INAUGURAL LECTURE

MISSION 2007 : A NUTRITION SECURE INDIA

M S Swaminathan

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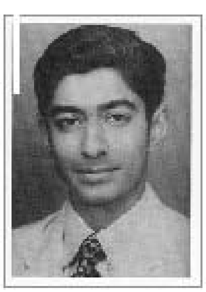
I have known Dr. Gopalan for nearly fifty years. I first met him at the Board of Biology of the Atomic Energy Department, headed by Dr. A.R. Gopal Iyengar. Dr. Gopalan's vision since then has taken shape in very significant directions. First of all, I would like to congratulate him on the 25th Anniversary of this great Institution, which he has built up brick by brick with the help of so many others as he has acknowledged in his speech. I call this Institution a Centre of Learning, a Centre of Knowledge and a Centre of Authority in areas relating to nutrition, for all times to come.

Secondly, we are also celebrating the life of a great young man, Shri C. Ramachandran. I call it a celebration because this young man achieved a lot within a short time. He was a creative genius and a role model, I would say, I can compare him with Ramanujam, who also died young, but during his short life achieved a lot. Had he lived long, he could have created wonders. Persons like him are a source of inspiration to students and scholars about what one can accomplish if one has the determination to do the very best in life.

Thirdly, I wish Dr. Gopalan a long and fulfilling life on his birthday today. I would also like to thank Mrs. Gopalan for the selfless support she has extended throughout and helped in converting Dr. Gopalan's dreams to reality.



C Ramachandran

Genius and a role model
for the younger generation

Keeping in view the subject of the symposium tomorrow, Dr.Gopalan suggested that I speak on some aspects of "Nutrition Security". I call this "Mission 2007"- a call to make India nutritionally secure by Aug.15, 2007, which marks the 60th Anniversary of our independence. From the beginning of this Millennium, several efforts have been made to achieve this goal.

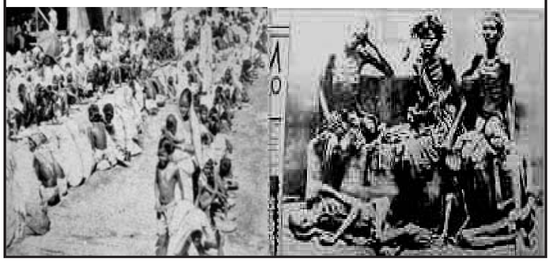
Nutrition Security

Our aim should be to achieve relative nutrition security for every man, woman and child in this country in accordance with the vision of Mahatma Gandhi 'to provide bread to those who are hungry'. The first duty of independent India is to ensure that no one goes to bed hungry or stays malnourished. Dr. Gopalan has devoted his whole life for this purpose and his emphasis has been on a paradigm shift from food security in macro-terms to nutrition security at the individual level. There are million tonnes of food grains in our godowns, hence, Nutrition Security at the level of each individual – every man, woman and child is possible and substantial progress, is a must in years to come.

I define Nutrition Security as "physical, economic, environmental and social access to balanced diet and clean drinking water for every child, woman and man". Nutrition security would require following inputs:

- Physical: production and communication.
- Economic: purchasing power - one must have the money to buy commodities for a balanced diet, for example, fruits and vegetables.
- Environmental: Hygiene, sanitation and safe drinking water.
- Social: equity in gender terms, social factors including intra and inter family distribution of balanced diet.

The Great Bengal Famine 1942-43



There has to be a paradigm shift from emphasis on food security at the macro level to nutrition security at the individual level. These have been the goals of Nutrition Foundation of India. I would briefly review where we are today in our journey towards a “Nutrition Secure India”.

India’s Major Achievement

On the 50th anniversary of our Independence in 1997, our then President and also a great admirer of this Institution and Dr.Gopalan himself, Shri K.R. Narayanan, said that India had two major achievements in the last fifty years. Firstly, our ability to not only preserve, but also strengthen our democratic traditions up to the grass root level through the Panchayati Raj. The second was food self-sufficiency through the green revolution. What should be the goal for the 60th anniversary of our independence on 15th August 2007? In my view, it should be the elimination of poverty induced endemic hunger.

Let me give you another example. The NFI is a wonderful example of what can be achieved by one individual with a small group of people in 25 years. Let us examine what the nation has achieved in 25 years - I speak of a span of 25 years starting from the Bengal Famine of 1942-43, which Amartya Sen says was an unnecessary famine, because at that time there was ample food production. But entitlements, or access to food was uneven and as a result not available to everyone.

Science and Agricultural Progress 1968
The Beginning of Wheat Revolution

Synergy between Technology and Public Policy

The period from 1963-1968 was very significant in our country. In 1968, our late Prime Minister Smt. Indira Gandhi announced that we had achieved a breakthrough in agriculture production through the great Wheat Revolution. A stamp was released on that occasion. It was the first time where the science of agriculture was recognized as a principal catalyst of agricultural progress in India. Food grain production had grown four-fold in the last five decades. Per capita availability of food grains has been sustained in spite of three-fold increase in population over the same period.

Current Challenges

Even in the midst of progress and development in agriculture, however, we have to think seriously whether the progress is going to be sustainable over a period of time. For example Punjab and Haryana, the bread baskets of India, are today on the brink of environmental unsustainability. Studies and maps from FAO reveal that hunger persists in the midst of plenty. As seen in the map, India’s position in terms of hunger is almost the same as parts of sub-Saharan Africa and other parts of Africa. It is very unfortunate that our estimates vary. If we see the 55th round of NSS, nearly 150-160 million people are chronically undernourished. Other data show figures over 400 million. Dr.Gopalan’s paper on “Low Birth Weight babies” (LBW) in this region clearly showed that even now about a third of our babies weigh less than 2.5 kg at birth. LBW children suffer from many handicaps higher morbidity and mortality during infancy, lower growth trajectory and higher risk of non-communicable diseases in later life. These revelations are great reminders of unfinished tasks. We have no time to relax now in terms of achieving Nutrition Security for our people.

Text Box 1 Towards a Food Secure India
A Call for Policies Initiatives and Public Action

Hunger	**Food Security**
Chronic	Availability
Hidden	Access
Trans ient	Absorption

Awareness - Analysis - Action

During 2000-04, along with the World Food Programme office in Delhi and its Director, Mr. Pedro Medrano in particular, we have been working on mapping the extent of food insecurity in India using 22 to 25 different parameters. The result of these efforts have been compiled and published as:

- Food Insecurity Atlas of Rural India
- Food Insecurity Atlas of Urban India
- Atlas of the Sustainability of Food Security in India

These are also available in CD ROM format. In all these atlases, we have studied and mapped hunger in all its dimensions for example chronic hunger, arising from poverty, hidden hunger caused by micronutrient deficiencies, and transient hunger resulting from natural calamities like droughts or floods (Text Box 1).

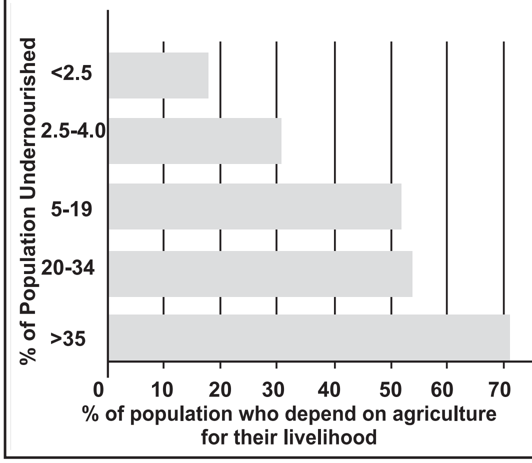
Food Security

Food Security is availability of food, which is a function of production; access to food, which is a function of purchasing power or livelihood opportunities and finally absorption or utilization of food in the body, which is a function of safe drinking water, primary health care and environmental hygiene. In the post Green Revolution scenario of increased production, the questions that arise are, why are our babies low birth weight? and why are so many people in our country still hungry, and have low BMI?

Employment Situation

One of the reasons is that in our country, growth rate in non-farm employment is very low. The number of people getting jobs outside the routine farm operations like ploughing, weeding and harvesting has not grown over the years in villages. On the other hand, in countries like Thailand and China, non-farm employment has grown significantly. I first got an opportunity to

Figure 1: Undernutrition and Dependence on Agriculture – 2000



study the Thai experience, when I was a member of the UN Commission on Nutrition. In India, we have a large number of people dependant entirely on the primary sector of the economy, hence we have a greater degree of under-nutrition (Figure 1). Rapid progress in diversifying our employment opportunities is very necessary. As long as one remains unskilled, the maximum one can expect is a minimum wage. A shift from unskilled to skilled work is very important; a large section of our labourers, particularly women do not even get the minimum wages.

Population Growth

It is often asked why inspite of so many institutions and great scientists, poverty, under nutrition and hunger continue to prevail in India? Why has FAO put India in a rank amongst other poor countries, which may not have the same infrastructure in terms of technology and educational facilities as India has? Our population has grown enormously. For example, China is adopting very rigorous methods of controlling population. It is a wise decision, as the future of their country will be jeopardized if they have more population. When I chaired the National Population Committee in 1993, I recommended that we must have a clear understanding not only of drug-based approach or contraceptive – based approach, but also take into account the social dimensions and issues and generate social awareness about the population supporting capacity of the

Text Box 2 Village Level Socio-Demographic Charter

Recommendations of the Swaminathan Committee on Population Policy, 1994

- Ecology: Population Supporting Capacity of the Ecosystem
- Food and Drinking Water Security
- Education: Universal School Education
- Health: Primary Health Care, immunisation
- Livelihoods: primary, secondary and tertiary sectors
- Gender Audit: LBW Children; sex ratio; school enrolment
- Maternity and child care code

If population policy fails, nothing else will have a chance to go right

ecosystem. We can start this right from schools. Educational tools should include the "Socio-Demographic Charter" which can be prepared by every school in the village, which looks at population supporting capacity (Text Box 2). For example, 1 tonne of wheat or rice can support 3 to 6 persons. So how much do we produce in this village? What is the population? Is there enough water for all? All these should be calculated and information charts produced.

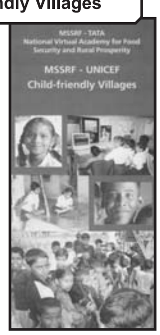
Recently we have initiated an overall rural education programme in association with UNICEF called the "Child Friendly Villages" (Text Box 3). Such child friendly villages can have a number of parameters starting from sex ratio, to number of low birth weight children and marriage below 18 years. For a Nutrition Secure India, we need a greater understanding and awareness about the environment and also about the problem of excess population and how far our country can support excess population.

IT Enabled Services

The Jamshedji Tata National Virtual Academy for Rural Prosperity established at the MSSRF in 2004 is another initiative for information empowerment of the masses. Jamshedji Tata, after whom Jamshedpur is named, was one of the great pioneers of industry during the colonial times. This Academy includes interconnected use of modern technology like internet, cable, community radio, TV and a local vernacular press in a much more effective way. For example, now fisher women of Veerampattinam, a village in Pondicherry are be able to download information from the U.S oceanography website on wave heights and information regarding the condition of the sea from Hyderabad. Community radio is another remarkable example of technology today, which can empower people with correct information, and knowledge for solving problem.

Text Box 3 MSSRF - UNICEF Child Friendly Villages

- Mobilise the community to ensure that no girl gets married before the age of 18 years
- Record male/female sex ratio at the time of birth and again at the age of 5 in the village
- Promote education among adolescents – both boys and girls – on HIV / AIDS and prevention and treatment of other illness including tuberculosis, diarrhea and acute respiratory infections



Through the new programme of the Indian Space Research Organisation (ISRO) and the new education satellite which our Prime Minister recently launched; best medical facilities or help can be made available even to the remotest of the villages. Reaching the 'unreached' and the poorest need not be just slogans any more. These are 'doable' at affordable cost.

Widening Food Baskets

On the production front, we need to widen the food basket because the global food basket is very narrow. Three or four crops dominate food security. If one looks at the book 'Lost crops of Incas', one realizes that a few centuries ago people were dependant on 200-300 crops for their health and food security. For example, millets, and red gram (pigeon pea) give excellent yield and enrich soil fertility. They improve the physical properties and chemistry of the soil. Even today, in Tamilnadu (in the Eastern Ghats region) 190 plants are used for health and security, which also includes some medicinal plants. Many of them are disappearing because of low economic value. We must generate an economic stake in conservation by linking "orphan crops" with markets.

Role of Community

One of the important mechanisms to address this problem is "Community managed gene, seed, water and food security system", which has got all the facilities of gene bank, seed bank, water bank and grain bank. Recently Ms. Komala Pujari, a representative of the tribal community in the Jeypore tract of Orissa, went to receive the “Equator Initiative Award” from the United Nations for the most outstanding community food security system developed by the Tribal community in Koraput, Orissa, a Center for diversity of rice. Such examples show the pathway to sustainable food security.

Micronutrient Deficiencies

One of the main problems today is of micronutrient deficiencies, from which plants suffer. Micronutrient deficiencies in the soil like sulphur, zinc, and boron are quite common in semi-arid areas. If we give macronutrients along with micronutrients – yield is improved considerably.

Genetically Modified Foods and Organic Forms

Coming to Genetically Modified foods, I went through a chocolate wrapper, which says, “this milk chocolate contains no genetically engineered ingredients”. Genetically modified foods and organic foods are being pitched against one another in industrialized country. Uttaranchal promotes organic farming and wants to be declared as an ‘organic farming state’. Organic farming is a good idea as long as it maintains soil fertility and promotes plant health. Successful organic farming needs intensive scientific research. But scientific organic farming itself requires a lot of help from biotechnology. For example bio fertilizers, stem modulating green manure, and bioremediation. In West Bengal and Bangladesh, bioremediation is the best method of removing the arsenic and some other heavy metals from ground water.

Modern genetic analysis has become a very valuable research tool. For example, Synteny, which is arrangement of genes in different crops like Oats, Maize, and Barley, is characteristic of many plant genomes. Recently we have started “Human Genome Clubs” in economically under privileged corporation schools, to introduce children to the meaning of the human and rice genomes.

We are entering the age of genomics and proteomics and nanotechnology. International Rice Genome Sequencing Initiative is a multi-country initiative for mapping Rice Genome. In a country like ours, with diverse cultures, people should invest in genomics. Fortunately, we have both public and private sector also funds research in this area. The Public Sector programme, funds the Rice Genome Project. The best thing is public and private participation. We should not be discarding Mendelian genetics or only worshiping the molecular genetics. We should combine Mendelian and molecular genetics in an integrated way. There are many examples of what our research workers have achieved in term of modification.

In Delhi, Ashish Dutta and his group at Jawaharlal Nehru University have transferred genes from *amaranthus* into potatoes. The Golden Rice, is another example. Originally the Vit. A levels were less but now it is 60 micrograms of Vit. A per gram. Variability occurs among varieties in the content of zinc and iron. We should screen different crops for their micronutrient content. A food-based approach is the best method of promoting dietary diversity and improving nutritional status.

Data on iron and zinc content of different rice varieties are shown in Table 1. The importance of choosing varieties with high iron and zinc content is obvious. A useful gene donor is the Mangrove species *Aveccinia marina*, where genes for ferritin have been isolated to detect the seawater tolerance. The mangrove gene(s) carrying rice lines are undergoing field trials, in accordance with bio-safety regulations.

Recently, Department of Biotechnology has initiated a new programme- Harvest Plus. The major thrust of the programme is to develope

Table 1: Iron and zinc contents of brown (unmilled) rice of selected varieties
(from Gregorio et al. 2000) (Mean values with their standard errors)

	Iron (mg/Kg)		Zinc (mg/Kg)	
Jalmagna	22.0	1.4	31.8	7.7
Zuchen	20.2	1.8	34.2	5.0
Xuz Bue Nuo	18.8	0.8	24.3	0.7
Madhukar	14.4	0.5	34.7	2.8
IR64	11.8	0.5	23.2	1.4
IR36	11.8	0.9	20.9	1.4

six staple food crops with high iron, zinc and provitamin A content first through conventional breeding and later if necessary through genetic modification.

National Programmes under the Department of Biotechnology, Government of India, currently headed by Dr. M.K. Bhan, for micronutrient studies has initiated studies on rice for iron enrichment by gremplasm screening, wheat for zinc by marker assisted selection and maize for low phytase by transgenics and introgression to locally adapted genotypes. Bioavailability and bioefficiency work have been allocated to the National Institute of Nutrition, Hyderabad. NFI could be the hub of many such exercises.

The new genetics and organic farming should not be put against each other for benefit of humanity. When we want the way ahead we should combine the wisdom of traditional technologies with modern science and technology.

Another neglected area is the farm animal population. Nutrition is important not only for ourselves but also for our companions, our animal population which comprises 25% of world's farm population like buffaloes, cattle, sheep, goat and poultry. We can use the entire biomass like rice bran, husk and also rice stalk as animal food.

Now CFTRI has developed the brown rice technology. Mahatma Gandhi always advocated hand-pounded rice to preserve the most nutritious layer, the aleurone layer. New technologies have been developed where we will not lose this nutritious layer. We must popularize them in a big way. It must be used efficiently with modern science and technology.

Food for Work Programs

India has a large food for work programme mainly developed for rural infrastructure development such as rural roads, watershed development and rural building. It is recommended that this programme must have a gender dimension. As far as women are concerned, they should not restrict themselves to food for work in construction activities but also for all-round human development, running crèches, and support services including running nutritious mid-day meal services. The concept of food for human development should be popularized.

Nutrition Security for Patients with HIV/TB infection

Nutrition security should be available for patients suffering from HIV-AIDS and TB, the two pandemic diseases. Nutrition in terms of health, in terms of control of diseases, also recovery from diseases should be the priority area for attention. In 1981, when Smt. Indira Gandhi asked me to chair a committee on the eradication of leprosy by 2000, I suggested that we must have nutrition support for leprosy patients in addition to access to multi-drug therapy. Data from Tuberculosis Research Centre, Chennai (TRC), has shown that prevalence of undernutriton is higher in patients with TB and HIV/AIDS. Mortality rate in tuberculosis patients shows an inverse correlation with body weight.

Way Forward

In my view seven basic steps, which are both affordable and 'doable' if implemented in mission mode will enable India to achieve nutrition security by 2007.

There are many nutrition safety net programmes in the country. Every government initiates programmes operated by different ministries and departments. What we need is the horizontal integration of the numerous vertically structured programmes and a delivery mechanism on the basis of a whole life cycle, starting from pregnant women and going up to old persons. There has to be nutrition security at the individual level. Self Help Groups of women can be harnessed and trained to assist in the delivery of the various programmes. If women, or self help groups of women do transaction, the cost will be low and the delivery system of such schemes will be more effective, transparent and corruption free. There are many gaps in our nutrition safety net programmes. One important area needing attention is maternal under-nutrition. Appropriate steps should be taken for adolescent girls and pregnant women to improve their health and nutritional status. Another important gap is infants and young children in the 6-24 months age group.

The second important point is a concerted effort to promote widening of the “Food Security Basket”. Instead of just depending on rice or wheat under the public distribution system, can we not revive our old food grains like various millets, pulses, oilseeds and tuber crops, which were life saving crops in the past? Even today they are life saving crops or part of the traditional cropping mechanisms adopted to avoid acute hunger. We must promote more number of crops in the food basket involving millets and also vegetables, especially green leafy vegetables. This can be done through decentralized storage and management of food at the community level through community food banks and community grain banks. In tribal areas of Orissa where such banks are in operation, the community stores the locally cultivated grain – *ragi* and its cultivation and consumption have received a boost.

Thirdly, the present Government is committed to implementing an Employment Guarantee Scheme (EGS). Our Prime Minister recently inaugurated the “National Food for Work Programme” in Andhra Pradesh in some of the areas of extreme distress, which witnessed farmers’ suicide. I think a time has come for us to combine the ‘Food for Work Programme’ and the ‘Employment Guarantee Scheme’ and evolve a “National Food Guarantee Scheme”. A National Food Guarantee Scheme according to some calculations will mean providing just another 15 million tonnes of food grains a year, a very affordable and manageable amount in our country. We are now at a stage where agriculture has become a gamble in the market; formerly, it was a gamble in the monsoon. For example, this year the cotton production is good. Farmers are asking how much cotton the Government can buy otherwise there is danger of the price crashing. This means that our consumption must grow and for that purchasing power has to grow. We have an advantage and opportunity of using food as cash and as currency in the country. Greater consumption and demand will stimulate farm families to produce more.

Fourthly, there has to be a thrust on self-employment for livelihood security. The growing Self Help Group movement is indicative of this. But this is largely concentrated in the Southern States. In these States, women in particular are organizing themselves into ‘self help groups’ and financial institutions are willing to give them loans not on the basis of collateral, but on the basis of viability of self help groups. If the government is going to increase rural credit, there has to be viability in utilization. We have developed detailed methods of converting self-help groups to sustainable self-help groups through backward linkages with technology and credit and forward linkages with market and management. All the available opportunities should be utilized.

Next is increasing productivity-based production or improving major farming system in crops, livestock, fish, poultry, agro-processing and agro-forestry. Enhancing the productivity of small farms will make a major contribution to the elimination of hunger and poverty.

It is important that there be a promotion of a food-based approach to nutrition security – through widespread cultivation and consumption of vegetables and fruits; nutritious use of underutilized food crops like millets and pulses is also important – a fact always emphasized by Dr. Gopalan.

Lastly, access to clean drinking water and maintaining environmental hygiene, are prerequisites for good health and absorption of nutrition by the body.

Conclusion

I want to conclude with a tribute to Dr. Gopalan’s late son and also to Dr. Gopalan’s contributions to institution building – both of NIN, which he has built to a world-class institution and as Director General, ICMR. At NIN, he organized the first Asian Congress of Nutrition where he brought all the Asian countries together on a common platform for the first time. Another very successful event was the IXth Asian Congress of Nutrition held in New Delhi. He has always been a visionary leader. He was the earliest to point out under-nutrition due to inadequate consumption is the nutritional problem of India.

Dr. Gopalan has been a fearless fighter throughout his life and has the courage of scientific conviction, which everyone should admire and follow. He has never diverted from what he thought to be true and never gave technical recommendations in order to please somebody- a mark of scientific integrity of the highest order. After retirement from positions in Government, he has devoted his energies to build up Nutrition Foundation of India and bringing the best in Nutrition Research and Nutrition Science to solve practical problems.

I hope we will all work together to reach the goal of Mission 2007: "A hunger-free India". In a political system, which responds to public opinion, we must go on pressing or putting emphasis on nutrition security as our first priority. Any country, which, undervalues its human resources and over values material resources, will always remains poor. Let us value the wealth of human resource in our country and develope our country on the basis of the economics of human dignity.

On the occasion of Dr.Gopalan's birthday and on the occasion of 25th birthday of his institution, Nutrition Foundation of India, I request all of you to join me and give a standing ovation to Dr. Gopalan.

