Cropping Pattern (Agricultural and Horticultural) in Different Zones, their Average Yields in Comparison to National Average/ Critical Gaps/Reasons Identified and Yield Potential

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ABSTRACT

Multiplicity of cropping systems has been one of main features of Indian agriculture and it is attributed to rainfed agriculture and prevailing socio-economic situations of farming community. It has been estimated that more than 250 double cropping systems are followed throughout the country and based on rationale of spread of crops in each district in the country, 30 important cropping systems have been identified. The statistics related to state-wise agro-ecosystems cropping pattern for 1998-99 and cropping pattern according to land utilization are provided. The major issues emerging in the irrigated cropping systems along with yield gaps of some of important cropping systems have also been provided in the text of this paper.

The information with regard to cropping pattern in horticultural crops particularly vegetables and tuber crops is not compiled and readily available. However, the constraints in production and zones/states of cultivation of these crops are given briefly alongwith research gaps and future thrust areas.

1. INTRODUCTION

Cropping systems of a region are decided by and large, by a number of soil and climatic parameters which determine overall agro-ecological setting for nourishment and appropriateness of a crop or set of crops for cultivation. Nevertheless, at farmers' level, potential productivity and monetary benefits act as guiding principles while opting for a particular crop/cropping system. These decisions with respect to choice of crops and cropping systems are further narrowed down under influence of several other forces related to infrastructure facilities, socio-economic factors and technological developments, all operating interactively at micro-level. These are:

Infrastructure facilities: Irrigation, transport, storage, trade and marketing, post-harvest handling and processing etc.

Socio-economic factors: Financial resource base, land ownership, size and type of land holding, household needs of food, fodder, fuel, fibre and finance, labour availability etc.

Technological factors: Improved varieties, cultural requirements, mechanization, plant protection, access to information, etc.

2. PREVALENT CROPPING SYSTEMS

Multiplicity of cropping systems has been one of the main features of Indian agriculture. This may be attributed to following two major factors:

- Rainfed agriculture still accounts for over 92.8 million hectare or 65 per cent of cropped area. A large diversity of cropping systems exists under rainfed and dryland areas with an over riding practice of intercropping, due to greater risks involved in cultivating larger area under a particular crop.
- Due to prevailing socio-economic situations (such as; dependency of large population on agriculture, small land-holding size, very high population pressure on land resource etc.), improving household food security has been an issue of supreme importance to many million farmers of India, who constitute 56.15 million marginal (<1.0 hectare), 17.92 million small (1.0-2.0 hectare) and 13.25 million semi-medium (2.0-4.0 hectare) farm holdings, making together 90 per cent of 97.15 million operational holdings. An important consequence of this has been that crop production in India remained to be considered, by and large, a subsistence rather than commercial activity. One of the typical characteristics of

subsistence farming is that most of the farmers resort to grow a number of crops on their farm holdings, primarily to fulfill their household needs and follow the practice of rotating a particular crop combination over a period of 3-4 years interchangeably on different farm fields.

Under influence of all above factors, cropping systems remain dynamic in time and space, making it difficult to precisely determine their spread using conventional methods, over a large territory. However, it has been estimated that more than 250 double cropping systems are followed through out the country. Based on rationale of spread of crops in each district in the country, 30 important cropping systems have been identified. These are; rice-wheat, rice-rice, rice-gram, rice-mustard, rice-groundnut, rice-sorghum, pearlmillet-gram, pearlmillet-mustard, pearlmillet-sorghum, cotton-wheat, cotton-gram, cotton-sorghum, cotton-safflower, cotton-groundnut, maize-wheat maize-gram, sugarcane-wheat, soybean-wheat, sorghum-sorghum, groundnut-wheat, sorghum-groundnut, groundnut-rice, sorghum-wheat, sorghum-gram, pigeonpea-sorghum, groundnut-groundnut, sorghum-rice, groundnut-sorghum and soybean-gram.

