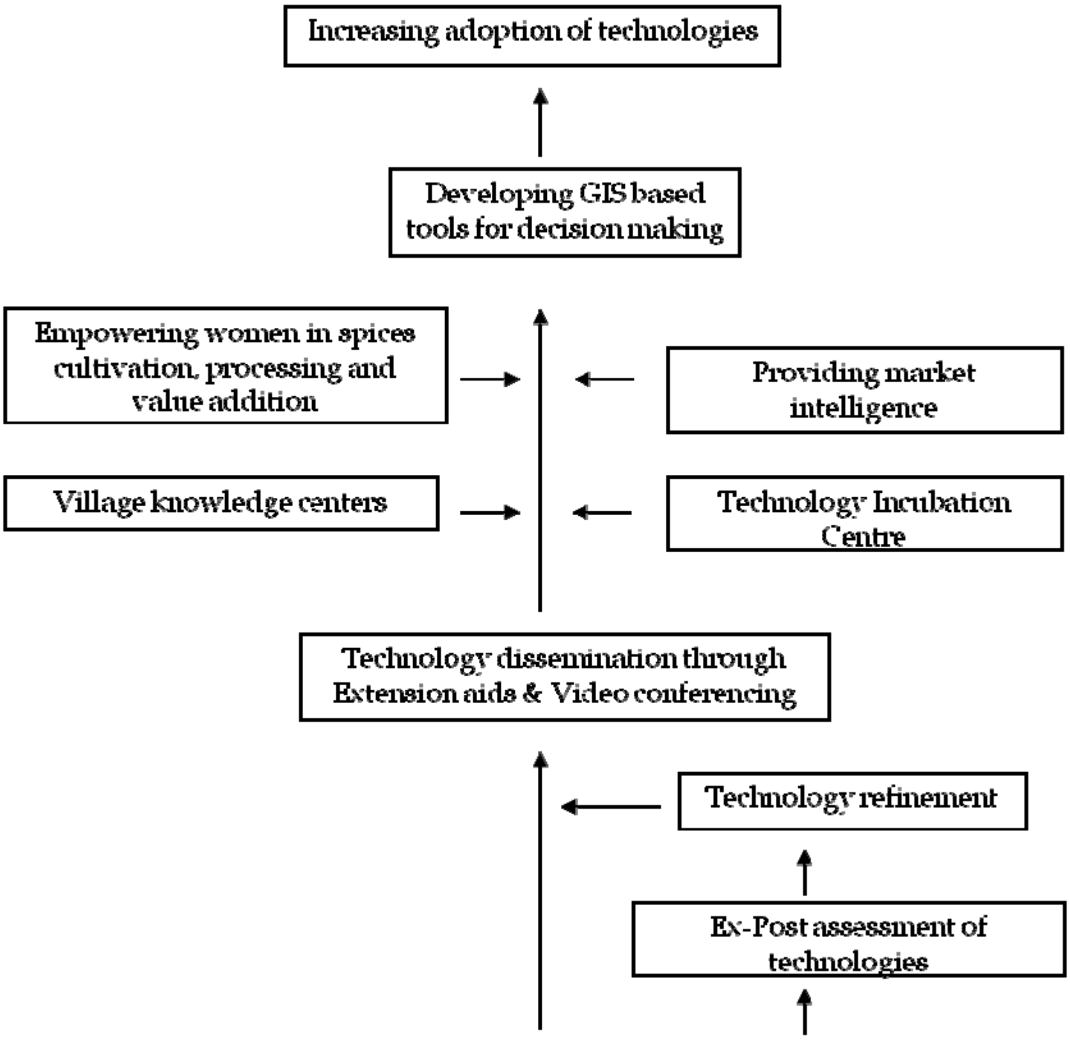

Figure 6: Technology transfer and Impact assessment

7. INTERACTIONS AND LINKAGES

IISR, Kozhikode has collaborative research programme with AICRPS, Spices Board, CSIR (CFTRI, Mysore & RRL, Trivandrum), Regional Cancer Centre, Trivandrum, and Sate Universities/ Agricultural Universities, where Coordinating Centers of the AICRPS are located, DASD Kozhikode, BIS, Directorate of Marketing, Spices Exporters Forum, Cochin and all related ICAR and NARS system institutes in the country to work on basic or applied research on spices. In addition in the frontier areas of science like bioinformatics, nanotechnology and knowledge management collaboration with NIT/ IITs and many foreign universities will strengthen the knowledge base and bring in vibrant progress.

Specific area of collaboration	Agencies
Biotechnology: Molecular microbiology of rhizosphere and its exploitation for sustainable spices production	• Centre for Environmental Biotechnology, University of Tennessee, Knoxville, USA • Soil and Water Science Department of the University of Florida, University of Florida, Gainesville, USA • Department of Crop and Soil Science, Oregon State University, Corvallis, USA • Department of Biology, Central Michigan University, Michigan, USA.
Biotechnology – Isolation of useful genes from spices for disease resistance and for production of secondary metabolites	• Department of Vegetable Crops, University of California, USA. • Department of Molecular and Cell Biology, University of California, USA. • Department of Plant Pathology, University of California, USA • Department of Wageningen UR Plant Breeding, Wageningen, The Netherlands.
Biotechnology– Development of disease resistant transgenics – utilizing the existing available genes.	• Department of Vegetable Crops, University of California, Davis, USA. • Department of Plant Pathology, University of California, Riverside, USA. • Department of Plant Pathology, Texas AM

	University, Texas USA
Biotechnology - Development of molecular markers to tag important agronomic traits in black pepper and cardamom	• Department of Vegetable Crops, University of California, Davis, USA. • Department of Plant Pathology, University of California, Riverside, USA. • Department of Plant Pathology, Texas AM University, Texas USA
Rhizosphere dynamics, C-budgeting, Crop modeling	• Rothamsted Agricultural Experiment Station, Harpenden, Herts, UK • Wageningen University, The Netherlands.
Nanotechnology – nano delivery systems for nutrient use efficiency	• Cornell University, USA • Wageningen University, The Netherlands.

8. EXPECTED OUTCOME

To achieve the targeted production and export in 2050, research output to overcome the production constraints becomes pivotal. The per capita consumption of the spices may increase by two folds as the purchase power on nutritious foods is expected to increase in future. IISR being the prime organization dedicated spices research, it is imperative that major thrusts in research programmes are oriented towards increasing productivity through mission mode programmes especially to overcome the major production constraints. Increasing the productivity per unit area through spice based farming systems, development of varieties with high degree of resistance to biotic and abiotic stresses, development of agro technology towards low input management, precision farming, developing ecofriendly IPM strategies, post harvest technologies with value addition and exploiting its medicinal properties, and popularization of proven technologies though extension network are the major areas. Besides, the new areas on nanotechnology, bioinformatics, carbon (C) and water foot prints and knowledge management would further strengthen the research programmes on climate resilient agriculture. These technological advancements will bring out the surge in productivity of spices, necessarily 2-5 fold increase in all major spices, to meet the consumption and export demand. The forecasted spices production by 2050 is expected to be achieved with an annual compound growth rate (ACGR) of less than three percent.

The growth of spices production will also lead to a significant growth in on-farm employment opportunities. The spice industry is expected to create surplus of employment potential in production alone as spice crops are labour intensive. Further, there is substantial scope for creating new jobs through value addition in spices. The envisaged increase in share of value added products in the export basket of spices needs strengthening of processing facilities both on farm and outside. The development of downstream processing, packaging and distribution activities can also generate millions of additional off-farm jobs. Thus the spice industry will help the country to achieve its goal of more than 10% growth rate in GDP and to sustain the same.