SESSION 1

NUTRITION ORIENTATION TO FOOD PRODUCTION POLICIES

AUGMENTATION OF PULSES PRODUCTION

Masood Ali
Director, Indian Institute of Pulses Research, Kanpur

Pulses are "basic ingredient" in the diets of a vast majority of Indian population as they provide a perfect mix of high biological value when supplemented with cereals (Table 1). Each plant of the pulse crop is virtually nature's mini nitrogen factory, which enables it to meet its own requirement and also benefit the succeeding cereal crop. Pulses are also an excellent fodder for livestock. Besides their dietary value and nitrogen fixing ability, pulses also play an important role in sustaining intensive agriculture by improving physical, chemical and biological properties of soil and are considered excellent crops for diversification of cereal based cropping systems.

The progressive decline in per capita availability of pulses (69 g in 1961 to 37 g in 2004) in India is a matter of great concern. This is attributed to the steady marginalisation of their cultivation in the wake of the "Green Revolution" and burgeoning population. With assured supply of cereals at an affordable price, the main focus of policy makers and planners now is on nutritional security. To alleviate protein-energy malnutrition, a minimum of 50 g pulses/capita/day is required in addition to other sources of proteins such as cereals, milk, meat, eggs, etc.

Table 1: Share of Pulses in Nutrition Supply

Per Caput/day	World	Asia	India
Energy (Kcal)	56.00	51.90	117.40
Protein (g)	3.50	3.10	6.90
Fat (g)	0.40	0.40	1.00

To make up this shortfall in supply besides further demand from burgeoning population, about 19.6 million tonnes of pulses are required by 2007, which is expected to touch 28 million tonnes by 2020. This can only be achieved by improving productivity and using additional areas for pulse production through diversification coupled with favourable Government policies.

Global and National Scenario

Globally, pulses are the second most important group of crops after cereals. In 2002, the global pulse production was 55.16 million tonnes from an area of 69.78 million ha with an average yield of 791 kg/ha (FAOSTAT 2002). The latest triennium production (1999-2001) averaging 54.41 million tonnes showed substantial growth of 1.42% per annum over 42.32 million tonnes recorded in 1980-82 (Table 2). Comparative data for the eighties and nineties reveal that the phenomenal growth was restricted only during the first decade (1980-82 and 1990-92) followed by near stagnation in the second decade. The share of developed countries in the global pulse production is around 15.80 million tonnes (29%). At present, the developing countries account for 87% of the total pulse area and contribute 71% to the global production with an average yield of 645 kg/ha, which is far behind the average yield of 1734 kg/ha harvested by the developed countries.

During the eighties, the growth was due to area as well as yield increase whereas in nineties, the yield growth was leveled off and area growth

Table 2. Area, production and yield of total pulses by regions (FAO 2001)

Region	Area {m ha}			Production (mt)			Yield (kg/ha)		
	1980-82	1990-92	1999-2001	1980-82	1990-92	1999-2001	1980-82	1990-92	1999-2001
World	62.08	67.47	69.00	42.32	54.45	54.41	682	807	789
Asia	35.01	35.30	35.41	21.87	23.93	25.41	625	678	721
India	22.85	23.54	22.00	10.24	13.05	13.63	448	554	619
Developing	52.78	56.73	59.88	31.89	35.82	38.60	604	639	645
Developed	9.30	10.74	9.12	10.43	18.63	15.80	1127	1736	1734

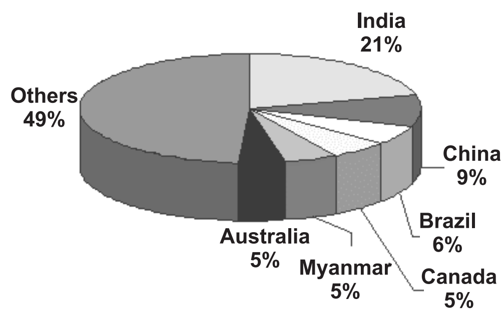


Figure 1: Share of Different Countries in Pulses Production

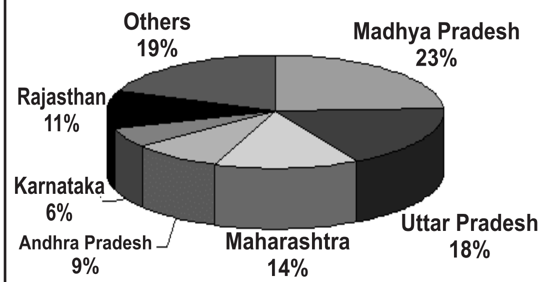


Figure 2: Share of Different States in Pulses Production

slowed down. Asia accounts for 51% of the global pulse area and 47% of its production. Positive growth was recorded for pulse production in Asia in both the decades and mainly attributed to growth in yield despite near stagnation of pulse production areas. Major pulse producing countries (Figure 1) in order of their contributions are India, China, Canada, Brazil, Australia, Nigeria, France, Myanmar, USA, Turkey and Mexico with about 68% of the production (FAOSTAT 2002).

The latest estimate reveals that pulses are grown in 22.6 million ha area in the country producing 15.23 million tonnes of production with average yield of 673 kg/ha. India is the key player with 25% share in the global pulse basket from an area of about 32%, the annual production being 13.63 million tonnes in latest triennium. The important pulse producing states (Figure 2) are Madhya Pradesh, Uttar Pradesh, Maharashtra, Rajasthan, Karnataka and Andhra Pradesh, which together account for 75% production. A look at the growth statistics shows that there was a positive growth in production of pulses in the country since independence. However, the source of growth varied with the periods. If area expansion was the major factor for growth during 1951-67, the yield improvement has been the key element in the post-All India Coordinated Pulses Improvement Programme (AICPIP) period (1967-2002). The past two decades have shown that the national pulse production has increased from 10.24 million tonnes in 1980-82 to 13.12 million tonnes in 1999-2002, registering a growth of 1.66% annually. However, the share of pulses in the total food grain production has reduced to 6.5% presently from 15.8% in 1951-55 (Figure 3).

Figure 3: Trends in Area, Production and Yield of Total Pulses in India

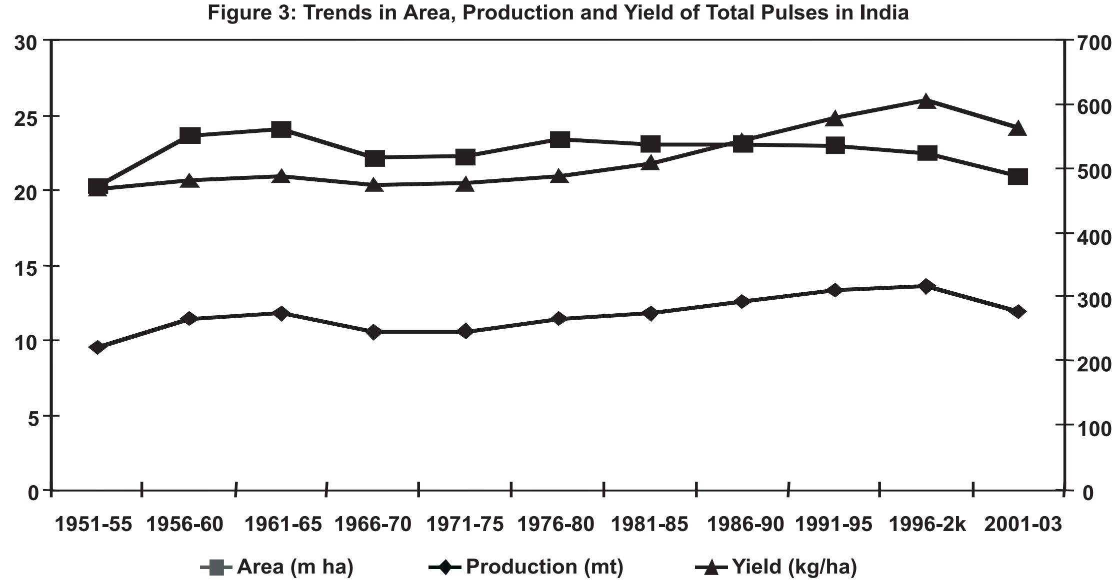


Table 3. Import and export of pulses in India

Year	Import		Export	
	Quantity (000' tonnes)	Value Rs. crores)	Quantity (000' tonnes)	Value (Rs crore
1990-91	791.95	473.24	-	-
1991-92	312.61	255.27	-	-
1992-93	382.62	334.37	34.31	53.44
1993-94	628.18	567.01	43.60	73.59
1994-95	554.27	592.73	50.51	90.41
1995-96	490.75	685.57	61.36	131.91
1996-97	654.91	890.34	55.22	131.58
1997-98	1008.16	1194.64	168.05	360.89
1998-99	563.60	708.81	104.10	223.03
1999-2000	250.77	354.69	194.18	419.56
2000-2001	349.84	498.47	244.08	537.08
2001-2002	2177.13	3155.66	159.55	366.18

Trade

The country is in gross deficit of pulses and thus requires meeting this shortfall through imports. During 2001-02, the country imported 21.77 lakh tonnes of pulses valued at Rs 3155.66 crore (Table 3). The most widely traded pulse crop is dry pea followed by dry beans, lentil and chickpea. Since, the majority of the pulses are consumed locally and do not enter the world market except in a small quantities (12% of the total production), any increase in demand from India generally leads to an increase in international prices; draining the precious foreign exchange and negative trade balance.

With rapid growth of the agriculture sector in the post-General Agreement on Trade and Tariff (GATT) era and the opening up of the markets for agricultural produce, there is a danger of cheap imports finding their way into the Indian market thus, making pulse production unsustainable and uneconomical. Expansion of pulses, for example chickpea in Australia and Canada, has been dramatic mainly because of the export opportunities available. In Canada, area and production of chickpea have increased from negligible in 1991 to more than 0.28 million ha with a production of 0.39 million tonnes at present, recording average productivity of 1368 kg per ha. This makes Canadian chickpeas quite competitive. Indian exports are mostly comprised of lentils to the Middle East countries.

Major Constraints

In the post-Green Revolution period, the per capita availability of pulses has declined sharply in the country, mainly due to mismatch in population and production growth. In spite of having the largest area under chickpea, pigeonpea, lentil, dry beans and total pulses in the world, India's position in average production of these pulses has not been decent, i.e., 24th position in chickpea, 9th in pigeonpea, 23rd in lentil, 104th in dry beans, 52nd in dry pea and 98th in total pulses (FAO 2001). Similarly in Asia, the country's position in average production of these crops is not commensurate to the first position held up for production. Except chickpea and pigeonpea, the average production of other pulses in the country is significantly lower than the average yield in the world. For example, average production of lentil, dry pea and dry beans in India is 791, 1000 and 447 kg per ha as compared to global averages of 938, 1830 and 705 kg per ha, respectively. India's productivity is meager in most of the pulses as compared with highest yielding country and the average productivity of the five top most productive countries.

Text Box 1
Production Constraints in Pulses

- Lack of high yielding varieties adapted to diverse growing condition
- Large area under rainfed cultivation (88%)
- Biotic and abiotic stresses (up to 30% losses)
- Poor plant stand
- Poor response to high input conditions and better management
- Moisture stress at terminal growth stage
- Inadequate seed replacement rate
- Emerging deficiencies of secondary and micro-nutrients
- Low risk bearing capacity
- Resource poor farmers
- Poor crop management

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The major constraints that limit the potential yield of pulses in the country are well known (Table Box 1). Besides socio-economic factors, these include biotic and abiotic stresses prevalent in the pulse-growing areas. Fusarium wilt coupled with root rot complex is probably the most widespread disease followed by Ascochyta blight mainly in the cool and humid climate of the north-west plain zone and botrytis grey mould in north-east plain zone causing substantial chickpea losses. While fusarium wilt, sterility mosaic, phytophthora blight and alternaria blight cause substantial pigeonpea losses, yellow mosaic, cercospora leaf spot and powdery mildew are considered as the most important diseases in both mungbean and uradbean. In lentils, diseases like rust, powdery mildew and wilt cause considerable damage. Powdery mildew and rust are the two most important and widely spread foliar diseases of dry pea throughout the country. There are some key insect pests, gram pod borer (*Helicoverpa armigera*) in chickpea and pigeonpea, pod fly in pigeonpea, whitefly, jassids and thrips in dry beans, aphids in lentil and bean fly in dry pea that cause severe damage to the respective crops. Weeds also cause substantial loss to pulses. Recently, nematodes have emerged as a potential threat in the successful cultivation of pulses in many areas.

The abiotic stresses include terminal drought, high temperatures during the reproductive stage, cold sensitivity during the vegetative and flowering stages and salinity/alkalinity throughout the crop period. These inflict major yield losses and instability in production. All these make pulse crops less productive with unstable performance. Consequently, pulses are perceived as marginal farmers' crops laden with high risk and poor yield. This perception discourages farmers to invest in requisite inputs vital for its successful cultivation. This is further confounded in the absence of favourable market intervention in the form of minimum support price and efficient procurement mechanism besides lack of liberal credit policy. On the technological front, pulses still need major breakthrough in yield levels through morpho-physiological changes in plant type and development of multiple disease resistant varieties coupled with tolerance to abiotic stresses. The potential of already generated technologies demonstrated in farmers' fields has not been realized at the national level mainly because of non-availability of quality seeds along with critical inputs in time, limited irrigated areas, low priority given to pulses by the farmers and poor crop management. Moreover, pulses are generally grown by resource poor farmers on marginal and sub-marginal lands under rainfed conditions, which is often characterized by extremely diverse and unpredictable environmental factors. Inadequate transfer of technologies, poor storage, lack of processing and marketing facilities further discourage farmers to extend areas for pulse production.

Technological Advances

Systematic and concerted research efforts over the years have resulted in increasing production technologies for pulse crops, which have brought about wider adaptability, yield stability, higher yield, and market specific characteristics like seed size and colour besides early maturity and tolerance to biotic and abiotic stresses. Focused programmes on breeding and refinement of production and protection technologies have shown a profound effect on crop productivity. About 480 varieties of various pulse crops have been released so far, out of which 360 were released after 1960. These varieties are not only high yielding but also withstand the onslaught of biotic stresses thus providing the much-needed stability in the production. As a result, there is a marked reduction in the periodicity, frequency and intensity of outbreaks of biotic stresses. In addition to resistance sources against key diseases and insect pests, substantial advances have also been made in recent years towards other components of integrated pest management such as cultural practices, bio-agents and bio-pesticides. By adopting these practices, it is now possible to control many of the pathogens hitherto unmanageable. The relative stability of pulse production as measured by low coefficient of variation also confirms the steady improvement in stability during the past decade. The coefficient of variation, which was 14.8% in 1951-60, has steadily declined to the present manageable level of about 7.32%.

One of the most important achievements of research efforts in pulses has been substantial reduction in duration of improved varieties. This has increased the per day productivity of pulses comparable to any rainfed crops including rainfed rice and wheat besides making them suitable for introduction in new niches and diversification of the existing cropping systems. Expansion of uradbean in rice fallows of coastal regions was possible due to development of short-duration and powdery mildew resistant varieties (LBG 17 and LBG 402). Development of extra-early varieties of uradbean/mungbean with synchronous maturity and resistance to yellow mosaic virus has helped their introduction and expansion in the Indo-Gangetic plain as catch crop during spring/summer season. Development of short-duration varieties of pigeonpea such as UPAS 120, Manak, AL 15, AL 201, Pusa 84, Pusa 992 and ICPL 151 has paved the way for area expansion under pigeonpea-wheat sequence in the irrigated areas of Punjab, Haryana, Delhi, north-western Rajasthan and Uttar Pradesh. Development of pigeonpea varieties suitable for planting in early September coupled with alternaria blight resistance has added new dimension to pigeonpea production in flood-prone area of north-east plains making maize-*rabi* pigeonpea sequence popular in Bihar. Similarly, identification of chickpea varieties suitable for late planting (KPG 59, Pusa 256, PBG 1 and Pusa 372) has led to diversification of rice-wheat system in the tail end of command areas of north India where irrigation is not enough to support good crop of wheat. A dramatic increase in chickpea area in southern and central India from 1.3 million ha in 1975 to 3.10 million ha in 1999-2000 has been possible due to development of high-yielding varieties like ICCV 2 capable to complete their duration before the onset of terminal drought. Other success story is the introduction of *rajmash* in the irrigated areas of eastern Uttar Pradesh, north Bihar, Vidharbha region of Maharashtra and Orissa as a *rabi* crop. This was possible mainly due to development of high-yielding varieties, such as Uday, Amber, HUR 15 and HUR 137 suitable for winter sowing, with matching agro-technology. Besides, production technologies for early pigeonpea, late chickpea, dwarf pea, *rabi rajmash*, *rabi* pigeonpea, spring/summer mungbean and uradbean have been developed. The management practices have been refined to increase efficiency of production inputs.

Production technology of promising crop rotations involving pulse crops such as pigeonpea-wheat, rice-chickpea, rice-lentil and rice-uradbean/mungbean, mainly popular in Peninsular India have been worked. Systematic research on inter/mixed cropping with emphasis on genotypic compatibility and spatial arrangement has led to identification of efficient intercrops, such as, pigeonpea with soybean, groundnut, uradbean, mungbean and sorghum; chickpea with mustard, linseed, safflower and coriander; lentil with mustard and linseed; uradbean/mungbean with spring sugarcane and sunflower; and *rajmash* with potato. These intercrops, in a particular row ratio significantly increased total productivity and land use efficiency besides improving soil health.

Strategies for Increasing Pulses Production

The country has experienced progressive decline in per capita availability of pulses from 69 g in 1961 to 37 g in 2004. With assured supply of cereals at an affordable price, the main focus of policy makers and planners now is on nutritional security. This can be only be achieved by adopting increasingly more productive technologies along with favourable developmental policies. To make the nation pulse sufficient, the productivity level of pulses has to increase substantially from the present level of 638 kg per ha to 800 kg per ha by 2007 with a minimum growth of 4.0% in production. This requires a proactive strategy from researchers, planners, policy makers, extension workers, market forces and farmers aiming not only at boosting the per unit productivity of land but also at reduction in the production costs. The following approaches require immediate attention, which can have substantial bearing

Text Box 2
Strategies for increasing pulse production

- Genetic options
- Management options
- Developmental efforts

on the pulse production without further constraining natural resources:

- Improving productivity
- Bringing additional Area under Pulses

If there is any group of crops, that have the scope of improvement, it is pulses, where the past efforts have not been as concentrated or provided the rewarding results seen with wheat and rice. Different approaches like genetic, management and developmental options are available for improving productivity (Text Box 2).

Genetic Options

Efforts are needed to design varieties of pulses with appropriate growth habits and efficient source-sink relationships besides restructuring the plant as per the environmental requirements and cropping systems. Introgression of unexplored genes from the wild relatives could be rewarding for broadening the genetic base of important traits such as yield, yield attributes and resistance to biotic and abiotic stresses in pulses. The prospect is bright for further improvement in stability of resistance through vertical gene management and multiple resistances. Thus, immediate attention is needed on the following options:

Improved plant type

It has amply been demonstrated in cereals particularly wheat and rice that physiologically more efficient plant types are essential for breaking the yield barrier and pulses are no exception to this. Pulses are grown under varying agro-ecological conditions and each set of conditions needs a specific plant type for higher productivity. Most of the pulses still have wild traits like indeterminate growth habit, pod shattering, pre-harvest sprouting and sensitivity to photoperiod and temperature regimes. It is presumed that the determinate types under good management would partition photosynthate to yield components with greater efficiency. Similarly, photo and thermo insensitive varieties will be able to have wide adaptability with minimum seasonal and regional effects on their phenology and yield potential besides a more synchronous reproductive ontogeny and greater harvest index. The greatest physiological potential of genetic improvement in the productivity of the pulse crops lies not with increasing total biomass, but with increasing the proportion of biomass partitioned into seed i.e., higher harvest index (HI). For example, HI in late pigeonpea is very low ranging between 18-20%. Due to some unknown physiological factors, carbohydrates and nitrogenous products start accumulating in leaves and stems in pigeonpea, and as a result, major proportion of these products remain stored in non-transportable form of reserved carbon and nitrogen. Some enzymes are very useful for breaking down the large non-transportable carbohydrates into smaller units and thereby facilitating sugar translocation from leaves. The regulatory aspects of these enzymes and mechanism of carbohydrates transport are essential to understand source-sink relation for improving productivity.

Besides these physiological considerations, the plant type has to be restructured as per the environmental requirement and prevailing cropping systems. Breeding objectives need to be directed keeping in mind the impact of altered plant types on the yield of the component crops. Simulation models developed recently for some of the pulse crops offer the potential to interpret and predict the performance of individual genotypes in different environments, thus, offering a possible role in decision-making regarding suitability of the proposed plant type in the target environment and prevailing cropping systems.

Exploitation of hybrid vigour

Due to partial outcrossing and spontaneously arisen genetic male sterility (GMS) system, pigeonpea has been considered for exploitation of hybrid vigour for the past two decades. Six GMS based hybrids viz., ICPH 8, PPH4, COH 1, COH 2, AKPH 4104 and AKPH 2022 were released in the past. These hybrids have shown definite yield advantage over traditional varieties. However, these hybrids could not become popular due to the need to manually rogue out the male fertile segregants within female rows after initiation of flowering. This leads to higher cost of production on account of labour in seed production, and imperfect elimination of the fertile sibs reduces the quality of hybrid seed. An economically sound seed production technology is required so that quality hybrid seeds are supplied at affordable price. With the development of cytoplasmic male sterile and fertility restorer lines in pigeonpea, commercial exploitation of hybrid vigour appears to be a near possibility for a possible breakthrough in yield potential of pigeonpea. Recently, two stable cytoplasmic male sterile lines GT 288A and 67A were developed utilizing cytoplasm of wild species, *Cajanus scarabaeoides* and *C. sericeus.* Simultaneous conversion of CMS lines into suitable agronomic backgrounds and identification of fertility restorer lines resulted in the development of experimental hybrids. The first CMS based pigeonpea hybrid, GTH-1, has been released for cultivation in Gujarat as it gave 32% yield superiority (1627 kg/ha) as compared to the best check GT 101 (1228 kg/ha). Besides higher yield, it matures in 140 days and has large white seeds.

More efforts are needed, which are, directed towards diversification and stability of cytoplasmic male sterility, genetic enhancement of component lines (A and R lines) through insulation against key diseases and insect pests and identification of heterotic cross combinations. Appreciable heterosis reported in other pulse crops make them suitable for its exploitation. However, this requires an efficient male sterility system coupled with fertility restoration before invoking this option in other pulse crops.

Exploitation of untapped yield genes

Wide hybridization in pulse crops has been attempted for broadening the genetic base of cultivated germplasm, creation of genetic variability for efficient plant types, introgression of genes for wider adaptability and minimizing the risk of epidemics. Important traits introduced from wild species into the cultivated varieties are resistance to cyst nematode and cold tolerance in chickpea, resistance to MYMV and bruchid in *Vigna* and male sterility in pigeonpea.