3. CROPPING SYSTEMS OF IRRIGATED ECOSYSTEM

Depending upon the natural water resources, each region has certain area under irrigated agriculture. But, broadly considering, two distinct irrigated ecosystems emerge. One is Indo-Gangetic Plain region comprising the states of Punjab, Haryana, plains of Uttar Pradesh, Bihar and plains of Jammu & Kashmir. The other ecosystem may be carved out of coastal areas of Andhra Pradesh and Tamil Nadu. At present 51 million hectare net-cropped area is irrigated by different sources, which constitutes about 35 per cent of net cultivated area. Estimates indicate that more than 56 per cent of total food grain comes from irrigated ecosystem while progress has been considerably sluggish in rain fed agriculture which still accounts for 92.8 million hectare or 65 per cent of net area sown and contributes only 44 per cent to national food grain production. If past trends are any indication, it may be visualized that in future also the major gain in production, at least 80 per cent of the incremental food needs required by 2025, has to come from irrigated ecosystem where new genotypes and intensive fertilizer use will continue to play dominant role in enhancing crop productivity.

The principal crops having sizeable percentage of area under irrigation in the country are; sugar cane (87.9%), wheat (84.3%), barley (60.8%), rapeseed and mustard (57.5%), rice (46.8%), tobacco (41.2%), cotton (33.2%), chickpea (21.9%), maize (21.8%) and groundnut (19.2%). Among the states, Punjab ranks first with 94.6 per cent cropped area under irrigation followed by Haryana (76.4%) and Uttar Pradesh (62.3%). The statistics related to state-wise agro-ecosystems cropping pattern for 1998-99 and cropping pattern according to land utilization are given in the following Tables:

4. ISSUES IN IRRIGATED CROPPING SYSTEMS

The major issues emerging in the irrigated cropping systems may be categorized into two groups; i.e., general and system specific.

General Issues

Resource characterization

Adequate information is lacking on site-specific characterization of land and water resources and climatic parameters, which is crucial for efficient land use planning and resource deployment.

Farmer's Participation

To develop and improve upon existing agro-technologies, it needs to be acknowledged that involvement of farmers in conceptualization and extension of technologies is of paramount importance. But in the past, a critical lacuna in agricultural research approach has been inadequate effort or lack of mechanisms to build up research programmes that take into account the experience and knowledge base that exists within the farming community. The farm family had never been the focal point of investigations. This top down approach of agricultural scientists had given a poor perception of the problems that they tried to solve. Nevertheless, it needed to be considered an integral component of cropping/farming systems research, particularly applied aspects of it.

5. CROPPING SYSTEMS ORIENTED PRODUCTION TECHNOLOGY

The past approach for agricultural research and development had been component based. It is indeed due to this piecemeal approach, that farmers have to encounter increasingly acute problems in managing and protecting natural resources and the environment. It has been hardly realized that field problems to which solutions are sought are rarely amenable to solutions through a single component/discipline oriented research. System oriented production research is needed to be strengthened as it is essential for maximizing land productivity by harnessing synergies generated through various interactions in soil-crop systems. Cropping

Table 1. State-wise Agro-Ecosystems Cropping Pattern for 1998-99
(% of the total cultivated area of the country)