Wild species of chickpea are rich reservoir of not only resistant gene against various biotic and abiotic stresses but also genes responsible for high yield, more seeds/pod, hybrid vigour, etc. Conventional crossing has been successful in producing inter-specific hybrids between *C. arietinum* and *C. reticulatum*. Incorporation of resistance to cyst nematode is an example of successful introgression from *C. reticulatum*. Similarly, transfer of cold tolerance from *C. reticulatum* and *C. echinospermum* has been achieved. Unfortunately, most of the desirable genes are in *C. bijugum, C. judaicum* and *C. pinnatifidum* and could not be exploited due to crossing barriers with the cultivated species. Recent success in inter-specific hybrid between *C. arietinum* and *C. echinospermum* and availability of new biotechnology tools for circumventing crossing barriers have further brightened the prospects of transferring useful traits from primary and tertiary gene pools in chickpea.

In pigeonpea, inter-specific crosses were made with the objective to broaden the genetic base of cultivated germplasm, incorporation of biotic and abiotic stresses and development of cytoplasmic genetic male sterile lines. Potential traits of wild *Cajanus* species useful for pigeonpea improvement have been identified. For instance, *C. scarabaeoides* possesses both physical and antibiosis types of resistance to pod borers while *C. sericeus* and *C. albicans* are rich in protein. *C. albicans* has tolerance to soil salinity. Resistance to phytophthora stem blight is available in *C. cajanifolius*. Several wild relatives were used in hybridization programme with *C. cajan* and sterile plants were isolated from the segregating populations. Male sterile plants were isolated from interspecific cross of *C. scarabaeoides,* and *C. sericeus* with cultivated species.

Vigna has six cultivated species namely mungbean (*V. radiata*), urdbean (*V. mungo*), cowpea (*V. unguiculata*), moth bean (*V. aconitifolia*), rice bean (*V. umbellata*) and adzuki bean (*V. angularis*) and six wild species, namely, *V. trilobata, V. grandis, V. dalzalliana, V. vexillata, V. radiata var. sublobata* and *V. mungo* var. *silvestris*. Inter-specific crosses between cultivated and wild species were attempted to transfer specific genes for resistance to diseases, insect pests and other edaphic stresses. Crosses between mungbean and uradbean were attempted to combine desirable features such as durable resistance to MYMV and cercospora leaf spot, synchronous maturity, resistance to shattering and high methionine content of uradbean and more seeds per pod, erect growth habit and better quality traits of mungbean. Synchronous maturity and shattering resistance have been successfully transferred from urdbean to mungbean. A wide range of variation for plant types and other agronomic traits was observed in segregating generations of a cross between mungbean and uradbean (Pant Mung 2 x AMP 36) resulting in isolation of several superior progenies. For example, more seeds per pod of mungbean can be transferred to uradbean. Bruchid resistance, a novel characteristic not found in the parent species, can be recovered in the segregating generations of mungbean x urdbean cross. A high yielding variety of mungbean, Pant Mung 4 with improved plant type and resistance to several biotic and abiotic stresses, has been developed from a cross between mungbean and uradbean. However, interspecific hybridization was successful only when mungbean was used as female parent with uradbean and uradbean with rice bean. Improved techniques have increased the possibilities of success between *V. mungo* and *V. angularis*. Wild type *V. mungo* var. *silvestris* is valuable source of resistance against biotic and abiotic stresses. Some accessions of *V. radiata* var. *sublobata* have resistance to MYMV and non-preference to bruchids. Such crosses were attempted and segregants for profuse podding and MYMV resistance were isolated. Similar observations were also recorded in a cross between urdbean and *V. mungo* var. *silvestris*. Crosses between mungbean and rice bean were attempted to combine two mechanisms of resistance to MYMV in mungbean.

Lens culinaris Medic is the only cultivated species of genus *Lens* with two subspecies *macrosperma* with large seeds, yellow cotyledons and no pigmentation on flower and vegetative parts and *microsperma* with smaller seeds, orange and yellow cotyledons and more pigmentation. Based on the crossability studies, *L. orientalis* and *L. odemensis* were found to share common gene pool with the cultivated species and can easily be crossed with cultivated species. Slight chromosomal rearrangements may cause partial sterility, but there are still ample opportunities of gene flow for utilization of these wild forms in lentil improvement programme. *Lens nigricans* can also be used in breeding programme through embryo rescue. *Lens ervoids* yielded partially fertile F1's through embryo rescue. In lathyrus, interspecific crosses involving *Lathyrus sativus* with *L. tingitanus* and *L. aphaca* have been tried for transferring disease resistance into cultivated species.

Transgenics in pulses

Most of the pulses have been shown to be amenable to genetic transformation using recombinant DNA and tissue culture procedures. However, a highly reproducible transformation and regeneration system is prerequisite for the introduction of foreign gene into desired background. Effective protocols are available for regeneration *via* organogenesis and somatic embryogenesis in pigeonpea and chickpea. Successful efforts have been made to obtain multiple shoots through direct and indirect organogenesis. Several explants like, embryonic axes, cotyledonary node and apical shoot meristems have been tested. For development of transgenics, both *Agrobacterium* mediated and direct gene transfer methods have been used. So far, most of the transformation in pulse crops is limited to transfer of marker genes. Efforts are on to develop transgenic plants of chickpea and pigeonpea, which are resistant to gram pod borer *(Helicoverpa armigera*) using Bt crystal protein genes. At IIPR, transformed callus and plantlets of chickpea and pigeonpea possessing *npt II, bar* and *Cry 1Ab* genes have been obtained through *Agrobacterium* mediated transformation. Similarly, transformed plantlets have been obtained in pigeonpea using gene gun and *Agrobacterium* methods. Transformed chickpea plants possessing Cry1Ab gene have also been reported from IARI and ICRISAT. NCL and NBRI also conduct research in the same direction. Besides use of Bt genes, genes of plant origin like, lectins, protease and amylase inhibitors also hold great promise. Plant chitinases with antifungal activity against several fungal pathogens have been purified. The potential of chitinases in biocontrol has stimulated interest to isolate genes encoding these enzymes and for cloning them into plants. NCL Pune has an elaborate programme on identification of novel plant genes conferring resistance against insect pests. Some of transgenic plants with genes for insect resistance are expected to be available commercially within the next 3-4 years.

Pyramiding of resistance genes

Characterization of the race structure of major fungal pathogens chiefly fusarium wilt, and development of gene deployment strategies to extend genetic resistance to it is immediately required to combat highly variable pathogens. Breeding for wilt resistance in chickpea and pigoenpea requires an understanding of the contemporary pathogen populations in the locations where resistance genes are to be deployed. *Fusarium oxysporum f.sp. ciceri* is well known for its pathogenic diversity in the country that can render a wilt-resistant cultivar resistant in one location and susceptible in another location. Based on the extensive research on the variability present in the *Fusarium oxysporum f.sp. ciceri* in India, four races namely, race1, race 2, race 3 and race 4 are identified out of seven reported on the global basis. The other three races are 0, 5 and 6, which are confined to Spain and California (USA). Nine race specific recessive genes have been identified for fusarium wilt in chickpea. These genes are *foc-0, h1, h2, h3, a, b, c, foc-4, foc-5* and are independently inherited except for allelic pairs. Similarly, enough genetic variability and sufficient lines resistant to different races of *Fusarium udum* are available in pigeonpea but none of the lines can have resistance to most/all of the races. Traditional way of transferring one or more resistance genes to a single cultivar relies on field and green house screening against different races, which is very laborious and time consuming. With conventional approach, breeding lines with a single dominant resistance gene cannot be distinguished from breeding lines with multiple resistance genes. However, if DNA markers were available for each resistance gene, the identification of plants with multiple genes would become easy. In recent years, DNA markers have shown great promise in lessening the time and expense for pyramiding resistance genes. So far 354 markers are reported in chickpea out of which three to four are reported to be closely linked with genes imparting resistance to race 1, race 4 and race 5 of Fusarium wilt. Besides mapping and identifying host plant resistance, efforts are being made to characterize pathogen populations making it feasible to deploy the relevant resistance genes to match the pathogen population. The ability to use marker-assisted selection to pyramid genes will make this technology an essential tool for pulse breeders in the present century.

Multiple resistance

Susceptibility of cultivars to biotic stresses adversely affects yield stability in pulse crops. In recent years, cultivars resistant to one or the other stress have been bred bringing stability to pulse production in the country. However, single gene based resistance proved to be ephemeral in nature due to susceptibility to other diseases and emergence of increasingly more virulent races/biotypes. Therefore, insulation of varieties against major biotic stresses is required to be taken up with the help of both conventional and molecular tools to meet the challenge posed by highly virulent and mobile pathogens. Stable resistance sources for many diseases and insect pests besides precise information on important aspects such as identification and characterization of races/ biotypes, rate of emergence of new races/ biotypes, genetic control, etc., are immediately sought for directed improvement in resistance breeding. In chickpea, varieties need to develop having multiple resistance against fusarium wilt, root rots, Ascochyta, and botrytis gray mould to succeed in farmers' fields. Similarly, pigeonpea varieties need to be insulated against wilt, phytophthora stem blight and sterility mosaic for stable performance. Uradbean and mungbean varieties are required to be resistant not only to mungbean yellow mosaic virus but also to cercospora leaf blight and powdery mildew. Besides rust disease, lentil and fieldpea varieties need to be resistant to wilt and powdery mildew, respectively.

Development of nutrient responsive and nutrient use efficient genotypes

Manipulation of the production environment with fertilizer application has been the most preferred practice to meet plant requirements. However, the same may not be the most economical solution to all mineral deficiency and toxicity problems of the soils in future. Altering the plants to grow on soils with mineral deficiency without compromising on yield or quality has great potential. Lower input requirements, reduced production costs and less pollution could be some of the benefits expected to accrue with nutrient use efficient plants. Information about genetic aspects of plant mineral nutrition should be derived to augment research strategy for developing nutrient use efficient genotypes in pulse crops.

Management Options

Integrated nutrient management

Pulses have shown varying degrees of response to fertilizers in different agro-climatic situations. While response to nitrogen is limited only to starter dose because of atmospheric nitrogen fixing ability, the pulses have shown significant response to phosphorus in terms of yield (Text Box 3). Foliar spray of 2% urea at flowering/pod filling stage has been turned out to be rewarding in terms of higher yield. Of late, deficiencies of the secondary and micro-nutrients such as sulphur, zinc, boron and iron are emerging and magnitude of response to such nutrients is increasing. Sulphur is one of the essential secondary nutrients required for proper plant growth. In recent years, introduction of high yielding varieties under intensive cropping systems coupled with use of sulphur-free fertilizers like urea and DAP and progressive decline in the use of organic manures/compost, has led to widespread deficiency of sulphur in soils. The recent statistics shows that out of 135 major pulse-growing districts, sulphur deficiency is pronounced in 87 districts. Recognizing this, a comprehensive research programme is initiated to determine response of different pulse crops to sulphur and find out an efficient and low cost source of sulphur. It has been observed that most of the pulse crops respond well to 20 kg of sulphur/ha and in some areas with light textured soils, the response is noticed up to 40 kg/ha. Gypsum, Pyrite or SSP has been proved to be low cost source of sulphur. Balanced and integrated nutrient management coupled with timely weed control need to be promoted.

Text Box 3
Integrated nutrient management

- Starter dose of 10-15 Kg N
- Application of P & K as per soil test
- Use of biofertilizer (Rh, PSB)
- Use of S and micronutrients
- Follar spray of 2% urea
- Recycling of crop residue, FYM

Enhancing biological nitrogen fixation

Biofertilizers have an important role to play in improving the nutrient supply and their availability in integrated nutrient management in pulse crops. About 10-15% increase in yield is possible through inoculation of seed with efficient Rhizobium culture. Besides Rhizobium, several other free-living microorganisms are reported to facilitate nutrient uptake. Phosphate solubilizing bacteria helps increase the availability of phosphorus, which needs to be capitalized. Vascular Arbuscular mycorrhizae (VAM)- an obligatory fungus has been reported to increase availability of plant nutrients and water, both being the most precarious in rainfed agriculture. It is, therefore, imperative to develop appropriate technology to exploit these naturally occurring soil micro-organisms and generate in-depth information on their synergies besides quantification of benefits to soil fertility and nutrient uptake. Inoculation of seeds with appropriate Rhizobium culture can substantially enhance the nitrogen fixing ability of pulse crops.

IPM module against gram pod borer

Gram pod borer (Helicoverpa armigera) is the key pest of chickpea and pigoenpea causing heavy losses. IPM modules for management of this dreaded pest has been developed and field-tested. Use of sex pheromone trap at 3-5 traps/ha for monitoring the pest is recommended.

The economic threshold level (ETL) is 1-2 larva per metre row length. The integrated pest management strategy comprises timely sowing to exploit host avoidance phenomenon, intercropping with mustard, barley and linseed in chickpea and sorghum in pigeonpea use of trap crops like Vicia sativa and African giant marigold, use of Nuclear Polyhedrosis Virus (NPV) @ 250 LE/ha or Bacillus thuringensis (Bt) @ 1-1.5 kg/ha, and erection of perches @ 20-30/ha to attract insectivorous birds. Spraying with 5% Neem Seed Kernel Extract (NSKE) or Achook @ 1.25 l/ha or need based use of chemical control like 0.07% endosulfan or 0.004% fenvelarate at 15-20 days interval is recommended.

Drought management

Over 86% pulses are grown in rainfed area where drought of different intensities and duration are often experienced causing substantial loss in productivity. Under these conditions, water harvesting and its recycling, choice of suitable crops and varieties, planting techniques, seed bed preparation, plant population management, balanced nutrition, *in situ* moisture conservation, and use of mulches and water absorbing polymers help in combating droughts. Water harvesting which implies diversion of runoff to an appropriate site through land treatment and storing in surface reservoirs for subsequent use as protective/life saving irrigation has proved boon in many dry areas. Small farm ponds with 1-10 catchment areas have been found quite beneficial which need to be promoted.

Developmental Options

In pulses, we have yet to realize in farmers' fields the yield potential being expressed consistently in research stations and demonstration plots through the 'first generation' research efforts. Substantial but untapped yield potential locked up in already existing technologies can bring substantial improvements in pulse production by narrowing the gaps. An aggressive approach towards transferring the technologies generated at research stations coupled with developmental policies to ensure timely availability of critical inputs is warranted for bridging the yield gaps. In addition to the yield gaps, inter-regional and inter-seasonal disparities in yield realization also exist. While very large area (37%) under various pulse crops fall under low productivity with lower than national average mainly in Andhra Pradesh, Karnataka, Orissa, Tamil Nadu and Rajasthan, there are states such as Bihar, Madhya Pradesh, Punjab, Uttar Pradesh and West Bengal harvesting more than the national average.

Improved production and protection technologies, including quality seeds, timely irrigation, farm operations, and effective control measures of biotic and abiotic stresses have the potential to double the pulses production. The present status of seed production in pulses indicates that indent for breeder seed is low because of poor seed replacement ratio (2-3%) as against the desired level of 10-15%. It is assessed that availability of quality seed in time can uplift about 20% production even with the available varieties. Therefore, a massive seed production programme is a must involving both public and private seed production agencies, NGOs and village panchayats. Mass production of quality biofertilizers and bio-agents needs to be taken up for wide distribution among pulse growers. In the low productivity regions, yield can substantially be raised by alleviating biophysical constraints like lack of water and unfavourable temperature through better management or by matching technologies to withstand the constraint without much reduction in yield. Even a modest gain of 100 kg per ha from 10 million ha, low productivity areas under pulses would have a far-reaching effect on pulse supply in the country.

Bringing Additional Area under Pulses (Horizontal Expansion)

Pulses have tremendous scope for expansion in space and time. Early-maturing varieties of pulses can fit well in various cropping systems, thus, increasing not only the area under pulses but also sustaining the cereal-based cropping systems in the long run. Four options are readily available for bringing additional area under pulses:

- Inclusion of short duration varieties of pulses as catch crop in irrigated areas
- Introduction in new niches
- Substitution of existing low yielding crop in the prevailing systems and

Table 4. Scope of area expansion under pulses through cropping system manipulation

Crop	Intercropping with	Specific area	Potential area (m ha)
Mungbean	sugarcane (irrigated)	Western U.P., Central U.P., Eastern U.P., Bihar	0.50 0.50
	cotton and millets (rainfed uplands)	Maharashtra, A.P. and T.N.	
	spring/summer sunflower (irrigated)	Western U.P., Haryana, Punjab	0.50
Pigeonpea	soybean, sorghum, cotton, millets and groundnut (rainfed upland)	A.P., Malwa Plateau of M.P., Vidarbha of Maharashtra, North Karnataka, T.N.	0.50
Chickpea	barley, mustard and safflower (rainfed upland)	South East Rajasthan, Punjab, Haryana, U.P., Bihar, Vidharbha of Maharashtra	0.50
Total			**2.50**

- Pulses as intercrop with wide space planted crops and relay crop.

The first option requires generation of high yielding varieties with early vigour, early and synchronous maturity, responsiveness to high input and resistance to key diseases and pests. The second option, which is most viable and practicable, rests on the development of short/extra-short duration high yielding varieties of various pulse crops along with matching agro-technology for growing them in non-traditional areas. Matching of crop phenology with the moisture availability coupled with insulation against key diseases and insect pests will be most crucial for successful introduction. The third option would require breaking yield barriers observed in the major pulse crops so as to make them more competitive and profitable in comparison to the cereal crops sought to be replaced from the prevailing cropping systems. The last option requires that the breeding programmes should be oriented to minimize the intercrop competition and maximize complementarities with the companion crops. Further, the management practices should be refined to enhance input use efficiency in the system. Development of short duration varieties insulated against major biotic stresses with appropriate production technology has resulted into identification of several remunerative and more productive cropping systems. Pigeonpea-wheat, maize-post rainy pigeonpea, cultivation of short duration pigeonpea in peninsular India, cotton-chickpea, rice-chickpea/lentil sequential cropping, growing short duration pulses as catch crops in rice-wheat cropping system, uradbean in rice fallows, relay cropping of lentil/lathyrus, parallel cropping of rajmash-potato, sugarcane based intercropping are some examples of diversification through pulses. An estimated 2.5 million ha additional area can be brought under

Table 5 New Niches for pulses production

Crop	New nitches	Potential area by 2020 (m ha)
Chickpea	U.P., Bihar, WB and Coastal Orissa	0.5
Pigeonpea (early)	North-west Rajasthan, Haryana, Punjab, U.P.	1.0
Pigeonpea (*rabi*)	Bihar, Orissa, Southern Gujarat, M.P., W.B., eastern U.P.	0.3
Mung bean (spring/summer)	Punjab, Haryana, U.P., Bihar, W.B.	1.0
Urd bean (*rabi*)	A.P., Karnataka, T.N.	1.0
Lentil	Eastern U.P., Bihar, Bundelkhand region	0.5
Lathyrus	Eastern U.P., north Bihar, Bundelkhand of U.P., W.B. and Chattisgarh	0.2
Rajmash	Central and eastern U.P., Bihar and Maharashtra	0.5
	Total	**5.0**

different pulses through cropping system manipulation, crop diversification and multiple cropping systems (Table 4).

It can substantially increase the cropping intensity. In addition, there is a scope for introduction of pulses in new niches such as wasteland, reclaimed soils and rice-fallow land by efficient watershed management and as a replacement of less remunerative crops. It is estimated that about 5 million ha area can be brought under pulses by the end of 2020 by adopting various developmental activities (Table 5).

Policy Support

Lack of assured market is one factor for the poor performance of pulses. It has been observed that market for pulses is thin and fragmented in comparison to cereals in many parts of the country. Due to serious problem of stored grain pests and lack of storage facilities, farmers are compelled to sell their produce to middlemen at low price. The minimum support price announced by the Government does not benefit farmers in absence of procurement mechanism. Moreover, all pulse crops are not covered under the minimum support price (Text Box 4). Therefore, procurement policy for pulses needs to be strengthened immediately coupled with distribution of pulses through public distribution system and a reasonable buffer stock needs to be built up to meet the contingencies. Appropriate market intervention and promotion of post harvest technology are equally necessary to encourage farmers to invest more in pulse production.

Text Box 4 Policy Issues

- Minimum support price
- Market Intervention
- Reasonable buffer stocks
- Pulse under PDS
- Credit facilities
- Crop Insurance
- Export

In addition to the losses suffered by pulses during during harvest, transportation and threshing, they also encounter insect pest damage during storage, which is estimated to be around 0.21 million tonnes, costing 315 crore rupees to farmers. A mass awareness programme to educate farmers on scientific storage along with distribution of seed storage bins can check the post-harvest losses and increase the shelf life of pulses. According to various estimates, total post harvest losses are to the tune of 20-25% out of which milling losses alone contribute for 10%. To generate employment opportunities and to augment income of the farmers, the value-addition and agro-processing activities have to strengthen by distribution of efficient *Dal* mills and information on final products and by-products of pulses. This would help protect the resource-poor farmers from the hands of middlemen and market forces, as pulse farmers do not get even half of what consumer pays to buy dal from the market. Subsidy in the form of critical inputs as easy and cheap credits besides crop insurance are some of the policies, which can propel the farmers to grow pulses with minimum risk.

HORTICULTURAL CROP PRODUCTION

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Nutritional security denotes the consumption and physiological use of adequate quantities of safe and nutritious food by every member of a family and encompasses the process of equitable distribution among members of households and communities. This calls for the consumption of a variety of food items which supply an entire range of essential macro and micronutrients. Fruits and vegetables are considered to be the richest sources of these essential and beneficial phyto-nutrients important for the human metabolism. Their large-scale production and consumption is, therefore, imperative for ensuring the nutritional security.

At the time of independence, the country faced two major nutritional problems. One was the threat of famine and acute starvation due to low agricultural production and a vareity of food items which supply an acute malnutrition due to low per capita availability of protective foods like fruits and vegetables. The other was chronic energy deficiency due to poverty, low-literacy, poor access to safe-drinking water, sanitation and health care. These factors led to the wide spread prevalence of infections and ill health in children and adults. Kwashiorkor, marasmus, goiter, beriberi, blindness due to Vitamin A deficiency and anaemia due to iron deficiency were major public health problems. The country adopted a multi-sectoral, multi- pronged strategy to combat the major nutritional problems and to improve nutritional status of the population.

The Green revolution resulted in increased food production that was sufficient to meet the needs of a growing population. The establishment of adequate buffer stocks and the Public Distribution System has ensured adequate per capita food availability and distribution at the national level. Improvement in per capita income, poverty alleviation programmes including food for work and Employment Assurance Scheme have resulted in better purchasing power and household food availability. Food supplementation programmes were initiated to meet the extra food requirements of vulnerable groups - namely pregnant and lactating mothers and pre-school children. The Government initiated programmes for the prevention of iodine deficiency disorders, anaemia and blindness due to Vitamin A deficiency.

In the last 50 years considerable progress has been made in many of these programmes. Famines no longer haunt the country. There has been substantial reduction in moderate and severe under nutrition in children and some improvement in the nutritional status of all segments of the population. Malnutrition induced diseases like kwashiorkor, marasmus, beriberi and blindness due to Vitamin-A deficiency are no longer rampant. However, the widespread prevalence of a milder form of chronic energy deficiency (CED) in adults and children is a matter of concern. Under nutrition continues to be a major problem in pregnant and lactating women; with over one-third of the newborns still weighing less than 2.5 kg at birth. Even though there has been a marked reduction in blindness due to Vitamin-A deficiency, the less severe forms of Vitamin-A deficiency persist. Universal access to iodized salt has not been achieved and there has not been marked reduction in iodine deficiency disorders. There is no decline in the prevalence or severity of anaemia and its health consequences. In the last two decades, there have been major life style and dietary intake alterations, especially, among the urban middle and upper income groups. As a result, newer problems such as obesity in adolescents and adults and increased risk of non-communicable diseases are emerging.

Nutritional Importance of Fruits and Vegetables

Man needs a wide range of nutrients to perform various body functions and to lead a healthy life. Carbohydrates, proteins, fats, minerals and vitamins constitute most of the foods that we consume. If we analyze the chemical composition of a healthy man weighing 65 kg, a major proportion of it comprises of water (61.6 percentage) followed by protein (17%), fat (13.8%) and carbohydrates (1.5%).

Energy needs are mainly derived from carbohydrates and fats. Animal products and pulses supply the required proteins while fruits and vegetables supply the required vitamins and minerals. A study of the recommended dietary allowance (RDA) indicates that an adolescent requires 3000 k calories of energy, proteins (55 g), Calcium (0.5 to 0.6 g), iron (25 mg), retinol (750 μg) and thiamin (1.5 mg) in addition to a number of other vitamins. Riboflavin (1.7 mg), nicotinic acid (21 mg), ascorbic acid (30 to 50 mg), folic acid 50 to 100 μg, vitamin B_{12} (0.5 to 1 μg), vitamin D (200 I.U.) and β carotene (3000 μg) are also necessary. These dietary requirements can be met through a balanced diet comprising of cereals (500 g), pulses (75 g), fruits (120 g), milk (200 ml), leafy vegetables (125 g) other vegetables (80 g), roots and tubers (90 g), fats and oils (40 g) and sugar (40 g). In order to ensure a balanced diet, the diet should constitute of 25 to 30% of fruits and vegetables. Fruits and vegetables form the second most important constituent in USA after cereals.

Fruits and vegetables can play a unique role in meeting the nutritional needs of our population. Taken fresh or in processed form, they not only improve the quality of our diet but also provide essential ingredients like carbohydrates, proteins, fats, vitamins and minerals.

Horticultural crops rich in carbohydrates

Carbohydrates are the building blocks of human body. They provide the ready energy in the form of sugars. Nearly 60% of a standard meal comprises of carbohydrates and (vitamins, minerals and sugars) contribute the rest.

Bael fruit

Unripe or half ripe fruit contains 31.3%-31.8% carbohydrates, 1.8% proteins and 2.9% fibre. It is also rich in minerals and vitamins. Its high vitamin C contents can overcome scurvy, which is caused by vitamin C deficiency.

Banana

The ripe fruit contains 20% of carbohydrates, rich content of potassium, iron and fair amounts of vitamin B and calcium. It is an important fruit of India with the largest area and production. Even though India is the largest producer of banana fruit in the world with a total production of 15.07 million tones, our per capita availability of banana is less than 1.5. kg/person/year. In India, fruits of some cultivars of banana like Nendran are also used for breakfast after steaming while banana chips are an important subsidiary food item in several Southern and Western Indian states.

Cassava

It is the richest source of carbohydrates and serves as a staple food in a number of underdeveloped countries. It produces about 25,00,00 calories of energy/ha compared to 11,00,00 calories from wheat and 17,60,00 calories from rice. In areas with no rice cultivation, it is used as a staple diet for the poor. It plays a major role in averting famines arising from food scarcity. Further, there has been reduction in cassava consumption and production due to changes in food consumption patterns during the 'Green Revolution'. Cassava also continues as the unchallenged monopolized raw material for sago production in India and presently there are more than a thousand industrial units in Tamilnadu. On a global basis, tuber crop is an important subsidiary food after cereals and grain legumes; it produces the highest rate of dry matter per day and is a major energy contributor. Most of the tuber crops have wide adaptability and can produce economic yields in marginal lands under varied agro-climatic conditions. To maintain rhythm in the supply of food materials and to keep pace with the increasing population, food crops like cassava will have to be retained within the cropping pattern of the marginal farmers.

Dates

The fruits are very rich in carbohydrates, mostly in the form of invert sugars (75 to 80%), phosphorus, potassium and iron.

Grapes

Both fresh grapes and dried raisins are a good source of energy due to high proportions of reducing sugars. The fruits are good sources of calcium, phosphorus, iron, tartaric acid and pectin. Traces of iodine and fluoride are also found in the fruits.

Jackfruit

It supplies a significant quantity of energy as it contains 20% of carbohydrates. The aroma rich fruit is a good source of protein, fat, β-carotene, thiamine, calcium, iron, potassium, and sodium.

Potato

Potato serves as a staple food in a number of countries. It possesses 22% of carbohydrates and 2% of high value protein, in addition to traces of vitamins A, B and C. Not only the total or average yield/kg/ha/day is more in potato when compared to rice, wheat or maize but its dry matter and protein content is also high than many other major crops. Energy and protein content of potato is 678 (10-K cal) and 176 kg, respectively. In comparison, per hectare food energy obtained from wheat, rice, maize and soybean is 394, 688, 458 and 525 Kg, respectively. Another useful feature of potato as a major food of the future is versatility of its uses in a variety of dishes. Potato is devoid of fat and thus, can be consumed in large quantities without running the risk of becoming overweight/obese. An adult male's total energy requirement can be met by consuming about 3.3 kg of boiled potato. Potato is an important horticulture crop in our country, which can be grown all the year round in one or the other part and in almost all types of soils. Potato varieties are now available, which can fit in both short and long-day conditions. Potato can be grown with rice-wheat rotation and can also fit in vegetable crop sequences or an inter-crop with onion, okra, french bean and radish. Potato consumption level exceeds 100 kg/year/head in U.K., Poland and Germany. Besides being nutritious, potato is a socially accepted food. It can, thus, form a part of our food and nutritional security programme.

Horticultural crops rich in Proteins

Proteins are essential for all living processes and carry out a wide range of functions. Protein supplementation is vital in early childhood to ensure complete brain development. On an average, 55 to 65 g of protein is essential for healthy human beings. Although fruits and vegetables contain less protein; but their biological value is high.

Almond

Its kernels are rich in protein (20.8%), fat (59.8%) and carbohydrates (10.5%). It is rich in magnesium, copper, manganese and zinc.

Cashew nut

The kernels are rich in proteins (21.2%), fats (46.9%) and carbohydrates (22.3%). The kernel oil is set to be more nutritive than olive oil. It is a good source of essential amino acids, thiamine, riboflavin and minerals.

Horticultural crops rich in fats

Fats are concentrated source of energy, which are involved, in a number of metabolic functions. Some fruits and nuts are rich sources of high quality fats containing essential fatty acids. In addition to almond and cashew the following crops contain significant quantities of fat.

Apricot

The nuts are rich in proteins and oils (40-45%), which is similar to almond oil in terms of nutritional qualities. Apricots are rich in iron and are an excellent remedy for anaemia. They are rich in natural sugars, vitamin A riboflavin, niacin, vitamin C and minerals like calcium.

Avocado

It is one of the richest sources of fat (24.5%) after olive. The fat is of high quality and is totally free from unpleasant butyric acid. The protein is of finest quality and is far superior to proteins-cum-cereals. It is rich in vitamin A and its regular intake offers excellent remedy in acute digestive disorders.

Walnut

The nuts contain 14 to 20% protein and 60 to 67% fat, in addition to significant quantities of vitamins A and B. The immature fruits are rich in ascorbic acid.

Horticultural crops rich in Vitamins

Fruits and vegetables are the richest source of vitamins. These water soluble and fat-soluble organic substances facilitate the metabolism of fats, amino acids and carbohydrates. Their deficiency leads to a number of diseases in children and adults.

Vitamin A (Retinol)

Retinol is essential for clear vision in dim light. The deficiency leads to redness, inflammation and gradual loss of vision. About 750 µg of retinol is required per day for a healthy vision. Fruits and vegetables are rich sources of vitamin A, particularly, those containing yellow pigment, β-carotene. Red palm oil is one of the richest sources of retinol. All leafy vegetables, carrots, fresh apricots, cape gooseberry, ripe mango, orange, raspberry and ripe papaya are also rich in retinol. Many ripe yellow fruits (mangoes and papayas), vegetables (tomatoes, carrots and yellow pumpkins) and tuber crops are rich sources of carotene. Leafy vegetables like amaranth, beet leaf, palak, bassela, fenugreek, coriander, drumstick leaves, curry leaves, mint, radish leaves, etc. are rich sources of carotene. In general, the darker the green leafy vegetable, the higher the content of carotene it has. The daily requirement of vitamin A for an adult is estimated to be around 600 mg (2000 IU) of vitamin A. The requirement of vitamin A is relatively higher during pregnancy, lactation and child growth. Animal foods rich in vitamin A are expensive. Hence, the most inexpensive and convenient way to ensure an adequate intake of vitamin A is to include green leafy vegetables in the daily diet. About 500 gm of common leafy vegetables like amaranth will provide adequate β-carotene to meet the vitamin A requirement of an adult.

Vitamin A is an important micronutrient for maintaining normal growth, regulating cellular proliferation and differentiation, controlling development programmes for maintaining visual and reproductive functions. Vitamin A cannot be synthesized by humans and so must be consumed as an essential nutrient in the diet. Over the last two decades, there has been a marked decline in blindness due to vitamin A deficiency; but dietary intake of vitamin A has remained sub-optimal in the poorer segments of the population. As a result, clinical deficiency signs are being reported among pregnant and lactating women and children even today.

Vitamin B Complex

The B-complex vitamins are essential for proper utilization of carbohydrates, fats and proteins. The important vitamins, their metabolic role, sources, their requirement is summarized in the following table1.

Among the B-vitamins deficiencies, folic acid has become important not only because of its

Table 1: Sources of B-Complex vitamins

Vitamin	Metabolic function	Importance	Daily requirement	Source
Vitamin B_1 Thiamine	Utilization of sugar and starch	Deficiency leads to beriberi	0.5 to 2.0 mg	Green leafy vegetables
Vitamin B_2 Riboflavin	Protein metabolism	Deficiency leads to sore tongue cracking in mouth angles, redness and burning of eyes, scaliness of the skin	0.7 to 2.2 mg	Green leafy vegetables
Niacin	Component of co-enzymes	Deficiency leads to pellagra	8 to 26 mg	Nuts are good sources of niacin
Vitamin B_6 Pyridoxine	Protein and fat metabolism	Deficiency leads to convulsions in infants	0.6 to 2.5 mg	Vegetables
Folic acid	Multiplication and maturation of red blood cells	Deficiency causes anaemia in children and pregnant woman	50 to 100 mg	Fresh green vegetables
Vitamin B_{12}	Important for DNA synthesis	Deficiency causes anaemia in children and pregnant woman	1 ìg	Present only in animal foods

role in prevention of anaemia, but also because of its deficiency association reported as one of the risk factors for cardiovascular disease.

In India, diets are grossly deficient in riboflavin. Riboflavin plays a very important role in energy transduction reactions and its deficiency can impair optimal utilization of the macronutrients for the generation of chemical energy. The problem of vitamin-B12 deficiency has not been investigated, but considering the vegetarian nature of Indian diet, its deficiency may well be existing.

Vitamin C

It is required for collagen synthesis, bone and teeth calcification. Its deficiency leads to scurvy, which can be managed through a daily supplementation of 30 to 50 mg of vitamin C. Lime, orange, grape fruit, aonla, ber, guava, Barbados cherry, carambola etc are some of the good sources of vitamin C. Based on nutrient composition tables, the extent of dietary vitamin C deficiency would be more than it is revealed through calculations because vitamin C is rapidly destroyed in cooking and storage.

Minerals and trace elements

Minerals and trace elements play a vital role in a number of metabolic functions. Adequate mineral intake is necessary for children and adults to ensure proper growth as well as to replenish the day-to-day losses. Iron is a major component of haemoglobin in blood. Similarly, calcium and phosphorus are the major elements in bones and skeletons. The important minerals, their metabolic role, sources, their requirement are summarized in Table2.

Among the micronutrient deficiencies, those of iron, vitamin A and iodine have received greater attention because of high rates of morbidity and mortality associated with them. Zinc deficiency is receiving more attention in the West, but in India the magnitude of zinc deficiency and its clinical consequences are yet to be defined. In view of the changing profile of micronutrient deficiencies and their clinical consequences, there is a need for clinical and bio-chemical monitoring. Many of the micronutrients e.g., vitamin B-complex, iron and vitamin A have a common dietary source - green leaf vegetables. Therefore, multiple micronutrient deficiencies often coexist. Dietary deficiency is a major but not the only factor, responsible for malnutrition. Environmental factors contribute substantially and need to be addressed simultaneously.

Among pregnant and lactating women and in pre-school children, the magnitude of dietary deficiency of micronutrients is greater as they have higher requirements for these. The problem of micronutrient deficiency among elderly and those with chronic/repeated infections is being increasingly recognized in recent years. Special strategies will have to be devised to protect these vulnerable groups. For tackling the problem of micronutrient deficiencies, it is useful to take a holistic view and evolve strategies that would ensure adequate intakes of all micronutrients through dietary sources. The ultimate goal should be to eliminate the recognized diseases due to micronutrient deficiencies and substantially reduce, if not eliminate them.

Nutritional anaemia due to iron and folate deficiency is a major global public health

Table 2: Important sources of minerals

Mineral	Metabolic function	Importance	Daily requirement	Source
Calcium	Maintenance of skeleton and teeth	Deficiency leads to weak bones and teeth	0.4 to 0.6 g	Amaranth, drumstick leaves, fenugreek, guava, tapioca, turnip etc.
Iron	Formation of haemoglobin	Deficiency leads to anaemia	1 to 3 mg	Amaranth, drumstick leaves, fenugreek, guava, tapioca etc.
Electrolytes (sodium, potassium and magnesium)	Maintenance of cellular osmotic balance	Deficiency leads to cellular turgidity and muscular cramps	-	Amaranth, drumstick leaves, fenugreek, guava, tapioca etc.
Phosphorus	Component of nucleic acids, ATP	Deficiency leads to weak bones and teeth	1 g	Nuts, leafy vegetables, beans, bitter gourd, bottle gourd, ginger and onion

problem. India is one of the countries with the highest prevalence of anaemia. Low dietary intake and poor iron and folic acid intake are major factors responsible for high prevalence of anaemia in India. Poor bioavailability of iron in phytate fibre rich Indian diet aggravates the situation. Anaemia due to deficiency of other micronutrients like copper, zinc, pyridoxine and vitamin B12 is rare in India.

Strategies to ensure Nutritional Security

Several initiatives have been taken to improve horticulture crop production and their availability. These include increased budgetary support, development of Research and development (R&D) infrastructure, introduction and development of highly nutritive crops, varieties, availability of quality planting material and technology for higher productivity. These are discussed below.

Budgetary support for Infrastructure Development

Horticultural research and development was at very low ebb till the 3rd five-year Plan and received meager attention even thereafter. However, the plan investment in horticultural R&D increased significantly since the 8th five-year Plan, which resulted in considerable strengthening of the horticultural R&D programmes in the country. Separate Plan allocation for research on horticulture crops by the Indian Council of Agricultural Research (ICAR) was first made in 4th five-year Plan with a modest allotment of Rs. 34.8 million. This was enhanced to Rs. 4080 million during Tenth Plan. At present, allocation for research is about 7.6 per cent of the total outlay for agricultural research made by the ICAR.

The plan allocation for Horticulture development also started with a meager financial allocation of Rs. 20.5 million in the 4th Plan. However, it rose to Rs.76.2 million in 5th Plan, Rs.146.4 million in 6th Plan, Rs.250 million in 7th Plan, Rs. 10,000 million in 8th (utilization Rs.7890 million), Rs.21300 million in 9th Plan and Rs 1,00,000 million in Tenth Plan. While the increase in budgetary allocation from 4th to tenth Plan was 117 times for research, it was 400 times in respect of development programmes.

Research Infrastructure

The ICAR is the premier agency, which pioneered systematic research on agricultural crops in the country. Horticulture research in India received very little attention till the 3rd five-year plan. The establishment of the Indian Institute of Horticultural Research in Bangalore and the start of eight All India Coordinated Crop Improvement Projects to cover different horticultural crops was a landmark in the history of horticulture in IV five year Plan (1969-74). Rapid expansion of the infrastructure took place in 7th and 8th Plans. Today, the horticultural research in the country is being carried out at nine ICAR institutes (with 25 regional stations) and 12 National Research centers, one each on banana, citrus, grape, onion and garlic, mushroom, orchid, medicinal and aromatic crops, oil palm, seed spices, cashew nut, litchi and makhana besides one full fledged state university on horticulture at Solan, Himachal Pradesh.

Area specific, multi-disciplinary research is also being conducted under 14-All India Coordinated Research Projects, one each on Tropical, Sub-Tropical, Arid Fruits; Vegetables, Potato, Tuber Crops, Mushrooms; Ornamental Crops, Medicinal and Aromatic crops; Palms, Cashew, Spices and Betel vine. Post Harvest Technology is being researched in 215 centres located at various research institutes, and State Agricultural Universities. Research on horticulture is also being undertaken at several multi-crop, multi-disciplinary institutes. Departments of Horticulture in 24 Agricultural Universities, one deemed University and one full-fledged University of Horticulture and Forestry are also engaged in horticultural research. In addition, several network projects, one each on 'Hybrid research in vegetable crops', 'Drip irrigation in perennial horticultural crops', 'Protected cultivation of ornamental crops' and 'Phytophthora disease of horticulture crops' are now in operation. In addition to 280 adhoc schemes supported from Agriculture Produce Cess Fund; a number of foreign-aided projects have also been in operation on specific problems in different horticulture crops. As a result, the country now has a sound research infrastructure in horticulture to meet the growing needs and expectations of the fast developing industry.

Development Infrastructure

The Department of Agriculture and Cooperation in the Ministry of Agriculture is the nodal department for horticulture development in the country. It has directorates, one each on Cashew nut and Cocoa and Arecanut and Spices located in Cochin and Calicut (Kerala) besides three autonomous boards, National Horticulture Board, Coconut Development Board and Bee Keeping Board in the Ministry of Agriculture. In addition, the Ministry of Commerce has been promoting research; development and exports of cardamom, through the Commodity Boards set up for that very purpose - namely Spices Board, Tea Board, Coffee Board and Rubber Board respectively. Also, an Agriculture Produce Export Development Authority (APEDA) has been set up under the aegis of the Commerce Ministry to promote the export of horticultural commodities both fresh as well as value added products. Indirect organizational support for horticulture development is also being provided by two agencies in the Ministry of Agriculture, namely, the National Cooperative Development Corporation (NCDC) and the National Agricultural Cooperative Marketing Federation (NAFED) and its institute, the National Horticultural Research and Development Foundation (NHRDF).

Increasing the Availability of Nutritive Fruits and Vegetables

Introduction and cultivation of nutritive crops

Several new crops, rich in nutritional value, have been introduced for commercial cultivation, e.g.: Kiwi fruit in the sub-mountain areas of North India, olives in the mid hills of the North Western Himalayas, low chilling stone fruits in the North Western plains, oil palm in some coastal states, gherkin in south and west India, baby corn and sweet corn in specific pockets and broccoli, brussel sprouts, asparagus, celery and parsley near the cities.

Identification / Development of nutritionally rich varieties and Technologies

Fruit Crops

A large number of high yielding varieties have been developed in several horticultural crops. In fruits alone 123 varieties have been developed in 12 crops e.g. aonla (10), acid lime (4) apple (8), banana (5), custard apple (1), grape (13), guava (13), litchi (4), mango (28), papaya (17), pomegranate (11) and sapota (9). The attributes of some varieties in different crops are larger fruits, high yielding aonla, bananas resistant to sigatoka disease, custard apple with a high pulp percentage, grape varieties suitable for raisin making, less and soft seeded guava, early bearing litchi, regular bearing semi dwarf mango, gynodioecious varieties in papaya and pomegranate with soft and red colored aril.

Almond varieties with thin shells have been identified for large scale cultivation.

Aonla has become very popular in the arid zones of our country due to its high nutritive value and ability to grow in marginal soils. Areas under aonla have been steadily increasing in states like Rajasthan, Uttar Pradesh, Gujarat, Andhra Pradesh, Tamil Nadu and Karnataka. Improved propagation techniques helped raise quality-planting material required for area expansion. It is one of the richest sources of vitamin C. Large fruited heavy bearing varieties with free stone have been developed.

Apricot was more popular in the dry fruit segment earlier, but due to the introduction of improved varieties the consumption of fresh fruits is steadily increasing.

Improved varieties of *Avocado* are under evaluation and need to be popularized.

Improved technologies now make *bananas* available all through the year. A dedicated National Research Center on Banana focuses on: new variety development and improved production technologies. It is consumed both as a vegetable and table fruit in rural and urban India. Improved high yielding varieties suitable for high density planting have been evolved, which resulted in attaining the highest productivity levels in some states like Maharashtra.

Bael is being popularized across the country. Clonal selection led to the development of superior varieties, which are nutritionally rich. Improved propagation techniques helped their large-scale propagation and availability. Technology for the extraction of nutritionally rich and refreshing juice from bael has been standardized and is being popularized.

Ber, considered a poor man's apple has gained significant popularity in arid regions of India. Improved varieties with small seeds and high yielding abilities have replaced the conventional varieties in Rajasthan, Uttar Pradesh, Gujarat, Andhra Pradesh and Maharashtra. Improved propagation techniques helped in increasing the availability of improved varieties in a short span of time.

Cashew nut, which was introduced as a soil-reclaiming crop, has become a major foreign exchange earner for India. The domestic consumption has increased many folds due to its increased availability owing to improved propagation techniques, superior planting material and improved agro techniques. A dedicated National Research Center on Cashew at Puttur, provided the impetus to the overall development of cashew in India. Till date 27 varieties of cashew have been developed.