Acreage = Million hectare

States/ Agro –Ecosystem	Rice	Wheat	Jowar	Bajra	Maize	Other Coarse Cereals	Gram	Tur	Other Pulses	Ground-nut	Rape seed & Mustard	Other Oilseeds	Sugar-cane
Andhra Pradesh (Semi-arid)	9.2	Neg.	7.9	1.3	6.7	5.1	1.7	11.2	6.6	25.6	Neg.	10.3	5.1
Assam (Humid)	5.4	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	4.4	1.2	0.7
Bihar (Sub- Humid)	11.4	7.7	Neg.	Neg.	11.3	2.9	1.5	2.0	3.8	Neg.	1.5	0.8	2.7
Gujarat (Arid & Semi-arid)	1.4	2.6	2.4	11.2	6.7	5.8	1.7	10.4	Neg.	25.6	5.5	11.1	4.9
Haryana (Arid)	2.4	8.0	Neg.	6.6	Neg.	2.7	4.3	1.2	1.8	Neg.	7.4	2.1	3.2
Himachal Pradesh (Humid)	Neg.	1.4	Neg.	Neg.	5.1	1.2	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Jammu & Kashmir (Humid)	0.6	0.9	Neg.	Neg.	5.1	1.2	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Karnataka (Arid & Semi Arid)	3.2	Neg.	18.5	4.5	8.2	13.1	4.3	13.5	7.6	16.2	Neg.	9.7	7.6
Kerala (Coastal)	0.8	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Madhya Pradesh (Semi-arid)	11.9	17.0	8.1	1.5	14.0	9.4	31.7	11.5	21.2	3.4	10.5	23.1	1.2
Maharashtra (Semi-arid & Coastal)	3.3	3.7	47.9	19.0	4.6	24.0	10.7	29.1	14.7	6.9	Neg.	10.0	13.0
Orissa (Sub-humid)	10.0	Neg.	Neg.	Neg.	0.8	0.6	0.4	4.0	3.1	3.1	Neg.	1.4	0.5
Punjab (Semi-arid)	5.7	12.2	Neg.	Neg.	2.5	0.6	0.1	Neg.	Neg.	Neg.	1.1	0.7	2.5
Rajasthan (Arid & Semi-arid)	Neg.	10.1	5.4	44.9	15.6	19.9	33.5	Neg.	19.5	4.3	45.5	16.1	0.5
Tamil Nadu (Semi-arid & Coastal)	5.4	Neg.	5.0	2.2	Neg.	3.6	Neg.	3.2	4.3	14.4	16.8	4.9	8.6
Uttar Pradesh (Semi-arid & Sub-humid)	13.3	33.7	3.3	8.6	14.8	8.9	9.8	12.1	11.4	1.6	5.2	6.0	48.3
West Bengal (Humid)	13.2	1.4	Neg.	Neg.	0.7	0.2	0.2	Neg.	0.8	Neg.	Neg.	1.8	0.7
Others	0.8	1.5	1.4	0.2	3.8	0.7	Neg.	1.7	1.6	0.8	2.7	0.8	0.5
All India Acreage	44.6	27.40	9.98	9.28	29.54	29.54	8.41	3.47	23.82	7.57	6.60	26.71	4.08

Neg. = Negligible
Source : *Agricultural Statistics at a Glance 2000*, Directorate of Economics and Statistics, Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India, New Delhi.

system approach of resource management has been showing immense potential in enhancing resource use efficiencies and pest management.

Low Water Use Efficiency

Despite the fact that water is a precious and scarce resource, its application and use efficiencies have been quite low. Low water use efficiency is apparently attributable to:

i. Excessive use of water due to -
   - improper leveling of fields coupled with improper application methods, even in agriculturally advanced areas, and
   - faulty pricing policy for electricity and canal water leading to over irrigation.