Dates gained popularity in the arid regions of Gujarat and Rajasthan and area under dates in these states is expanding steadily. Improved varieties have been introduced from Afghanistan and the Middle East.

Grape improvement and cultivation technology are being perfected by a dedicated National Research Center on Grapes at Pune. Improved varieties of grapes have been evolved at IARI, IIHR and NRC, in addition to a number of agrotechnologies. Significant breakthroughs have been made in breaking productivity barriers through improved production technologies like salt tolerant rootstocks, high density panting, growth regulation and new training and pruning systems.

Jackfruit consumption is steadily increasing as a vegetable and fruit. Clonal selection helped us to isolate improved, high yielding, small-fruited types suited for smaller families. Improved propagation techniques have ensured the availability of superior clones in large numbers.

Mango is the most popular fruit in India. It has played an important role in the socio-economic and cultural life of the country. Almost all states of India cultivate mango and produce about 96,42,130 tonnes. Important states include UP, AP, Bihar and Orissa. Mangoes are very rich in carotenes and in particular, cultivars like Alphonso, Langra, Dashehari and Neelam have more than 2,000 μg of vitamin A per 100 gm. Regular bearing in some of the varieties has been achieved. Every year millions of plants are produced through improved propagation techniques and are planted to rejuvenate old and senile orchards. High density planting has become a reality due to dwarfing rootstocks and hybrids. Agro techniques to minimize spongy tissue have been standardized.

Papaya is a popular fruit in both the orchards and the kitchen gardens. Efforts made by research workers to improve its productivity have resulted in 11 varieties, namely Co1 to Co 6, Coorg Honey Dew, Pusa Delicious, Pusa Majesty, Pusa Giant and Pusa Dwarf. Papaya is rich in β-carotene. The carotene content, however, varies with the variety, which ranges from 960 in Sunrise (OP) to 3,808 in Solo (OP). The β-carotene content in papaya also varies with the stage of maturity.

The problem of a large number of sterile male plants in papaya progeny has been solved and several gynodioecious types have been released. Tissue culture propagation of papaya has also been successful. In tropical climates, the tree bears fruit throughout the year. In North India, the crop is available only for four months. High density planting has become successful due to dwarf varieties like Pusa Nana.

The Central Plantation Crop Research Institute, Kasargod led the research and development efforts in **plantation crops** to develop a number of improved varieties and technologies. Production of coconut hybrids through establishment of seed gardens of Tall (T) x Dwarf (D) and D x T hybrids is standardized. About 12 varieties of coconut and 5 varieties of arecanut were developed at this center.

High yielding dwarf varieties of coconut have revolutionized its plantations in the coastal regions of India. Innovative processing and packaging has resulted in year round availability of nutritious tender coconut water even in remote areas in the trade name of COCOJAL. Similarly highly nutritious coconut milk is available across the country for culinary purposes.

National Research Center on Oil Palm at Pedavegi, developed 2 improved varieties in oil palm. The area under oil palm increased steadily with the improvement in the propagation technology availability of quality planting material.

Vegetable Crops

In vegetable crops, 375 varieties have been released. These include 265 open pollinated, 108 F1 hybrids and 2 synthetics. Of these, several disease resistant varieties in brinjal (Phomopsis and bacterial wilt), cabbage (black spot), capsicum (bacterial wilt), cauliflower (black rot), cowpea (bacterial blight), chillies (leaf curl), okra (yellow vein mosaic), onion (purple blotch), french bean (bacterial wilt), pea (powdery mildew and rust), tomato (bacterial wilt, root knot nematode) and multiple resistances in watermelon are included.

Amaranthus is a rich source of β-carotene. Research indicates that the β-carotene content of *Amaranthus gangaticus* is 38,601 μg and that of *Apaniculathus* 66,308 μg/100 gm dry matter. The carotene content of *Amaranthus gangaticus* at tender stage is 5,520 μg/l00 gm of edible portion. A daily inclusion of 30-50 gm of amaranthus in the diet is sufficient to meet the vitamin A requirement of an adult. A loss of 30 per cent of vitamin A has been reported on boiling leafy vegetables for a period of 30 minutes. At IARI, New Delhi, 30 lines of Amaranthus Spp, including *A. tricolor, A. dubius* and *A. cruenthus* were analysed for β-carotene. The β-carotene content ranged from 14.38 to 36.13 mg per 100 gm dry matter. It was observed that red and green-red lines had the highest range of β-carotene. The anti-nutritional factor-oxalate level varied from 3.04 to 6.8 percent on dry matter basis. The red and green red types had the highest oxalate level. The lowest oxalate content was recorded in *Amaranthus dubius*. Research work is going on to select lines, which should have high contents of dry matter, crude protein and β-carotene with a low oxalate level

In *Carrot,* the area and production of carrot is estimated to be 20,124 hectare and 2,87,000 tonnes, respectively in India. However, in major growing areas in the country, particularly in the North, red coloured tropical varieties are grown which are low in carotene. In comparison, in the southern states the orange variety Nantes, rich in carotene, is very popular. A carotene-rich variety, Pusa Meghali having 11,500 μg of carotene per 100 gm of fresh roots, has been developed at IARI. Pusa Kesar (red lycopene type) has low carotene, that is, 7,000 μg/100 gm of fresh roots. The available high carotene lines (HCL) having carotene contents (up to 475 ppm) need to be used either directly as introductions or in the breeding programmes. Educating the people to grow and consume orange-coloured varieties, which are rich in carotene compared to red ones, is important.

Cassava, is a staple food and consumed in bulk. It can become a very useful source of vitamin A in areas where it grows - Kerala, Tamil Nadu, Gujarat and more recently in Karnataka. Cassava tuber contains β-carotene ranging from 22 μg/100 gm to 220 μg /100 gm of tuber. The carotene content of the tubers of cassava of different varieties seems to vary erroneously. The attempts made to breed varieties rich in carotene having a deep yellow coloured flesh resulted in lines having carotene roughly from 324 to 900 μg/100 gm. Cassava research in India is being carried out at a dedicated Central Tuber Crops Research Institute at Thiruvananthapuram. High yielding varieties with less cyanide content have been evolved. Cassava forms the base for the thriving Sago industry in India.

Palak (*Spinacia oleracea)* contains 9.5 percent oxalate whereas *spinach* (*Pinacea oleraces*) contains 6.3 percent oxalate on a dry weight basis. Spinach is a good source of β-carotene as it contains 5,580 μg of β-carotene per 100 gm. Improved varieties of palak released are: all green Pusa Jyoti and Pusa Hans from IARI, New Delhi and Jobner Green from RAU, Jobner.

In *Potato* 34 high yielding varieties have been released for different regions of which 9 are grown commercially. Kufri Chipsona-1 & 2 are suitable for processing. Two TPS populations TPS-C3 and HPS 1/13 have been identified for raising commercial potato crop. Central Potato Research Institute, Shimla pioneered the potato research in India and made significant contribution to crop improvement and production technology. A number of varieties suitable for processing have been evolved for meeting the thriving potato snack industry in India.

In *Pumpkin,* the yellow and orange-fleshed fruits are high in carotene. Analysis of the edible part of the ordinary variety of pumpkin gives 50 μg to 100 μg β-carotene per 100 gm. Though a potential source of vitamin A, pumpkin still remains a neglected vegetable. However, some progress has been made. A high yielding pumpkin line, CM 14, with yield of 34 tonnes/ha and with fruits containing high levels of carotene, has been developed by KAU, Kerala for cultivation in southern states. IIHR, Bangalore has released a variety, Arka Chandan, which is very rich in carotene content (2,000 μg/100 gm). IARI, New Delhi has also developed and released a very high yielding variety of pumpkin - Pusa Vishwas. The flesh colour of this variety is golden yellow and it is rich in carotene content.

In *Tomato* several recently developed high yielding varieties of vegetables have a high carotene content. Besides being rich in ascorbic acid content, "tomato is also rich in vitamin A". Several F-hybrids, which are high yielding and nutritionally rich have been developed, for example, Arka Vishal, Arka Vardan, Pusa Hybrid-I, Pusa Hybrid-2.

Some of the *tuber crops* are also rich sources of β-carotene. These are one of the cheapest sources of dietary energy. The deeply coloured tuber crops and leaves are rich in carotene. *Sweet potato* is a very important food crop in the developing world. This is one of the seven crops in the world, which produces over 100 million metric tonnes of total food per year. Luxury types of sweet potato differ from the staple and supplemental types. Nutritionally, luxury types would supply large amounts of vitamin A precursor. Fresh tubers of sweet potato are a good source of vitamin A. They are known to contain sufficient β-carotene, up to 151.5 μg /100 gm in fresh tubers. Sweet potato leaves are also used as a green leafy vegetable in some parts of the world. This is also a good source of vitamin A. However, the nutritive value varies substantially with the colour and portion used. In sweet potatoes, there are many new varieties, which are high in carotene and can be used as salad. In the deep-pigmented variety, Gold Rush, developed in the USA, the pigment is made up of 90 per cent carotene. High carotene varieties are used as salad in developing countries. These need to be popularized in India. Three varieties have been released from TNAU - COI, CO2 and CO3.

These include curry leaf, which is a perennial tree grown for the leaves which are eaten raw. It is a backyard crop in many homesteads. The crop is almost free from pests and diseases. The leaves are a rich source of carotene. Leaves of *lettuce* are consumed raw in salads and are a rich source of carotene. Loss of carotene due to cooking as in other vegetables is avoided by using lettuce in the diet. *Chekkurmanis* is another leafy vegetable, which is multivitamin and multimineral packed. The tender shoots and leaves of this drought prone crop are used for culinary purposes. This can be grown as a fence or hedge crop in a kitchen garden. There are many other leafy vegetables, which are important from the carotene content point of view. These are fenugreek, mustard green, bassela and *Spomoea aquatica*, which need to be given importance. *Drumstick* (*Morninga pterigosperma*) is a perennial tree vegetable used mainly for its tender fruits, leaves and flowers. It performs well under dry and arid tracts and has a good yield. Drumstick is a highly valued vegetable in Kerala. It is an essential ingredient of popular culinary preparation. Besides the fruit, its leaves are also edible: 100 gm leaves contain 1,130 μg of carotene.

Propagation of Quality Planting Material

Vegetative propagation technique for many horticultural crops, which are hitherto propagated by seed e.g., a*onla*, *bael*, *ber*, black pepper. Cardamom, cashew, cassia, cinnamon, clove, custard apple, jackfruit, *jamun*, nutmeg, sapota and walnut have been standardized. Seed Plot Technique has been standardized in potato resulting in successful disease free potato seed production in the tropics and sub tropics of the country. Micro-propagation and *in vitro* micro-tuber production have been developed in potato. Micro propagation protocols were developed in banana, grape, strawberry, cardamom, ginger, turmeric and betel vine. Rootstocks in citrus, grape, mango and apple have also been identified for commercial use.

Tissue cultured plants of papaya, are now marketed for extraction and processing of papain. Efforts to standardize technologies for micro propagation of cashew, litchi, mango and walnut have not met with success. Success has also been achieved in applying meristem culture in banana to generate bunchy top free planting material. Success stories from China, Taiwan, Japan and Spain in generating virus free citrus plantations have lent optimism to applying micro-grafting in citriculture industry.

Agro-Techniques for Higher Productivity

Agro-techniques have been developed in all major crops suitable for different regions. These include high-density plantations in banana, citrus, mango and pineapple and high production technology in several crops like pineapple, black pepper and cardamom. Several varieties in pea (Arkel) cauliflower (tropical varieties) onion (N-53) radish (Pusa Chetki) and tomato (Pusa Sheetal) have enabled off-season production and almost all the year round availability of vegetables.

The introduction of high-density plantings is one of the most innovative technologies to achieve high productivity per unit area both in perennial and short duration crops. High density planting in tree crops was first introduced in Europe in case of apple in sixties, with the development of Malling and Malling Merton Series of rootstocks. Subsequently, this was tried in other crops. Today, majority of apple orchards in America, Australia, Europe and New Zealand use this intensive system of fruit production. Intensive orchardising system has also been adopted in peach, plum, sweet cherry, pear, banana, pineapple, papaya and more recently in mango. High-density orchards not only provide higher yield and net economic returns per unit area in the initial years but also facilitate more efficient use of inputs and easy harvest. Future high density plantings have to be made possible through development of dwarfing scion varieties, standardisation of rootstocks - interstocks, as also a combination of canopy management and growth regulators.

In vegetables, development of agro-techniques in all major vegetables, standardization of kharif onion technology in North India, development of vegetable based cropping system and IPM schedules in several crops has been standardized. A number of potato based multiple and inter cropping systems have been developed. Technology for raising commercial potato crop using TPS has been developed. A national seed production programme was established at CPRI, Shimla with a current production of 26,000 tonnes of breeder's seed.

In vegetables, over 220 tonnes of foundation seed of different vegetables crops is being produced by National Agricultural Research system. Seeds of 39 varieties of temperate vegetables are being raised at Katrain, while those of F1 hybrids both in public and private sectors. Self incompatible and male sterile lines have been identified in a number of vegetables for hybrid seed production.

Poly-house production of vegetables has extended the availability of vegetables besides ensuring a regular supply of vegetables. It has also made crop production profitable even under adverse agro-climates like hot desert and high rainfall areas. Uses of hybrids in vegetables have increased productivity per hectare by 40-55 per cent. Development of leaf nutrient standards in several crops and drip irrigation schedules in banana, grape, papaya, pomegranate and mandarin were standardized for improving yield and quality of fruit, which ultimately results in the saving of water by nearly 30-40 %.

Use of Plant Growth Regulators

Several plant growth regulators are commercially employed in production and quality improvement of horticultural crops. These include Dormex for hastening bud burst in grapes; NAA and 2,4-D for control of fruit drop in mango and citrus; urea spray for crop regulation in guava, paclobutrozol and calcium carbide for flower induction in mango and pine apple and GA for improving berry elongation in table and raisin grapes.

Crop Protection

Improved disease detection techniques such as ELISA and ISEM for improving seed quality and tissue culture technique for rapid multiplication of potato have been standardized. IPM strategies have been developed for fruit borer in brinjal, diamond back moth in cabbage, thrips in chillies, *Phytophthora* foot rot in black pepper, "Katte", rhizome rot in cardamom, rhizome rot in ginger, late blight and bacterial wilt of potato. The biological control measures for the mealy bug in grape, fruit borer in tomato and okra have also been developed.

Post Harvest Management

Pre-harvest treatments to control post harvest losses in citrus, mango and grape have been standardized. Maturity standards for mango, guava, grape, litchi, *ber* have been perfected. Chemical treatment for regulation of ripening in mango, sapota, banana have also been standardized. Optimum storage temperatures have been calculated out for several fruits, vegetables and tuber crops. A mango harvester and fruit peeler; hand and pedal operator cassava chipping machine, harvesting tools (5-14 times efficient); implements for mechanization of potato cultivation e.g., oscillating tray type potato grader, fertilizer application cum line marker, potato culti-ridger, soil crust breakers, potato digger and automatic potato planter diggers were designed and fabricated indigenously. Low cost environment friendly storage system for fruits, vegetables, potato and onion has been developed. Vapour heat treatment for control of fruit fly and agro-techniques for control of spongy tissue in mango have been developed.

Progress has also been made towards enhancement of shelf life of fruits by film waxing, fungicidal application, growth regulators and ethylene absorbents. A state of the art washing, grading, packaging line has been installed at NRC citrus at Nagpur. A mango harvester and peeler has been developed.

In vegetables, use of perforated and stackable plastic crates has been standardized for forced air curing of onion and potato. Similarly, besides solar drying of vegetables, low cost onion storage structures using bamboo pipes have been designed. Passive evaporative cooling system has been developed for storage of potatoes for 3-4 months during summer and low cost zero energy cool chamber has been designed for on-farm storage of fruits and vegetables.

Availability of raw material and changes in food habits have also resulted in increased number of processing units (4270 in 1994 to 5198 in 1999) installation capacity (12.60 lakh tonnes to 21.00 lakh tonnes) which in turn have given way to increased production (5.59 lakh tonnes to 9.40 tonnes) of processed produce.

There is a need to use innovative technologies for grading, packaging and storage. While significant advances have been made in recent years by introduction of corrugated fibreboard cartons; recent research has succeeded in developing equipment for grading. Commercial prototypes have been developed utilizing acoustic response ultrasonic photometry, light reflectance, delayed light emission, short-wave radiation response and machine vision technique. Equipment has also been developed for orientation of fruits and vegetables to meet the needs of different types of grading machines.

We also have to make use of innovative technologies in packaging and storage. These include Modified Atmosphere Packaging (MAP), Controlled Atmosphere Packaging (CAP), Modified Humidity Packaging (MHP), Biodegradable Film Packaging and Controlled Atmospheric Storage and Hypoboric Storage. However, lot still needs to be done before these can be applied in our conditions. Trials conducted by APEDA for export of mango from Maharashtra and Andhra Pradesh have indicated that CAP shipment has achieved partial success. Problems with quality issues like overcoming chilling injury, latex staining, uneven ripening of stored fruits still need to be attended to, effectively.

Modern cold chain is a temperature management facility involving a number of equipments such as pre-cooling units, cold storage, humidity controlled atmospheric storage, reefer-container, mobile coolers and integrated handling and storage systems. It provides ideal conditions for preserving perishable agro-commodities from their point of origin to their point of consumption. It consists of pre-cooling units, refrigerated transport, cold storage and refrigerated retail shops. The cool chain is vital for perishable commodities like fruits and to keep them in prime condition, thus, reducing their wastage.

By adopting innovative processing methods and increasing the scale of operation, quality of processed products can be improved and cost reduced. Extrusion processing, individual quick freezing (IQF), osmotic and asceptic processing technologies hold considerable promise. Similarly, another innovative process is Individual Quick Freezing (IQF). This process permits production of free flowing frozen foods and, therefore, various IQF commodities can be mixed together like dry ingredient and can be packed in bulk container.

Impact of Research and Development

The technologies discussed above have resulted in significant achievements through increased area, production and productivity.

Fruits

Area under fruits increased from 1.22 million hectares (1991-92) to 4.01 million hectares in 2001-02. India, with a production of 43.1 million tonnes (2001-02), is the second largest fruit producer (next to China) in the world (Table 3). India produces 65% of world's mango, 11% of world's banana, ranking first in the production of both the crops. It has the highest productivity of grapes in the world and significant expansion has been taken up in *aonla*, *ber*, pomegranate and sapota cultivation.

In coconut, the area has been increased from 1.53 million hectares in 1991-92 to 1.89 million hectares in 2001-02. India has become one of the largest coconut producing countries of the world. Production of coconut has gone up from

Table 3. Area and production of important horticultural crops in India

(Area m.ha., Production m.tonnes, Productivity t/ha)

Commodity	1991-92			2001-02			% increase		
	Area	Prod	Pty	Area	Prod	Pty	Area	Prod	Pty
Fruits	2.87	28.63	9.98	4.01	43.11	10.72	39.7	50.2	7.5
Vegetables	5.59	58.53	10.47	6.15	88.62	14.41	10.0	51.4	37.6
Spices	2.05	1.9	0.93	2.31	3.00	1.30	12.7	57.9	40.1
Coconut	1.53	6.93	4.53	1.89	8.82	4.67	23.5	27.3	3.0
Cashew	0.53	0.30	0.57	0.77*	0.50*	0.65*	45.2	66.6	14.0
Arecanut	0.21	0.24	1.14	0.31	0.38	1.23	47.6	58.3	7.3
Others	0.21	0.26	1.24	1.46	1.84	1.26	595.2	607.6	1.61
Total	**12.33**	**96.53**	**7.83**	**16.59**	**146.27**	**8.79**	**34.6**	**51.0**	**12.2**

*figures for 2002-2003

6.9 million tonnes to 8.82 million tonnes nuts. The productivity in coconut has increased by 33.0% during the period. Coconut contributes 700 billion rupees to the GDP of the country. The contribution of the crop to the total edible oil pool in India is around 6 per cent.

India is the leading producer, processor and exporter of cashew kernels in the world. In cashewnut, area has increased from 0.533 million hectares in 1991 to 0.77 million hectares in 2001-02. The production in cashew has gone up from 0.30 million tonnes to 0.50 million tonnes in 2001-02. Cashew stood fourth in position amongst horticultural products exported from India, after tea, coffee and spices. India continues to dominate the world in area, production and productivity of arecanut and has achieved self-sufficiency in arecanut production (0.38 million tonnes). Most of the production is domestically consumed.

Vegetables

India ranks second in the world vegetable production (88.62 million tonnes) after China. Vegetable production has increased three times in the last 50 years (Table 3). A large area is now covered with F1 hybrids in vegetable crops resulting in increased yield and thus a better socio-economic status of farmers. Vegetables like tomato, cabbage, cauliflower, radish and onion are now produced almost all the year round and India has attained self-sufficiency in seed production of temperate vegetables. The productivity of vegetables has increased from 10.4 t/ha to 14.4 t/ha in 2001-02 (Table 3). Mushroom production has increased from 100 tonnes in 1970 to 30,000 tonnes in 1996-97. Mushroom cultivation has spread to almost all parts of the country.

In potato, area, production and productivity has increased from 0.234 million hectares, 154 million tonnes and 6.59 t/ha in 1949-50 to 1.2 million hectares, 224.9 million tonnes and 17.6 t/ha respectively in 2001-02. The annual compound growth rate for potato during this period was 6.07 compared to 5.6% for wheat, 2.7% for rice and 2.74 for total food grains. India is the only country in South East Asia having a national disease free seed production programme producing 2600 tonnes of breeder's seed annually.

In cassava, productivity increased from 7 t/ha in 1960-61 to 22t/ha during 1992, which is more than double the world average (9.81t/ha). Sago and starch industry based on cassava also developed.

Achieving Nutritional Security

Horticultural crops, particularly fruits and vegetables not only add greater variety to the diet in terms of colour, flavour and texture, but these are also rich sources of nutrients. They have high vitamin A and C content and a fair amount of vitamin B-complex. They make excellent contribution to the calcium and iron levels in the diet and provide minerals, besides, high quantity fibre for maintenance of normal gastro-intestinal motility. Thus, fruits and vegetables constitute 25-30 per cent of recommended Indian balance diet. Besides, increased per capita availability of these commodities through increase in area, production and productivity, efforts are also underway to develop improved quality of fruits and vegetables. Carrot variety Pusa Meghali and pumpkin variety Arka Chandan have high carotene content while some F1 hybrids in tomato have high lycopene content. Even in the most advanced countries like the USA, fruits and vegetable are the second important constituents of food. Some major crops that can supplement food and nutritional security are banana, potato, sweet potato and leafy vegetables.

Emerging Challenges

The burgeoning population, shrinkage of arable land for agriculture due to urbanization and industrial growth and global competition have limited the possibilities for horizontal expansion. The answer, in horticulture, therefore, lies in vertical growth in terms of appropriate location-specific high value crops with maximum productivity and cost effectiveness.

After attaining food security, our efforts have been focussed on achieving nutritional security by laying emphasis on production, protection and post harvest management of horticultural crops. We now have the mandate to increase per capita availability of these crops in order to meet the domestic, and export needs, besides the needs of the processing industries. The overall demand for horticultural produce is estimated at 300 million tonnes by 2011-12 (Table 4).

Despite several achievements, there are several challenges to be met for achieving the targeted produce. The land area is limited while the population of India has already crossed the billion mark. The global scenario has been changing with signing of WTO by India, removal of quarantine curbs resulting in access to domestic market. Thus, it has become necessary to be competitive internationally. Simultaneously, the Indian scenario has also been changing fast. Horticultural crop production has moved out of rural confines to urban areas. Traditional enterprises have given rise to horticulture business. Hi-tech greenhouse technology has been introduced in vegetable and flower production. Other features include increased use of micro-irrigation, exploitation of biotechnological tools in mass production of planting material and increased international trade.

The past success in the horticultural production has been a direct result of two major policy initiatives of the Government of India, namely, promotion of diversification of Indian Agriculture and introduction of far reaching economic reforms. However, the emerging worldwide trend, which is also reflected in our country, indicates a paradigm shift in dietary needs of people. This means that the demand for horticultural produce will continue to rise with rise in income levels.

Since the growth of horticultural crops is economically rewarding, this sector is expected to grow and contribute to food and nutritional security, provided, the sector is nurtured with focussed infrastructural development and having a conducive policy environment. The sector has recieved proper attention in the formulation of Agricultural Policy of Government of India, which aims at a systematic development of horticulture.

Future Thrusts

The report of the working group on Development of Horticulture in the Tenth plan proposes several thrust areas for priority attention. The areas relevant for nutritional security are briefly discussed below.

Improving Production

To achieve the targets set for tenth plan and beyond, it is necessary to increase production. This can be increased substantially by utilizing available arable land; by changing crop priorities and promoting use of wastelands for growing suitable horticulture crops. Since dry land regions account for more than 60 per cent of area, strategies without focussed attention to these areas may not yield desired results. There is also need to emphasize horticulture crop production in states having potential for area expansion like Orissa, promotion of cost effective poly houses in the arid temperate

Table 4 Projected demand of various horticultural produce

Commodity	**Production (Million tonnes)**			**Growth Rate (%)**
	2001-02	**2007-08**	**2011-12**	
Fruits	43.0	75.00	81.00	8.8
Vegetables	88.6	160.00	185.00	10.9
Spices	3.0	5.00	5.50	8.3
Coconut	8.8	18.00	20.00	12.7
Cashewnut	0.5	1.50	1.70	24.0
Others	2.2	6.00	6.80	20.0
Total	**146.1**	**265.50**	**300.00**	**10.5**

regions of Lahaul & Spiti, Leh & Ladakh and production of off-season vegetables using greenhouses. Urgent attention needs to be paid for better utilization of area through inter-cropping/mixed cropping in existing orchards, growing crops in vacant space, growing of shade-loving crops in developed orchards, etc. Mango, cashew, sapota, jack fruit can be inter-cropped with suitable crops of the region; coconut, arecanut and oil palm with cocoa, banana, pineapple, bush pepper, flowers and medicinal and aromatic plants. Black pepper, tree spices, bush pepper, pineapple, medicinal plants, ginger, turmeric can also be planted in the inter-spaces. Some of the other practices including adopting a Mission Mode approach for integrated development of medicinal & aromatic plants should also be employed. Eastern and North Eastern regions of India have the potential for horticulture development, which has not been tapped fully. Thus, Integrated Development of Horticulture in North Eastern and Eastern India needs to be taken up. Special thrust needs to be given to increase the production of raw cashew in the country, which is presently inadequate to meet the requirements of the processing capacity installed in the country. Development of horticulture, in island ecosystems and emphasis on nut crop development in the North Western Himalayas, is also a need.

Improving Productivity

The average productivity of most horticultural crops in India is low. There is, thus, a wide gap between yields obtained and potential yields with improved varieties and technologies. Programmes, therefore, need to be taken up to reduce the yield gap by improving productivity. The main emphasis should be on improving the productivity by production of disease free, quality planting material of only released and recommended varieties / hybrids, both in the public and private sector. Improving orchard efficiency and by gap filling and rejuvenation of old, unproductive, senile plantations through substitution of old varieties with improved high yielding varieties in crops like mango, apple, cashew, rubber, tea and coconut. High density planting by reduction in planting distance or by use of plant growth inhibitors and dwarfing rootstocks as recommended for crops like mango, citrus, apple, banana, pineapple and some temperate fruits will go a long way. Use of protected cultivation under controlled conditions for growing fruits like strawberry, vegetables such as cucumber, cabbage, capsicum, tomato and temperate vegetables in plain areas and high value cut flowers for domestic use and export need to be promoted. The cultivation of crops, which produce higher biomass/unit area/unit time like, banana, pineapple, papaya, potato, sweet potato, tapioca, elephant foot yam should be taken up in areas requiring poverty alleviation and nutritional security.

Reducing Cost of Production

In view of the global competition, as a result of implementation of WTO w.e.f. April 1, 2001, reduction in unit cost of production of horticultural commodities, which are exported, has become inevitable. There is also a danger of large-scale imports of horticulture commodities from abroad if our local production costs are not lower / comparable. Appropriate programmes are therefore, required to reduce the cost of production by reducing the cost of planting material by mass multiplication of horticulture crops using micro-propagation, wherever feasible. For instance in banana, cardamom, vanilla, ornamental and medicinal plants, reduction in cost of fertilizer by determination of plant needs through leaf nutrient standards and applying only required quantities, efficient utilization and conservation of water and applied nutrients through drip / micro irrigation and fertigation, weed control, moisture conservation and solarization techniques. Integrated nutrient management should be followed by cover cropping with leguminous crops in perennial plantations and incorporating them to improve soil fertility, thus, supplementing the fertilizer needs; and thereby reducing cost of production. Promotion of integrated pest and disease management, thus, reducing costs of chemical pesticides and fungicides should be taken up. There is a need to reduce post harvest losses by proper pre and post harvest handling, proper packaging and creating suitable infrastructure like low cost cold storage for fruits and vegetables, storage for potato and onion cold chain transport and other technologies. Use of pre-cooling units, controlled/ modified atmosphere/ refrigerated containers, particularly for transport by sea; will go a long way in enhancing the shelf life of fruits and vegetables such as mango, grape, litchi and reducing transport losses.

Increasing Value Addition

Value added products are now attracting a greater export market like oleochemicals, oleoresins, essential oils and so the development of new value added products in spices, coconut and cashew will go a long way in export promotion. The development and popularization of newer processed fruits, vegetables, ready to serve food items; modernizing processing units and capacity of existing units need to be encouraged. The prescribed international and domestic SPA standards should also be disseminated and adhered to.

Price Stabilization

Horticulture crops suffer price fluctuations due to over production, underproduction and fluctuation in exports, lack of short and long term storage facilities, lack of market intelligence and inadequate database. The strategy suggested for price stabilization is a collection of reliable database, developing a long-range export policy and timely introduction of Market Intervention Scheme (MIS), Minimum Support Price (MSP) and creation of Price Stabilization funds.

Use of Hi-Tech Horticulture Technologies for Production of Nutrition Rich Fruits and Vegetables

The population of India has already crossed a billion mark, while the yield of several crops has reached a plateau. The challenge now is to grow more food of high nutritive quality, on a continuously shrinking land area. The solution lies in developing and adopting hi-tech horticultural technologies to boost productivity in an eco-friendly manner.

Genetically Modified Varieties

Some of the traits that are being modified through genetic engineering include high productivity, pest, herbicide and drought resistance, increasing shelf life and improving nutritional quality. Such varieties have been developed in a number of fruits and vegetable crops.

Micropropagation

It is a proven means of producing millions of identical plants. An added advantage is production of pathogen-free planting material. Tissue cultured plants of papaya, are now marketed for extraction and processing of papain. Tissue cultured anthurium, orchids and gerberas have attained commercial importance. Efforts to standardize technologies for the micropropagation of cashew, litchi, mango and walnut have not met with success.

Micro-Irrigation / Fertigation

It has been very successful for irrigating horticultural crops like mango, banana, grapes, pomegranate, guava, citrus, brinjal, cucumber, okra, capsicum, coconut, cashew, etc. The emphasis now is on applying liquid fertilisers through microirrigation. This results in saving 30% fertilizer, increasing 100% yield, saving of 70% water, preventing weed growth, saving energy and improving quality of produce.

Integrated Nutrient Management

An increasing need is being felt to integrate nutrient supply with organic sources to restore the health of soil. Bio-fertilisers offer an economically attractive and ecologically sound means of reducing external inputs and improving the quality and quantity of internal resources. These are less expensive, eco-friendly and sustainable. The beneficial microbes in the soil, which are of great significance to horticultural situations are the biological nitrogen fixers, phosphate solubilisers and the mycorrhiza fungi.

Organic Farming

With increasing health consciousness and concern for environment, the organic farming system has been drawing attention worldwide. As a result, there is a widespread organic movement. Demand for organic products, especially, in developed countries, has been increasing by leaps and bounds. Major components of organic farming are crop rotation, maintenance and enhancement of soil fertility through biological nitrogen fixation, addition of organic manures and use of soil microorganisms.

Integrated Pest Management

Integrated Pest Management (IPM) aims at judicious use of cultural, biological, chemical, host plant resistance/tolerance, physical-mechanical control and regulatory control methods. Agenda 21 of the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992 identified Integrated Pest Management in agriculture as one of the requirements for promoting sustainable agriculture and rural development.

Protected Cultivation / Green House Technology

It is a high tech, high precision technology for intensive cultivation of vegetable and flowers virtually year round. It is the best alternative for poor soil and bad climate as it can alter/ modify environment for optimum plant growth and production of uniform, high quality produce.

Post Harvest Management

There is a need to lay sufficient emphasis on post harvest management of horticulture produce. Some technologies, which require evaluation and follow up include MAP, MHP, biodegradable film packing and hypobaric storage. Cool chain is another temperature management facility, which can suitably preserve perishable horticultural crops from the point of origin to consumer. However, India is not yet ready for cool chain except for products that are to be sold through modern stores in metropolitan cities and for exportable items.

Conclusions

Although, India has the highest productivity in some horticultural crops like grape and banana; much needs to be done in rest of the horticultural crops where the productivity levels are dismal when compared to the world average. Tremendous scope to enhance the productivity exists through a number of interventions. Since the land resources available are shrinking day-by-day for agricultural related activities due to increasing urbanization and industrialization, a prudent option open to Indian horticulture is to increase the productivity levels to meet the increasing demands. Although, it is difficult to get fertile lands in this changing scenario degraded soils and problematic soils, which are available in abundance, can be brought under cultivation with horticultural crops. Fruits and vegetables rich in nutritive value like aonla, ber, bael can be grown in such soils. Concrete efforts are needed from different agencies to reclaim such marginal and degraded soils and bring them under productive cultivation. Advances in biotechnology opened up avenues to tailor-made agricultural products to tackle specific deficiencies. Biotechnology advances in rice to create vitamin-A rich strains (golden rice) offer unique scope for genetic improvement in horticultural crops as well. The greatest advantage of such fortification of nutrient value lies with the horticultural crops because a number of them can be consumed in a fresh condition. Efforts are underway to create edible vaccines to tackle a number of diseases by genetically engineering fruits and vegetables, which are consumed raw. Similar efforts to genetically engineer fruits and vegetables with high nutritive value will, therefore, hold enormous promise for horticultural crops. Introduction of plastics in agriculture dramatically improved the productivity and quality of a number of horticultural crops. Nutritious exotic vegetables can now be grown in polyhouses to meet the nutritional requirements in adverse climates like cold deserts which are covered with snow during a major part of in a year. The rampant malnutrition among the tribes in the cold deserts of Lahol and Spiti, Ladhak and Kargil is a matter of past due to year round cultivation of vegetables in improvised protected structures.

Horticultural crops possess pharmaceutical and nutraceauticals principals to tackle serious ailments. For instance, a disorder like, age related macular disorders (AMD), which is prevalent in old people is due to acute deficiency of leutin, a constituent of carotinoid pigments. Since the body cannot synthesize its leutin requirements for the development of retina, external supplementation through fruits and vegetables is the only means of supply; therefore, reduced intake of fruits and vegetables often results in AMD in old people. Besides ensuring the human sight carotenoid pigments also act as anti-oxidants, antagonizing the destructive free radicals, which are produced in the body.

Focused efforts are required to promote container growing and kitchen gardening in the urban areas to meet the nutritional requirements of the families. The technology for container growing of fruits and vegetables is available in a number of research organizations, which can be popularized among the urban population to ensure adequate nutritional supplementation. The demand for organic fruits and vegetables is increasing in a rapid pace. Such horticultural produce grown through organic means is nutritionally superior and free from the injurious pesticide residues that are otherwise found in inorganically grown produce. Growing awareness, therefore, about the organic fruits and vegetables would further enhance the supply of nutrients in a safer way.

MILK: STRATEGIES FOR FURTHER AUGMENTATION OF PRODUCTION AND CONSUMPTION

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Milk and milk products have remained a valued foodstuff for the predominantly vegetarian population of India. It is considered a part of a balanced human diet because of it's high content of quality protein, calcium and vitamins particularly vitamin A, niacin, riboflavin and folic acid. In western diets, nearly 75 per cent of total calcium intake (1000-1500 mg) comes from milk and milk products. However, daily calcium intake in average Indian diets barely exceeds 500mg. A 250 ml serving of cow milk contains calcium that is equivalent to 60 per cent of Indian Council of Medical Research's (ICMR's) Recommended Dietary Allowance (RDA) for adults (400mg). An equal amount of buffalo milk contains 95 per cent of calcium RDA for adults. Besides these, milk also contains several bioprotective molecules that ensure good health. Conjugated linoleic acid (CLA), which is known to have anticarcinogenic and antiatherogenic activity in addition to being effective in immuno modulation, is naturally present in milk and milk products. Milk also has immunoglobulins, lactoferrin, lysozymes, lactoperoxidase and vitamin B12-binding protein, which have antimicrobial effect. In view of the importance of milk on nutritional well-being and public health, there is an urgent need for augmenting milk production and consumption through appropriate technological interventions.

Milk Production

Dairying plays a vital role in providing not only nutritional security but also income and employment to a large segment of Indian population. It is estimated that nearly 20 million people are employed in the livestock sector in principal (11 million) or subsidiary (9 million) capacity. The distribution of livestock asset value is more equitable than land. While marginal and small landholders (<2.0 ha) own 63 per cent of the arable land, they own nearly 67 per cent of the bovines. The sector is also very gender sensitive as over 90 per cent of the activities related to care and management of dairy animals are carried out by the women. The contribution of the livestock sector to the total national gross domestic product (GDP) is around 5.5 percent.

Dairying in India has shown remarkable progress in recent years. India registered a total milk production of 86.96 million tonnes in the year 2003, which is far above the USA(77.25 MT). On a global basis, India, with almost 16.9 per cent of world's human population, contributed nearly 14.7 per cent of the world's milk production of 592 million tonnes in 2003. In 1970 India's share in global milk production was only 9 per cent[1]. This growth has been achieved by following a multi-pronged strategy and the extensive intervention of Government agencies coupled with an increased demand, driven by population growth, rising income levels and rapid urbanization. With crop production reaching a plateau in terms of production and productivity, there is a need to adopt commercially viable diversification such as dairying. Some of the issues, which are important for sustainable growth in milk production in the country, are discussed in this manuscript.

Genetic Improvement for Quality Animals

A cross breeding programme was envisaged in the mid sixties for improving the performance of indigenous breeds. While the programme, theoretically, offered attractive ways to enhance available genetic material in the country but there were major problems in implementation. Eventually, the good quality bulls needed for natural mating in breeding tracts became scarce, leading to a further deterioration of indigenous breeds in these tracts. There is, thus, an urgent need to produce quality indigenous bulls to provide the best male germplasm for breed improvement. The indiscriminate cross breeding spread all over the country has led to extinction of many known breeds and spread of sexually transmitted diseases like Infectious Bovine Rhinotracheitis (IBR) at an alarming rate[2]. To overcome these problems, it is essential to ensure close co-ordination between different agencies involved in dairy development. Certain areas that need urgent intervention include:

- Development of an extensive infrastructure support system for preservation and supply of frozen semen through Government and private sector participation.
- Encourage participation of private sector and NGOs in the delivery of artificial insemination services at the farmers doorstep
- Improving natural breeding services for buffaloes
- Testing and monitoring the health of bulls and screening for communicable reproductive disease
- Strict quality control of semen supply and institutional restructuring for supply of quality semen to a specialized, autonomous and professional state-implementing agency
- Selection and training of NGOs and extension workers who could then train others in modern techniques for rearing dairy animals
- Improving the indigenous breeds possessing desirable characteristics, like disease resistance, heat tolerance and efficient utilization of low quality feeds.

Animal Health Issues

In the last four decades efforts were made to control communicable diseases (Rinderpest, Foot and Mouth Disease, Hemorrhagic Septicemia, Black Quarter and Anthrax). Effective implementation of a vaccination programme has eradicated Rinderpest. Other diseases have not been controlled because of poor vaccination coverage; inspite of the fact that effective vaccines are available. Several newer diseases Blue Tongue, Contagious Bovine Pleuro Pneumonia (CBPP), Mucosal diseases are emerging as major problems.

Foot and Mouth Disease (FMD) is of considerable economic importance. It not only reduces milk yield but also limits the export potential of livestock products. Although massive vaccination programmes have been undertaken in the past, it has not yielded the desired results mainly because FMD protection is based on herd immunity. Effective vaccination requires that over 85 per cent of the animals in the area be vaccinated to establish herd immunity. Currently, only about 5 per cent of animals at risk are vaccinated. However, ring vaccination programme initiated in a few selected districts may help in creation of disease free zones.

Further strategies for ensuring animal health would, therefore, require concerted efforts in the following directions:

- Physical surveillance through villages, stock routes and institutional searches to detect hidden cases of Rinderpest to provide a safeguard against re-emergence of the disease.
- Expanding the scope of the programme on creating disease-free zone by covering other areas in the country (currently only Andhra Pradesh, Maharashtra, Gujarat, Punjab, Haryana, Delhi and Western Uttar Pradesh are covered).
- Creation and effective implementation of disease surveillance mechanisms using IT tools.
- Upgrading facilities for animal disease diagnosis and accreditation as per international standards.
- Proper animal quarantine, certification and enforcement with major emphasis on control of trans-boundary animal disease.
- Implementation of Livestock Health Schemes for dairy animals.
- Encouraging participation of private veterinary practioners to deliver animal health services at farmers' door.
- Education and training of farmers to use scientific principles in the management of animals including cleanliness, hygiene and prophylactic measures.

Issues Related to Feed and Fodder

The Bovine population in the country has been increasing at the rate of more than 1 per cent annually, which has offset the attempts to generate newer feed from non-conventional resources and agro-industrial by-products to meet the increasing demand. The permanent pastures and grasslands in our country is only 3.6 per cent of the total geographical area; the cultivable land for fodder production has remained static at around 4.8 per cent. The population growth rate (1.94 %) is a limiting factor for expanding the cultivation land for fodder production. Augmentation of feed and fodder resources must, therefore, focus on two issues. One, the centuries old crop-livestock integrated, mixed farming system which is under enormous stress has to be strengthened through better utilization of crop residues and secondly, the intensive dairy farming system has to adopt green fodder in a more scientific way. The working group on animal husbandry and dairying for Tenth Five Year plan has noted that the available fodder can meet the demand of only 46.7 per cent of the livestock. It is, therefore, essential that a multi-pronged strategy be adopted to bridge the gap:

- Judicious utilization of available agro-by-products like oil meals and cereal by-products by better management so that residues are collected, compressed, nutritionally enhanced, stored and distributed.
- Establishment of efficiency of utilizing non-conventional feed resources like mango seed kernel, mahowa cake and neem cake. and the development of specifications for utilizing these ingredients.
- Promote the adoption of feeding technologies developed to increase nutrient supply to animals by manipulation of the animal's digestive track through active as well as passive means.
- Encourage farmers to use new feed technologies like by-pass protein technology, total mixed ration, complete feed block technology and mineral mixture. to augment milk production and, thus, reduce the cost of production.
- Serious efforts should be made to use modern biotechnological tools to modify organisms capable of degrading ligno-cellulose feeds at high rate.
- Farmers need to be educated and provided with incentives to increase area under fodder cultivation by utilizing wasteland in and around villages.
- Promote the cultivation of high yielding varieties of green fodder, particularly, those which the permit multicuts.
- Encouraging participation of progressive farmers, NGOs and institutions in training local farmers for producing good quality fodder or utilizing available feed resources and enriching low quality fodder by scientific methods.
- Planned cultivation of suitable fodder trees and shrubs on village bunds as an integral part of agro-forestry programme.
- Creation of facilities for storage and preservation of food grains or agro-by-products to minimize damage and wastage.
- Enforce adherence to quality control measures for animal feeds and the establishment and strengthening of feed analytical laboratories in strategic locations in the country.

Intensive Dairy Production Systems

The traditional crop-livestock integrated farming system, provides means of livelihood to landless and marginal farmers, and continues to dominate the dairy economy in India. It is based on low input and crop residue use. The system, however, has an inherent disadvantage, as the focus of farmers' attention is crop production with dairying remaining as a subsidiary activity. In the context of the present liberalized economy and global trade opportunities, quality of milk, particularly in terms of sanitary and phytosanitary measures, is of paramount importance. The traditional milk production system, which is very scattered, lacks the infrastructural support and mechanism to ensure quality. A feasible alternative could be the semi-intensive or intensive dairy production system, which could be adopted as a commercial venture. This would require the development and dissemination of a package of scientific practices to maximize animal productivity/output per unit.

Institutional Lending System in Livestock Sector

Public sector banks have only recently shown interest in providing credit support to the farmers. However, the organized financial sector is still inhibitive in financing livestock programmes. As a result, most livestock farmers end up taking loans from private agencies at high interest rates. Government intervention is, therefore, essential to ensure that financial institutions such as NABARD reserve a sizeable proportion of their lending to meet the short and long-term capital requirements of the animal husbandry and dairying sector. Venture capital funds need to be created to support private sector participation in the creation of infrastructure for both milk production and processing activities. Credit cards for dairy farmers on the lines of the Kisan Credit Card could be another alternative to provide financial support to the farmers for various dairying activities.