ii. Non-adoption of appropriate cropping systems. For

Table 2. Cropping pattern according to land utilization statistics

Crops	1996-97		1997-98	
	Area (000'ha)	% share of total area	Area (000'ha)	% share of total sown area
1	2	3	4	5
I. Food Crops	**140055**	**73.87**	**140046**	**73.41**
1. Total Food Grains	**125119**	**65.99**	**125004**	**65.53**
(A) Cereals & millets	**101852**	**53.72**	**101262**	**58.08**
Rice	43497	22.94	43476	22.79
Jowar	11506	6.07	10796	5.66
Bajra	10258	5.42	9669	5.06
Maize	6398	3.37	6420	3.37
Ragi/Marua	1836	0.97	1756	0.92
Wheat	25955	13.69	26704	14.00
Barley	767	0.40	871	0.46
Other cereals & millets	1635	0.86	1570	0.82
(B) Pulses	**23267**	**12.27**	**23742**	**12.45**
Gram	7095	3.74	7735	4.05
Tur (Arhar)	3501	1.85	3366	1.76
Other Pulses	12671	6.68	12641	6.62
2. Sugar	**4506**	**2.38**	**4316**	**2.26**
Sugarcane	4440	2.34	4252	2.23
Others	66	0.04	64	0.03
3. Condiments & spices	**2818**	**1.49**	**2955**	**1.55**
Pepper black	191	0.11	189	0.10
Chillies	952	0.50	854	0.45
Ginger	77	0.04	81	0.04
Turmeric	133	0.07	138	0.07
Cardamom	95	0.04	94	0.05
Betel nuts	265	0.14	271	0.14
Others	1105	0.58	1328	0.70
4. Total fruits & vegetable	**7554**	**3.98**	**7713**	**4.04**
(i) Total fruits	**3076**	**1.62**	**3260**	**1.71**
(A) Fresh fruits	2531	1.33	2690	1.41
Mangoes	1043	0.55	1111	0.58
Citrus fruits	274	0.14	315	0.17
Banana	435	0.23	460	0.24
Grapes	37	0.02	36	0.02
Pome fruits	93	0.05	116	0.06
Papaya	51	0.03	54	0.03
Apple	5	Neg.	4	Neg.
Others	593	0.31	594	0.31
(B) Dry fruits	**545**	**0.29**	**570**	**0.30**
Cashew nut	530	0.28	554	0.21
Others	15	0.01	16	0.01
(ii) Vegetables	4478	2.26	4453	2.23
Potato	1247	0.66	1205	0.63
Tapioca	235	0.12	254	0.13
Sweet Potato	130	0.07	127	0.07
Onion	407	0.21	384	0.20
Others	2459	1.39	2483	1.30
5. Other food crops	**58**	**0.03**	**58**	**0.03**
II. Non food crops	**49537**	**26.13**	**50716**	**26.59**
1. Oil seeds	**28213**	**14.88**	**28754**	**15.07**
Groundnut	7713	4.07	7245	3.79
Castor seed	783	0.41	641	0.34
Sesamum (Till or Gingelly)	2114	1.12	1877	0.98
Rapeseed & Mustard	6201	3.27	6700	3.51
Linseed	783	0.41	794	0.42
Coconut	1676	0.88	1723	0.90
Niger seed	536	0.28	546	0.29
Safflower	713	0.38	627	0.33
Soybean	5445	2.87	5987	3.14
Sunflower	1980	1.04	1953	1.02
Others	200	0.11	661	0.35
2. Fibres	**10381**	**5.47**	**10083**	**5.29**
Cotton	9160	4.83	8877	4.56
Jute	915	0.48	908	0.48
Mesta	204	0.11	202	0.11
Sunhemp	64	0.03	57	0.03
Others	38	0.02	39	0.02
3. Dyes & tanning material	**30**	**0.02**	**32**	**0.02**
Indigo	3	Neg.	2	Neg.
Others	27	0.02	30	0.02
4. Drug, narcotics & plantation crops	**2190**	**1.16**	**2199**	**1.15**
Opium	23	0.01	13	0.01
Tobacco	454	0.24	465	0.24
Cinchona	7	Neg.	7	Neg.
Indian hemp	(a)	Neg.	(a)	Neg.
Tea	471	0.25	475	0.25
Coffee	302	0.16	304	0.16
Rubber	514	0.28	523	0.27
Others	419	0.22	412	0.22
5. Fodder crops	**7981**	**4.21**	**8937**	**4.68**
6. Green manure crops	**70**	**0.04**	**67**	**0.04**
7. Other non-food crops	**672**	**0.35**	**644**	**0.34**
Total area sown under all crops (I+II)	**189592**	**100.00**	**190762**	**100.00**

Note: (a) Below 500 hectares; Neg.: Negligible

Source : *Indian Agriculture in Brief, 27th edition, 2000*. Directorate of Economics and Statistics, Department of Agriculture & Cooperation, Ministry of Agriculture, New Delhi.

example -
- extensive cultivation of rice in sandy soils of Punjab, and
- advancement of rice transplanting to April/May in Punjab and Haryana.

Land Degradation Problem

Soil salinity hazards due to ground water rise and impeded natural drainage in certain canal command areas are well known.