Milk Consumption Trends

India has a per capita milk availability of 219 g, far below the world average of 285g per day, but meets the recommended nutritional requirement of milk by ICMR (220 g/person/day). However, the actual (economic) demand in near future would outstrip this supply. Thus, if the supply is not increased to match the demand, the excess demand would result in an increase in the milk prices, thereby, affecting the consumption and nutritional security of lower income groups. To meet the projected demand of 254 million tonnes by 2020, the milk production should, therefore, increase at 5.73 per cent per annum[1]. The demand for milk and dairy products is income elastic and growth in per capita income is expected to increase demand for milk and milk products. Studies in the past have indicated that the proportion of income spent on milk and milk products increased from 11.7 per cent in rural areas and 14.7 per cent in urban areas in 1970-71 to 21.6 and 16.7 per cent in 1999-00, respectively[3]. This shows that demand in rural areas has increased more than in the urban.

A commodity-wise break up shows that 56 per cent of the milk produced in India is available as a marketable surplus for urban areas but a fairly large proportion of it is converted into milk products, mainly khoa, paneer, butter, ghee and traditional sweets. The share of the organized sector is very small (approximately 16 %). While the Government/co-operative sector markets nearly 80 per cent of the milk as liquid milk, the private sector markets only 30 per cent as liquid milk and the remaining 70 per cent as milk products, mostly comprising of powder, butter and ghee. The future for commodities like powder and ghee does not appear to be sustainable. Hence, a major shift in product mix for organized dairy industry is needed. Empirical evidence also suggests that the composition of an average Indian's food basket is gradually shifting towards value added products. It is, therefore, essential for the Indian Dairy Industries to initiate the manufacture of mass-market products for domestic as well as export markets[4]. The following issues are, therefore, immensely important.

Improvement in Quality of Milk and Milk Products

The Indian Dairy Industry will be able to amass possible benefits by being a global contender in trade only after its products are at par with the rest of the world in terms of price and quality. The price competitiveness of Indian dairy products is often a direct offshoot of their quality, as price reduction is generally considered an indication of poor quality. Often, this results in unpredictable situations of trade in India. When international prices are low, the Indian market is threatened with imported goods. On the other hand, quality problems prevent an increase in exports even when global prices are high.

So, to maintain a strategic advantage, it becomes imperative that stringent quality measures are followed in all areas of the post-harvest handling of food products. A positive attitude towards the implementation of good hygiene practices at the primary milk production level and translating these as good manufacturing practices (GMP) at the plant level should be the first steps taken. There is a need to promote clean milk production, prompt chilling and minimize/eliminate various pollutants and contaminants like pesticide residues, antibiotic drug, hormone, heavy metals and adulterants during processing and transportation. To ensure microbiological safety of milk and milk products, there is a need to develop cost effective, reliable and simple kits based on immunomagnetic separation (IMS) and for PCR based assays for rapid detection of these pathogens at the field level.

Environment Friendly Processing Technologies for Enhanced Efficiencies

Newer technologies such as UHT processing and Membrane processing are now available, which can be used to increase processing efficiently and reduce environmental impact. UHT processing is suitable for extending the shelf life of liquid milk as well as products like milk concentrate, cream, desserts and kheer. Currently available membrane processes like microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and Reverse Osmosis (RO) could be effectively employed for fractionating valuable components to develop newer intermediate dairy products, which can be incorporated in various functional food formulations.

Dairy Ingredients in Non-Dairy Food Applications

Several milk products have nutritional and therapeutic properties. Whey proteins are ingredients of speciality food products for paediatric and geriatric age group. Milk proteins are endowed with unique nutritional and functional characteristics that make them ideal ingredients in different food formulations. Hence, it is used in the manufacture of bakery products, comminuted meat products, beverage and confectionary products[5].

While the demand for dairy products for value addition will continue to grow, the dairy market of the future will have new challenges. While a section of consumers, particularly domestic, will demand low priced products others would be willing to pay a premium for quality and uniqueness. The challenge for the dairy industry would be to identify the segmented consumption pattern and develop tailored products.

Shelf Stable and Convenience Foods

Convenience, ready-to-reconstitute and ready-to-eat foods are gaining popularity at a pace never seen before. Though, the market for such foods is still limited to urban consumers, defence personnel, tourists and caterers; future growth of processed dairy food market will be driven to a significant extent by such products. Preservation processes employed for such products are either sterilization or dehydration. The severity of heat treatment as employed in sterilization result in severe damage to the nutritional, rheological and sensory properties. There is, thus, a need for developing processes, which can result in milder heat treatment, coupled with optimization of other preservation factors to achieve longer shelf life. Development of such technologies particularly for indigenous dairy products will open new vistas for value addition and export.

Application of New Packaging Options

High moisture content makes dairy products prone to microbial and chemical spoilage. Many packaging materials have been developed to address these problems. However, recent innovations in modified atmosphere packaging and active packaging further enhance the product quality. In modified atmospheric packaging (MAP), the gaseous composition of atmosphere is altered to retard the various reactions leading to deterioration of milk / dairy products. Active packaging (AP) is a group of technologies in which the packaging material performs some desirable role other than providing an inert barrier between the product and the out side environment. Such packaging options, if applied to processed foods, will greatly improve their shelf-life and increase their acceptability.

Indian Dairy Products

Indian dairy products play a significant role in the socio-economic and religious activities of our population. It is estimated that about 50 to

55 per cent of total milk produced (approx. 42 million tonnes) is converted into a variety of Indian dairy products by the unorganized sector (halwais) employing various unit operations like heat and acid coagulation, heat desiccation and fermentation. The market for these products is valued at about Rs 250 billion, which speaks volumes about the tremendous potential of the sector.

There is an increasing demand for Indian dairy products both among the large domestic and global consumer base. The changing global scenario in the post WTO era offers us an opportunity to become a global player in ethnic food markets. Process mechanization, sanitary and phytosanitary measures are, therefore, necessary to ensure that the indigenous milk products meet international quality standards.

Value Addition with Buffalo Milk

Buffalo milk constitutes nearly 55% of the total milk production in India. It is rich in fat, minerals like calcium (Ca) and phosphorus (P) and tocopherol, has higher content of lactoferrin, less content of urea and higher ratio of Ca and P. The inherent nutritional and physico-chemical properties of buffalo milk is an added advantage for Indian consumers. Buffalo milk is usually preferred over cow milk for khoa making, since the former gives greater yield and has a more desirable flavour, body and texture. Hence, the competitive advantages of buffalo milk need to be fully exploited for value addition and development of new products with special attributes.

Functional Ethnic Foods

With the evolution of novel technologies and scientific developments in the past years, an increasing number of potential nutritional products with medical and health benefits, so called “functional foods” have gained an important place in the world market. Functional foods are expected to perform particular functions such as the enhancement of the biological defense mechanisms, prevention/ recovery from a specific disease, control of physical and mental conditions and slowing the aging process. Foods can be modified with the addition of phytochemicals, bioactive peptides, omega-3 PUFA and probiotics and/or prebiotics to become functional. The potential for producing healthy functional foods incorporating valuable dairy and non-dairy ingredients in existing and new product formulations need to be exploited.

Research Support on Upgradation of Food Laws

New developments in processing technologies will require changes in the existing regulations as feed back from the control systems to identify and manage both existing and emerging risks. Research efforts are, therefore, needed to generate an accurate scientific data on new dairy processing technologies, food packaging, methods for assessing contamination and chemical exposures. Emerging opportunities for the export of our dairy products, particularly indigenous milk products, require that database on presence and levels of pesticides, biocides and chemicals are created and upgraded periodically.

Biotechnological Applications in Food Processing

Biotechnology has been exploited for centuries in animal and plant strain selection for food production, use of starter cultures to develop fermented dairy products and use of yeast strains in the production of alcoholic beverages. Biotechnology encompasses a wide range of technologies such as genetic manipulation, fermentation technologies, protein separation technologies and enzymes for food processing.Biotechnology can play an important role in development of tests for rapid detection of food pathogens and also in the development of a new range of functional foods with a potential to improve human health. Biotechnological approaches could greatly improve food quality through development of starter cultures and starter adjuncts for flavour improvement in fermented foods.

Conclusion

Milk and milk products are not only a valued source of nutrition and provide income and employment to a large section of Indian population. Several years of strategic planning and effective programme implementation by Government and public sector agencies have ensured that India emerges as a leading producer of milk in the world. However, the rising population and plateau in crop production trends necessitate that a renewed impetus is given to Indian dairying to meet projected demand. Some of the issues that need to be tackled on priority are: genetic improvement for quality animals, improvement of animal health, enhancement and enrichment of feed & fodder resources, establishment of commercial dairy farms and provision of institutional financial support. Furthermore, the post WTO scenario provides India with an opportunity to market its' products in other parts of the world, particularly to the over 150 million non-resident Indians. Tremendous export potential, therefore, exists for unique traditional milk products. The potential for producing functional foods incorporating valuable dairy ingredients in existing and new product formulations will also have to be exploited. Dairy scientists and entrepreneurs should adopt a holistic approach to product development encompassing new dimensions of value addition, newer processing know-how, to meet the international quality and safety standards.

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INDIAN FISHERIES AND AQUACULTURE: PRESENT STATUS AND FUTURE PROSPECTS

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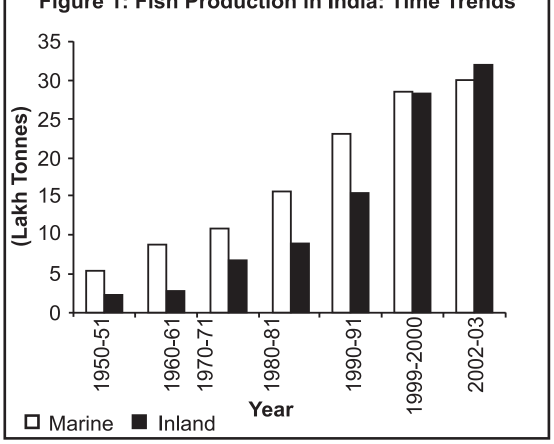
Global fish production from capture has remained relatively stable over the past two decades while fish production through aquaculture has progressivly increased. The Indian fisheries sector has come a long way since independence (Figure 1) and has contributed immensely to the food basket of the country, with annual production levels of over six million tonnes of fish and shellfish from capture fisheries and aquaculture. India is the fourth largest producer of fish and is playing an important role in global fisheries. Furthermore, with production over 3.1 million metric tonnes, the country occupies second position in the world from the inland fisheries sector. In the last five decades, Indian fisheries have made great strides, with the annual production increasing from 0.75 million tonnes of fish and shellfish in 1950 to about 6.1 million tonnes in the year 2002, indicating an increase of over eight fold. The share of inland fisheries sector, which was 29% in 1950-51, has gone up to over 50% at present (Table 1). While capture fisheries have solely contributed production from the marine sector, aquaculture contribution in the inland fisheries sector has been significant in recent years. The production from capture fisheries in the last two decades has grown by only 72% i.e. from 2.08 million tonnes in 1980 to 3.59 million tonnes in 2000, but the aquaculture sector has shown a growth of 468% in the same period, i.e. 0.37 million tonnes in 1980 to 2.1 million tonnes in 2000. The country has also emerged as one of the major in exports, recording a peak during the year 2000-2001, earnings Rs. 5957 crores (US $ 1.25 billion). However, there has been a decline of 7.56% during 2001-2002 due to economic recession and steep decline in prices of black tiger prawns in the international market. Fish production (inland and marine) in major fish producing states is shown in Figure 2.

Figure 1: Fish Production in India: Time Trends



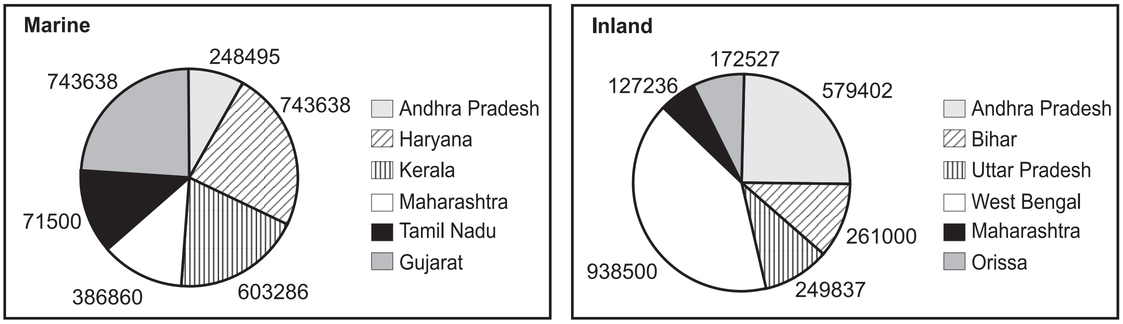
Inland Fisheries

India is blessed with huge inland water resources (29,000 kms of rivers, 0.3 million ha of estuaries, 0.19 million ha of backwaters and lagoons, 3.15 million ha of reservoirs, 0.2 million ha of floodplain wetlands and 0.72 million ha of upland lakes). It has been estimated that about 0.8 million tonnes of inland fish is contributed by different types of inland open water systems. Though, the production breakup of these water bodies is not available, it is believed that capture fisheries production from rivers and estuaries contribute only a small share of the total inland catch. The bulk of the production comes from reservoirs and floodplain wetlands, which are managed on the basis of culture-based fisheries or various other forms of enhancement. The 14 major rivers, 44 medium rivers and innumerable small rivers of the country with a combined

Table 1: Indian Fisheries

Potential Production	8.4 mmt
Present Fish Production	6.18 mmt
Inland	3.16 mmt
Marine	3.02 mmt
Fish seed production	18500 million fry
Hatcheries	1070
FFDA	422
BFDA	39
Export	Rs. 6,800 crores

Figure 2: State-wise Fish Production in 2002-03 (tonnes)



length of 29,000 kms provide for one of the richest fish faunistic resources of the world. While production figures from different riverine systems are not available, estimates made for major rivers showed yield varying from 0.64 to 1.64 tonnes per km with an average of 1 tonne per km. The average estimated yield in different estuaries range from 45-75 kg/ha.

Reservoirs form the largest inland fisheries resources in terms of resource size with 56 large reservoirs (>5000 ha), 180 medium reservoirs (1000-5000 ha) and 19,134 small reservoirs covering a water area of 1.14 million ha, 0.527 million ha and 1.485 million ha, respectively, with substantial areas added year after year due to construction of new impoundments created through erection of dams over rivers, streams or any other water course. In India, management of medium and large reservoirs can be considered akin to enhanced capture fisheries and their fisheries largely depend on natural recruitment. On the other hand, the fish catch of the small reservoirs depends on stocking and management and is termed as culture-based fisheries. Stocking in such small reservoirs is not merely a simple matter of releasing appropriate species into the ecosystem, but an important management option which needs evaluation of an array of factors, like biogenic capacity of the environment, the growth rate of the desired species, fishing condition, shallowness of the reservoirs and natural recruitment. In general, stocking of advanced fingerlings (10-15 cm) of Indian major carps at density of 400-500 numbers/ha is the option suggested for small reservoirs. However, the average national production levels obtained from the small reservoirs of the country have a productivity of about 50 kg/ha, and is low when compared to other Asian and Latin American countries.

Efforts on scientific management by CIFRI in several small reservoirs have shown that it is possible to improve the yield, for example 102 kg/ha in Baghla, 140 kg/ha in Bachhra, 150 kg/ha in Markonahalli (all are in Uttar Pradesh), 194 kg/ha in Aliyar, 182 kg/ha in Tirumoorthly (both are in Tamilnadu), 108 kg in Meenkara and 316 kg/ha in Chulliar (both are in Kerala). It has been estimated that the 1.5 million ha of small reservoirs can produce at least 0.15 million tonnes against the present levels of less than 0.07 million tonnes. The medium and large reservoirs can yield another 0.15 tonnes through proper species and stock enhancement. Thus, greater thrust is warranted to exploit the fisheries potential of these water bodies through culture-based fisheries in coming years.

Floodplain wetlands or beels are other potential fishery resources in the states of Assam, West Bengal and Bihar. They offer tremendous scope for both culture and capture fisheries. These water bodies play vital role for recruitment of fish stocks of the riverine system and provide nursery grounds for commercially important finfishes and shellfishes. It has been estimated that these beels possess potential to yield as much as 1000-1500 kg/ha/year, while the present level remains at only 100-150 kg/ha. The rich nutrients load and availability of fish food organisms make water bodies ideal for culture-based fisheries leading to higher growth of stocked fish species compared to the reservoirs. The marginal areas of the beels can be utilised for construction of ponds or pens of suitable sizes for raising the required fingerlings for stocking the beels.

Table 2: Marine Fish Production Trends (000' tonnes)

State/Dts	2000-01	2001-02	2002-03	2003-04	2004-05 (Target)
Andhra Pradesh	182	204	224	297	29
Goa	67	66	72	90	110
Gujarat	620	650	743	609	700
Karnataka	175	128	180	187	190
Kerala	566	593	603	608	not received
Maharashtra	402	414	386	400	400
Orissa	121	113	115	116	125
Tamil nadu	367	370	379	373	374
West Bengal	181	184	181	181	181
A&N Island	27	27	28	31	32
Daman & Diu	16	21	11	10	not received
Lakshadweep	12	13	7	10	15
Pondichery	38	39	39	42	45
TOTAL	**2780**	**2829**	**2991**	**2958**	

Considering the present threat of increased pollution levels and siltation of open water resources like rivers, estuaries and lagoons and also the over-exploitation of these resources leading to stagnation of fisheries production, thrust on culture-based fisheries in reservoirs and floodplain wetlands holds the key for future of the inland fisheries development in India.

Marine Fisheries

Marine fisheries have played a pivotal role in ensuring food and nutritional security of the growing population, employment generation, enhanced income and foreign exchange earnings. India has vast resources in terms of a 8,129 kms long coastline, 0.5 million sq. km of continental shelf and 2.02 million sq. km of exclusive economic zone. It is only after the establishment of Central Marine Fisheries Research Institute in 1947, that the marine fisheries development was put on sound footing. Major thrust areas include research on biology of commercially important species and monitoring their stocks for proper management; judicious exploitation and conservation; conducting exploratory surveys and mapping of the productive fishing grounds, locating new areas and resource; and carrying out environmental studies related to fisheries. Marine fish production trench in major coastal states between 2000-2004 is given in table 2.

In the first two Five Years Plans, emphasis on marine fishery sector was on the mechanizations of indigenous crafts, introduction of mechanized fishing boats, improvements in fishing gears, establishment of infrastructure facilities such as processing plants, ice plants, cold storages and landing and berthing facilities. These programmes, backed by the discovery of rich fishing grounds in inshore waters paved the way for establishment of Sea Food Exports Industries. In the next three Five-Year Plans, the above programmes were continued with greater emphasis on introduction of mechanized fishing boats and adoption of synthetic materials for fishing gears. Research on various aspects of marine fisheries and exploration of their resources was intensified (Text Box 1). With the declaration of an Exclusive Economic Zone of 200 miles in 1976, the programmes relating to deep-sea fishing were intensified. While in fifties and sixties, mechanized boats with trawl nets and motorized indigenous crafts were introduced for efficient harvests from the inshore region, in seventies, purse-seines were introduced along the south-west coast. These developments resulted in expansion of fishing areas and increase in production. Improved harvesting technologies coupled with increasing demand of fish for domestic and export market have resulted in significant increase of production over the last fifty years, i.e., from 0.53 mmt in 1951 to 3.0 mmt in 2001-2002. However, the intense exploitation of resources in coastal areas up to 50 meters by artisanal and small-mechanized

Text Box 1
Marine Fisheries Resource Management

- Intensification of exploitation in offshore grounds.
- Enhancement of coastal stocks through sea-ranching.
- Creating of artificial fish habitats in the inshore grounds.
- Regulation of fishing efforts, effort rationalisation and closed fishing season.
- Gear, area and temporal restrictions and mesh size regulation to prevent growth over fishing and recruitment over fishing.
- Fishery forecasts linked to biotic and abiotic features.
- Promoting tuna long lining, purse seining and oceanic squid jigging.
- Monitoring ecosystem health.
- Utilisation of bycatch by conversion into value added products.
- Development of infrastructure for production and post-harvest.
- Human resource development.
- Creation of environmental awareness.
- Organization of extension programes and inter-institutional linkages.

fishing sector resulted in the annual catch plateauing, with a decrease in catch per unit effort. While the contribution of the artisanal sector to the total production was significant in the sixties, their contribution at present is low (only 13%) and mechanized and motorized sector contribute 87% of total production.

Technological research in fisheries did not receive much attention in India until the establishment of Central Institute of Fisheries Technology (CIFT); which gave a foundation for research in the design of various fishing crafts, gears, fishing techniques, methods of handlings and post-harvest processing and utilization. Initially motorization of indigenous crafts was taken up as a first step of mechanized fishing. Subsequently, several designs of small, medium and larger sized mechanized boats were introduced into the fishing industry. Fish detection facilities were introduced in large boats with facilities for proper gear handling for enhancing their efficiencies. Various designs and sizes of mechanized crafts were introduced besides specialized fishing vessels like trawling-cum-fish carrying, trawler-cum-purse-seiner, boats for long line fishing and trolling.

Gear designing was given greater emphasis for enhancing the production from the mechanized vessels and diversification of fishing activities. This led to development of different gears, introduction which were stern trawling, out-rigger trawling, mid-water trawling, purse seining and long lining. Introduction of gears like four-seam trawl and bulged-belly trawl could increase the catching efficiency by about 30%. Specialized gill nets were fabricated for lobster fishing. The use of non rotting synthetic fibre in fishing gears was another significant development. Of late, the use of mechanical fishing accessories, ancillary fishing equipment and electronic testing devices of practical value in fishing operation have also added a new dimension for enhancing the catch per unit effort of a specific gear and craft.

An increase in fishing intensity, declining stocks, conflict between the fishing sectors, decreasing catch rate, decreasing recruitment, inappropriate exploitation pattern, habitat degradation and resource degradation have been identified to be the major problems of coastal fisheries, presently. Several regulatory measures like regulation of mesh size, regulation of fishing areas, seasonal closure of fishing, ban of the destructive gears, promotion of marine sanctuaries, promotion of artificial reefs and sea ranching, effecting code of conduct for responsible fishing have to be implemented to ensure sustainable growth in this sector.