Indiscriminate Exploitation of Ground Water

The excessive pumping of ground water for irrigation purposes in intensively cultivated areas of Punjab, Haryana and Western Uttar Pradesh has caused lowering down of the ground water table in certain pockets. Declining water tables not only raise production costs due to higher energy requirements for pumping water from greater depths but such rapid rates of decline spark serious questions about the long-term sustainability of rice-wheat system itself in these areas. Contrary to this, the vast potential of ground water in Eastern Uttar Pradesh, Bihar and adjoining areas remains untapped.

In-efficient Land Use

Diversion of highly productive irrigated land to non-agricultural uses; such as industry, housing etc., specially at rural-urban interface needs to be viewed seriously.

Decline in Factor Productivity

Due to imbalance in fertilizer use, widespread deficiencies of secondary and micro-nutrients and reduced organic matter contents of cultivated lands, a declining trend for responses to nutrients, specially to nitrogen, in major cropping systems is being observed on farmers' fields. That is, to sustain earlier yield levels farmers need to apply higher fertilizer doses.

Imbalance in Fertilizer Use

The problem of imbalance in fertilizer use has been accentuated on three accounts

With intensive cropping, nutrient removal by crops from soil has far exceeded replenishment through fertilizers and manures. This is causing negative balance of nutrients in soil. And if this trend continues, a serious threat persists for sustainability of the major cropping systems of irrigated areas.

Due to continuous cereal-cereal cropping in most of the irrigated fertile lands during post green revolution period, multiple nutrient deficiencies have emerged. The long term experiments have clearly shown a decline in organic carbon, nitrogen and P in cereal-cereal intensive cropping.

Farmers have developed tendencies to use higher doses of nitrogenous fertilizers, may be because N is comparatively cheaper than P and K. This, therefore, has resulted in widening ratios of N:P and N:K to undesirable levels.

Build up of Diseases/Pests

With crop intensification under high input use, serious threats of occurrence and build up of some obnoxious pests and diseases have crept in. This factor again hinders the vertical growth and questions are being raised about the sustainability of the environment under intensive input use, which is otherwise needed for maximizing crop yields. Heavy infestation of *Phalaris minor* in continuous rice-wheat cropping system in north western plains is a glaring example.

Inadequate Considerations for Environmental Quality

With a pressing need for producing more and more from less and less land resource, a serious threat is lurking upon the environmental quality. A potential danger may be envisioned in the form of pollution of natural water bodies and underground aquifers due to nitrate leaching and phosphates causing irreparable harm to natural ecosystems under high fertilizer use without improving their use efficiencies.

6. SPECIFIC ISSUES RELATING TO SOME IMPORTANT CROPPING SYSTEMS

Rice-Wheat

Rice-Wheat system is the most widely adopted cropping system in the country and has become mainstay of cereal production. The states of Uttar Pradesh, Punjab, Haryana, Bihar, West Bengal and Madhya Pradesh are now the heart land of rice-wheat cropping system with an estimated area of 10.5 million hectares. Despite enormous growth of this cropping system in the country during the past few years, reports of stagnation in the productivity of these crops, with possible decline in production in future, have raised doubts on its sustainability. Important issues emerging as a threat to the sustainability of rice-wheat system are:

- Over mining of nutrients from soil,
- Disturbed soil aggregates due to puddling in rice
- Decreasing response to nutrients
- Declining ground water table
- Build up of diseases/pests
- Build up of *Phalaris minor*
- Low input use efficiency in north western plains
- Low use of fertilizer in eastern and central India
- Lack of appropriate varietal combination.

- Shortage of labour during optimum period for transplanting paddy in Punjab

Rice-Rice

Rice-rice is the popular cropping system in irrigated lands in humid and coastal ecosystems of Orissa, Tamil Nadu, Andhra Pradesh, Karnataka and Kerala and it is spread over an area of six million hectares. The major issues in sustaining productivity of rice-rice system are:

i. Deterioration in soil physical conditions.
ii. Micronutrient deficiency.
iii. Poor efficiency of nitrogen use.
iv. Imbalance in use of nutrients.
v. Non-availability of appropriate transplanter to mitigate labour shortage during critical period of transplanting.
vi. Build up of obnoxious weeds such as *Echinochloa crusgalli* and non-availability of suitable control measures.