Freshwater Aquaculture

Indian aquaculture has shown significantly higher growth rates than those of capture fisheries in the last decade, with the quantity increasing from 1.01 million tonnes in 1990 to 2.10 million tonnes in 2000. Freshwater aquaculture has continued to form a major share of the aquaculture production, with a contribution of over 95% in terms of quantity. It is only the three Indian major carps, which share as much as 1.6 million tonnes. On the other hand, shrimp forms the main component of brackish water aquaculture sector with production crossing a lakh tonne mark, recently. Freshwater aquaculture in India has made notable strides in recent years with a growth trend similar to that of the world. With an annual growth rate of over 6% during the last decade, the sector possesses higher growth rates than other food producing sectors. The sector has evolved from the stage of a domestic activity in the East Indian states of West Bengal and Orissa to that of an industry in recent years, with states like Andhra Pradesh, Punjab, Haryana and Maharashtra taking up fish culture as a trade. With technological inputs, entrepreneurial initiatives and financial investments, the pond productivity has gone up at a national level from 500-600 kg/ha/yr to over 2000 kg/ha/yr, with several farmers and entrepreneurs achieving higher production levels of 6-8000/ha/yr. Carps is the mainstay of culture practice in the country, which is supported by strong traditional knowledge base and scientific inputs in various aspects of management. Carps contribute 87% of the total aquaculture production. Though the country possesses a large number of potential cultivable carp species, it is only the three Indian major carps; catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*), that contribute a lion's share with production (0.546, 0.567 and 0.517 million tonnes, respectively recorded during the year 2000). Scientific interventions in the last five decades have led to the development of a host of carp culture technologies with varied production potentials depending on the type and level of inputs. Further, other produce like catfishes, freshwater prawns and molluscs for pearl culture have also been brought into the culture systems. In addition, a range of other non-conventional culture systems, like sewage-fed fish culture, integrated farming systems, cage and pen culture, running water fish culture have made freshwater aquaculture a growing activity across the country. Being mainly organic-based, the freshwater aquaculture practices are also able to utilise and treat a number of organic wastes including domestic sewage, enabling eco-restoration.

Carp breeding and seed production

Seed being the basic input in any culture systems, its production has been accorded highest priority in terms of broodstock management, establishment of hatcheries, refinement of induced breeding techniques, rearing and production of quality seed across the country. The technology of induced breeding of carps under control condition has become a common practice of the farmers today. The breakthrough of induced breeding through hypophysation is, undoubtedly, the most important aspect that led to the growth of freshwater aquaculture sector. The technology has made mass production of quality seed under control condition possible, thereby, reducing the dependence on natural seed collection. Development of several ready-to-use synthetic inducing agents, as alternative to pituitary hormone, made the technology of induced breeding easier and more farmer friendly. Besides Indian major carps, the technology of breeding of Chinese grass carp and silver carp has also been domesticated all over the country. Various carp species are domesticated to breed before and after the monsoon. The technology of multiple breeding of carps has been able to demonstrate 2-3 fold higher spawn recovery from a single female during season through 3-4 times breeding within an interval of about 45 days. The technological evolution of hatchery design and operation from initial earthen pits to double-walled hapa and subsequently to glass-jar and circular eco-hatchery provided scope to produce and handle mass quantities of eggs during hatching. Carp hatcheries in the public sector have contributed to an increase in seed production from 6,321 million fry in 1985-86 to over 18,500 million fry at present. Even states like Assam and West Bengal are producing seeds much beyond their requirement, showing the prospects of export trade and its economical viability. However, in the wake of increased emphasis on diversification of carp culture, greater research thrust is warranted for commercial production of important medium and minor carp species.

Despite the domestication of induced breeding technology and production of carp seed to the tune of over 18,500 million fry in the country, the availability of stocking materials of desired species and size still remains a constraint. Raising of seed in the initial two stages is associated with high rates of mortality due to several management problems. Packages of practices have been developed and standardized for raising fry and fingerlings with higher growth and survival levels. Higher survival levels of fry of over 40-60% through intensive rearing during nursery stage have been demonstrated at stocking densities of 5-10 million/ha in earthen ponds and up to 30 million in ferro-cement tanks. A farmer is now able to harvest 3-4 crops of fry even in a season of 3-4 months i.e., during June-September. Further, at 2-3 lakh/ha stocking densities the technology of fingerlings rearing can result 60-80% survival, with mean fingerlings size of 100 mm in a rearing period of 3 months.

Grow-out culture of carps

Research and development efforts in the last five decades have greatly enhanced average fish yields in the country making carp culture an important economic enterprise. The three major Indian carps were the principal species cultured by the farmers in ponds since ages and production from these systems remained significantly low till the introduction of carp polyculture technology. Introduction of exotic species like silver carp, grass carp and common carp into the carp polyculture system during early sixties also added new dimension to the aquaculture development of the country. It is the Pond Culture Division of the erstwhile CIFRI, Cuttack that was responsible for the development and refinement of scientific carp culture in India through its research in several centres under the All India Coordinated Research Project on Composite Fish Culture and Fish Seed Production. With the adoption of technology of carp polyculture or composite carp culture, production levels of 3-5 tonnes/ha/year could be demonstrated in different regions of the country. It is the technology of carp polyculture that has revolutionized the freshwater aquaculture sector and brought it from a level of backyard activity to that of a fast growing organized industry. Research over the years has led to the development, refinement and standardization of a host of technologies with varied production levels depending on the input use. The technology of intensive carp culture has demonstrated higher production levels of 10-15 tonnes/ha/yr.

The necessity of bringing more species of promise into the carp culture practice is being emphasized. Species like *Labeo calbasu, L. gonius, L. bata, Puntius pulchellus, P. sarana, P. kolus* and *Cirrhinus cirrhosa* are considered to be important candidate species due to their production potential, consumer preference and high market price, and there is a need for greater research thrust for diversification of carp culture sector.

Culture of catfishes

Though catfishes possess considerable commercial importance, their culture in the country is yet to make any mark. *Clarias batrachus* (magur) and *Heteropneustes fossilis* (singhi) are the two air-breathing catfishes, which are well adapted to adverse ecological conditions. While the technology of induced breeding and seed production of these two important catfish species has been perfected, their large-scale production is yet to be taken up. With more or less similar pond management measures as that of carp culture practices and stocking with 20,000-50,000 fingerlings/ha, production levels of 3-5 tonnes/ha are achieved in grow-out culture of magur, which attain 100-200 g in 6-8 months. These groups of fishes can suitably be cultured both in monoculture and polyculture systems. In spite of the availability of huge potential resources in the form of swamps and derelict waters that could be effectively used for commercial farming and huge market demand of these species, large scale culture of these species is yet to receive due attention. Development of balanced supplementary feed owing to its carnivorous feeding habits and availability of desired quantity of seed of right size are the two critical aspects, which have to be addressed. Research with regard to development and standardization of induced breeding and grow-out technologies of several other non-air breathing catfishes like *Mystus* seenghala, *M. aor*, *Pungasius pungasius*, *Wallago attu*, *Ompak pabda* are also being envisaged in view of the high consumer preference for these in different parts of the country.

Culture of freshwater prawn

The giant freshwater prawn, *Macrobrachium rosenbergii* is the largest and fastest growing species among freshwater prawns. The technology of hatchery of the species has been developed and standardized for obtaining commercial production seed with an average survival level of 60% from zoea I to PL. The development of hatchery technology for *M. rosenbergii* and later the technology of seed production of Indian riverine prawn, *M. malcolmsonii* has opened up possibilities for diversification of freshwater aquaculture. There are about 35 freshwater prawn hatcheries established mainly in the states of Andhra Pradesh, Tamil Nadu and Kerala producing about 200 million seeds per annum, as against the projected demand of 10,000 million seed for development of at least 0.2 million ha water area in coming years.

During the last five years, freshwater prawn farming sector has witnessed overwhelming growth with as much as 24,000 ha additional area, thus bringing total area coverage of the country to about 37,000 ha achieving production over 30,000 tonnes. Monoculture of freshwater prawn at stocking densities of 30,000-50,000/ha has shown production levels of 1.0-1.5 tonnes/ha in a culture period of 7-8 months. Further, polyculture of freshwater prawn along with carps has also demonstrated to be a technologically sound culture practice and economically viable option for enhancing the farm income of the farmers. With the increased thrust of the farming practice in last few years, inadequacy of seed has become a major constraint. Establishment of a chain of commercial hatcheries in the coastal states of the country to meet this need should receive due attention.

Freshwater pearl culture

While marine pearl culture in India had its beginning in the early seventies, freshwater pearl culture remained an unexplored area till late eighties until the research programmes by the Central Institute of Freshwater Aquaculture, Bhubaneswar were initiated. The investigations by the institute in last one and half decades have not only led to development of the base technology of surgical implantation by using three commonly available freshwater mussel species, *viz.*, *Lamellidens marginalis*, *L. corrianus* and *Parreysia corrugata,* but also standardized different steps involved for the production of cultured pearls. Three different surgical procedures that is, mantle cavity insertion, mantle tissue implantation and gonadal implantation techniques have been standardized for obtaining different kinds of pearl products. In mantle cavity insertion method, the products obtained are shell attached, half round or design pearls depending upon the shape of nuclei implanted. While in mantle tissue implantation procedure the products are unattached, irregular to oval graft pearls or small round nucleated pearls, in gonadal implantation the pearls produced are unattached and slightly larger round pearls.

In spite of fact that freshwater pearl culture possesses several advantages in terms of commercial-scale availability of natural stock of pearl mussels with over 50 species; wider area of farming, even in non-maritime regions; operational ease in management of freshwater culture environment; absence of natural boring and predatory organisms; traditional pearl marketing environment; availability of economically viable indigenous technology; overall cost effectiveness of operations; and most importantly the availability of cheap labour force, which can be trained for taking up the pearl culture, commercial farming of the freshwater pearl mussel is yet to be established in the country. Emphasis on entrepreneurship development through institutional backup for technology transfer; assistance by financial institutions for credit; Governmental interventions for greater technology dissemination and subsidies; and organized and coordinated effort for market promotion are the aspects that need serious attention for the future development of the sector.

Integrated fish farming

Integrated fish farming is the combination of two or more normally separate farming systems where byproduct i.e., waste from one sub-system is utilized for sustenance of other; for example fish-pig/poultry/duck farming. Though organized integrated farming systems are not very common in the country, use of organic manures in the form of cattle wastes and poultry droppings are common in most of the farms of the country, especially, in carp culture farms. Production levels 3-5 tonnes/ha/year have been demonstrated by the integration of fish with poultry/duck/pig, with waste derived from these farm animals as principal input and without provision of any supplementary feed. The system is not only found to provide considerable potential and scope for augmenting production, but also offer enormous scope for employment generation, betterment of rural economy and improving the socio-economic status of rural community.

Cage and pen culture

Commercial fish farming in cages is almost non-existent in the country, even though the practice is widely accepted globally. The information on cage culture in the country is limited to a few experimental trials with major carps and catfishes, with a maximum-recorded production of 3.3 kg/m^3/month during grow-out culture of grass carp. With over 3 million ha potential area under reservoirs, which are otherwise either unutilized or under utilized, the emphasis on cage culture is inevitable in coming years to meet the ever-increasing demand of fish. Further, cages can also be used for nursing fry in reservoirs where transportation of desired quantity and size of seed from distant places are difficult.

Pens are usually constructed in shallow margins of reservoirs, tanks and ox-bow lakes. They can effectively be utilized for raising fry and fingerlings, which has been demonstrated in several trials carried out all over the country. The system possesses great potentials considering the availability of large extent of the water resources in terms of reservoirs, swamps and ox-bow lakes in the country.

Sewage-fed fish culture

The practice of recycling sewage through agriculture, horticulture and aquaculture is in vogue traditionally in several countries, including India. Sewage-fed fish culture in *bheries* of West Bengal is an age-old practice. Though the area of coverage is gradually reducing, about 5700 ha is still utilized for growing fish by intake of raw sewage into the system and as much as 7000 tonnes of fish, mainly contributed by carps, are produced annually from these water bodies. Experimental result has shown high potential productivity of the system with record of over 9 tonnes of fish/ha within a culture period of one year. As sewage arising out of domestic wastes content high level of nutrients, emphasis on this practice has been on the recovery of nutrients and raising protein rich fish from the filth. To overcome from the concern of public health relating to consumption of fish cultured in sewage water, depuration measures by keeping the harvested fish in clear freshwater at least a fortnight before marketing has been suggested. Recently aquaculture has also been employed as a major option for treatment of domestic sewage. The Central Institute of Freshwater Aquaculture has evolved an aquaculture-based sewage treatment system incorporating duckweed and fish culture for treatment of domestic sewage.

Ornamental fish culture

Ornamental fish form an important commercial component of fisheries with world trade of over US$ 7 billion. The relatively minimum requirement of space or attention compared to other pet animals is the reason for growing interest in keeping aquaria in household levels. In spite of India possessing a rich diversity of ornamental fishes with over one hundred varieties of indigenous species, in addition to similar number of exotic species that are bred in captivity, the export of ornamental fishes from the country is only about Rs. 10 million; the potential of the country has been estimated to be US$ 30 million. The export at present is mainly confined to a few indigenous species from northeastern states and few varieties of exotic species. In spite of having vast potential domestic and international demand the sector has not received due attention either from research or by the industry and calls for systematic cataloguing of potentially important ornamental varieties, detailed study on their biology and behaviour, breeding and husbandry. The sector possesses great potential for growth by the establishment of commercial breeding and culture farms as a cottage activity with minimum levels of investments in different locations of the country.

Coldwater fisheries development

The country possesses significant aquatic resources in terms of upland rivers/streams, high and low altitude natural lakes, manmade reservoirs, both in Himalayan region and western ghats, which hold large populations of both indigenous and exotic cultivable and non-cultivable fish species. Important food fishes in the region are mahseers and schizothoracids among the indigenous species and trouts among the exotic varieties. Research efforts over the years have led to development of technology of seed production of important cultivable species like trout, mahseers and snow trout. High survival rates of hatchery seed in case of trout along with successes in production of mahseer seed under control conditions have led to possibilities of farming. Breeding of different species of snow-trout *viz., Schizothoraichthys niger, S. esocinus, S. micropogon* and *S. planifrons* and *Schizothorax richardsonii* has also become possible and the technology has been perfected for mass production of the seed under controlled farm conditions.

Brackishwater Aquaculture

Brackishwater aquaculture in India is an age-old practice in *bheries* of West Bengal and *pokkali* fields of Kerala. The modern and scientific farming in the country is only about a decade old. The country possesses huge brackishwater resources of over 1.2 million hectares suitable for farming. However, the total area under cultivation is just over 13% of the potential water area available i.e. 157,400 ha in 2001-2002. Shrimp is the single commodity that contributes almost the total production of the sector. The production levels of shrimp recorded marked increase from 28,000 tonnes in 1988-89 to 127,170 tonnes in 2001-2002. Moreover, the black tiger prawn, *Penaeus monodon,* also contributes the lion's share. The other shrimp species being cultivated are *P. indicus, P. penicillatus, P. merguiensis, P. semisulcatus* and *Metapenaeus* sp. Culture of crab species like *Scylla serrata* and *S. tranquebarica* has also been taken up by few entrepreneurs. There are several other finfish species like *Mugil cephalus, Liza parsia, L. macrolepis, L. tade, Chanos chanos, Lates calcarifer, Etroplus suratensis* and *Epinephelus tauvina* which possess great potential for farming, but commercial production of these species is yet to be taken up in the country.

The studies on induced breeding of shrimps were initiated by the Central Marine Fisheries Research Institute in the early 70s'; an experimental hatchery was established by the Institute in 1975 at Narakkal, Kerala, MPEDA took the lead for establishment of two large-scale hatcheries *viz*., TASPARC and OSPARC in 80's that gave a boost for the establishment of a number of commercial hatcheries in the private sector. The technology of hatchery production of shrimp seed involving broodstock development, induced maturation and spawning, larval-rearing and post-larval (nursery) rearing has been standardized. At present about 226 shrimp hatcheries are operational with a total production capacity of 10.5 billion PL20/year.

Though brackishwater farming in India is an age-old practice, the scientific and commercial aquaculture of the country at present is restricted to shrimp farming owing to the high export potential of the shrimps. The development of shrimp farming in the country took place only during early 90s with several industrial units joining the sector. Semi-intensive culture practices mainly with black tiger prawn have demonstrated production levels of 4-6 t/ha in a crop of 4-5 months. The high return coupled with credit facilities from commercial banks and subsidies from MPEDA have helped in the development of shrimp farming in the country to a multi-billion dollar industrial sector. In spite of disease problem that has been plaguing the sector since 1994-1995 the industry has learnt to live with certain modifications in pond management, which has resulted in sustaining the shrimp production of the country during last two years. During the year 2000-2001 the shrimp production of the country from aquaculture has witnessed a record production of 97,100 tonnes valued as Rs. 3,620 crores. Further, Mullets and milkfish are important cultivable brackishwater herbivorous fish, with high growth potential. Seed production technology of seabass, *Lates calcarifer* is available for commercialization.

Mariculture

Intensive researches during last two decades by the Central Marine Fisheries Research

Institute have led to the development of several viable technologies with regard to seed production and culture of important marine crustaceans, molluscs and seaweeds. Several programmes on sea ranching of exploited stocks such as pearl oyster, *Xancus pyrum*, *Trochus* sp., *Turbo* sp. and giant clam have been taken up in the country.

Mussel culture

Green mussel, *Perna viridis* and brown mussel, *Perna indica* are the two important mussel species available in the country. The culture technology of these has been standardized. Mussel farming is carried out either in rafts or by long line methods. While long line system is very flexible and can withstand turbulent sea, raft system is more rigid and suited for more calm seas. Mussels attain harvestable size of 70-80 mm in 6-7 months of culture period; production levels of 12-14 kg mussels/meter of rope have been reported. In a raft size of 8 m x 8 m as many as 100 ropes can be suspended and the culture is done at about 5-10 m depth. Economic analysis of the mussel farming made based on pilot scale studies on raft culture by CMFRI showed over 40% profit margins on investment of about Rs. 24,000 per raft of 8 m x 8 m during a culture period of 6-7 months.

Edible oyster culture

The culture of edible oyster in India was initiated as early as the beginning of this century. However, intensive researches on various aspects of the culture were taken up only during seventies. The technique of oyster farming consists of two items, collection of spat and growing the spat to adult stage. *Crassostrea madrasensis* is the only species that is found to be important for commercial farming. The species reach harvestable size (80 mm) in a culture period of 7-8 months and production levels of 8-10 tonnes of shell on oysters/ha are obtained. Estimated economics of the culture of edible oysters in a unit area of 300 sq. m with rack and ren method showed over 44% of profit over an initial investment of about Rs. 21,000 including Rs. 16,000 as fixed cost. Technology has been developed for hatchery production of seed, which has opened up scope for establishment of large-scale commercial farms.

Pearl culture

The success of marine pearl culture in India was achieved in 1973 by the Central Marine Fisheries Institute at its Tuticorin Regional Centre. Raft culture techniques are followed for culture of pearl oysters and the important species being *Pinctada fucata*. Oysters of over 20 g at its post-spawning recovery stage are used for nucleus implantations. The oysters after thorough washing in cleaned seawater are narcotized by using menthol, which helps in relaxation of adductor muscles within 45-60 minutes. The surgery involves grafting of a piece of mantle of the donor oyster in the gonad of the oyster, followed by implantation of a spherical shell-bead nucleus of about 3-7 mm diameter. Multiple implantations are also done depending on the size of nucleus. The post-operative culture period for the implanted oyster is usually 3 months to 18 months depending on the size of nucleus implanted.

Seaweed culture

Seaweed forms an important component of the marine living resources, available largely in shallow seas, wherever, suitable substratum is available. Agar agar and algin are two principal industrial products of seaweeds. Seaweed is also used as food, fodder, fertilizers and in several other industrial and pharmaceutical products. The seaweed resources of the country are mainly confined to the coasts of Tamil Nadu and Gujarat. Since 1972, CMFRI is involved in experimental culture of different seaweed species and developed technologies for important agarophytes like *Gracilaria edulis, G. corticata* and *Gelidiella acerosa*. Both net and rope culture technologies have been standardized. Fragments of seaweeds are inserted in the twists of the coir rope nets of 4 m x 2 m in size for culture of *G. edulis* and the nets are fixed at about 1 m depth in near-shore water with the help of wooden poles. Into this method 1 kg of seed material would yield on an average 3 kg of *G. edulis* in a culture period of 60 days. 1000 such nets can be fixed in one-hectare area and production of 30 tonnes/ha can be obtained. With a minimum of four crops a total of 120 tonnes of fresh *G. edulis* can be produced in one year. In case of *G. acerosa* both coral stone method and net culture method have been standardized. Culture practices of several other species are on experimental scale.

Governmental support and assistance from public financing institutions with an element of risk coverage in the initial stages are necessary for establishment of commercial mariculture farms. Ownership or leasing right with protection against navigation, traditional fishing and encroachment are other pre-requisites for development of farming, which must be addressed by the Governmental interventions. Taking into account the potentials of production of fish and shellfish from different areas of the fisheries sector, following strategies for enhancing production have been evolved (Annexure).

Conclusions

Possessing 2.4% of the global land area India sustains 16% of the world population. Increasing per capita fish availability from the present level of only 8 kg to 11 kg (as recommended by World Health Organization) is the primary challenge before the country. Considering the limited scope of the capture fisheries from coastal waters and natural inland waters like rivers and estuaries, emphasis on aquaculture and culture-based fisheries from reservoirs and floodplain wetlands to meet the targeted fish requirement of 8.3 million tonnes by 2020 is appropriate considering the availability of vast water resources, rich cultivable species diversity and sound technological base.

Annexure : Action Plan for Enhancing Production

Coastal Aquaculture

Brackishwater area available
1.2 million ha.

Presently under utilization
0.1 million ha.

Present Production
0.9 lakh tonnes

Projected potential production
0.5 million tonnes

Strategies

- Increasing water area under aquaculture practices
- Increasing productivity of existing water bodies
- Diversification of candidate species
- Research support for sustainable, eco-friendly and techno-economically viable hatchery & culture systems
- Fish health management and disease diagnostics
- Fish nutrition and feed formulation
- Fish genetics and selective breeding
- Utilization of inland saline soils for aquaculture

Capture Fisheries

Present annual production
0.5 million tonnes

Estimated production potential
0.8 million tonnes

Strategies

- Management of stocks in reservoirs
- Stocking and selection of right species
- Maintaining proper harvesting schedules
- Fishery regulations, closed seasons, mesh regulation, fishing efforts.
- Culture based fisheries
- Pen & Cage culture technologies
- Resources specific harvesting techniques
- Management models for culture based fisheries
- Hill fishery resources assessment and management
- Development of sport fisheries in hill areas

Culture Fisheries

Present annual production
2.3 million tones

Estimated production potential
4.5 million tonnes

Strategies

- Increase in the coverage of areas of ponds and tanks for aquaculture practices
- Increasing productivity of existing water bodies
- Diversification and Intensification of culture practices
- Research support for sustainable, eco-friendly and techno-economically viable hatchery & culture systems
- Fish health management and disease diagnostics
- Fish nutrition and feed formulation
- Fish genetics and selective breeding
- Aquaculture technologies for hill fisheries

Harvest and Post-harvest sector

Strategies

- Fuel-efficient and resources specific craft and gear
- Eco-friendly and responsible fishing techniques for EEZ
- Post harvest value addition, waste utilization and by products from un-conventional fish species
- Biomedical, pharmaceutical and industrial products from aquatic organisms
- Expansion of domestic and international marketing network