In Kerala, reduction in area is mainly attributable to the conversion of paddy lands to more profitable and less labour intensive plantation estates. In Assam, low productivity under prevailing soil and climatic situations, poor drainage in submerged areas, low nutrient use and iron toxicity are some of the issues of concern. The other general issues of low productivity are build up of pests, diseases and weeds year after year and deterioration of soil health to a large extent.

Rice-Mustard

From a view point of food security and national economy, rice-rapeseed/mustard may be considered as an important cropping system. In this cropping system, the yield of Rice is satisfactory in all ecosystems, however, wide variations in yield of mustard were recorded from one ecosystem to another. Nevertheless, adoption of appropriate high yielding rice and mustard varieties, adequately supported by improved production technology, ensures desired productivity of the system. Observed gaps suggest that scope exists for at least two fold increase in yields of rice and mustard in the system.

In general, with a medium or short duration high yielding rice variety, a successful mustard crop is possible. The mustard crop remains in field upto march and thereafter summer season can be best utilized by another crop to increase the productivity of the system.

Table 3. Regional yield gap analysis for rice-mustard cropping system

Eco-systems	Rice yield			Mustard Yield		
	Improved Techno-logy	Farmer's field/ control	Percent Incre-ase	Improved techno-logy	Farmer's field/ control	Percent increase
Semi-arid	6276	2534	148	874	298	193
Sub-humid	6695	1804	271	2262	446	407
Humid	6742	2879	134	600	326	84
Coastal	4538	2224	104	1397	238	487

Source: Annual Reports 1989-95. PDCSR. Modipuram.

Rice-Groundnut

Groundnut is basically a Kharif crop grown under rain fed environment, however, Rabi/summer groundnut is emerging as an important high value crop under assured irrigation environments. The productivity of Rabi/Summer groundnut is almost double of the yield obtained in Kharif season. It has become possible to grow groundnut on well drained low lying fertile lands after harvest of preceding rice crop under assured irrigation.

Rabi/summer groundnut is grown in Periyar, Chengalpattu, Salem, Thanjavur, Coimbatore, Madurai, Arcot and Tiruchirapalli distts. of Tamil Nadu; Nalgonda, Nellore, Chittor, Kurnool, Mehaboobnagar, Anantpur, Warangal, Prakasham of Andhra Pradesh and Krishna districts of Karnataka; Cuttack and Puri districts of Orissa; coastal districts of Konkan, Marathwada region, Satara, Sangli, Pune, Ahmednagar districts of Maharashtra and Junagarh district of Gujarat. The area under summer groundnut in general and rice groundnut sequence in particular is increasing fast in most of the west and east coastal districts of the country. Besides this, spread of groundnut in rice fallows would make rice-groundnut cropping system more sustainable and remunerative.

Diagnostic surveys carried out for regional yield gap analysis revealed that a yield gap of about 0.5 to 1.5 t/ha exists between average yield of the region and yield obtained under improved practices for *Rabi*/Summer groundnut cultivation. Rainfall during September, soil type, selection of suitable early maturing varieties for rice and groundnut and agro-technologies developed to suit local conditions for rice-groundnut systems are important factors in achieving potential yield and to bridge the regional yield gaps in rice-groundnut sequence.

Excess rainfall received during September/October creates water-logging problems in medium and low lying fertile rice fields and affects groundnut yield adversely. Non release of irrigation water in time through canal system delays land preparation and sowing of groundnut after rice during Rabi season. Non-availability of adequate quantity of quality seeds of improved short duration bunch type groundnut varieties in time and high cost of seed are other factors, greatly limiting expansion of Rabi/summer groundnut area in rice growing tracts.

Rice-Pulses

Rice-Pulses cropping system is a dominant crop rotation in Chhattisgarh, Orissa and parts of Bihar. The higher productivity of rice, the base crop in the system, is possible and also imperative for this region if suitable varieties of paddy and pulses along with proper management are considered.

Factors limiting productivity of this cropping system in the region are as follows:-

A. Physical factors
- Droughts and erratic distribution of rainfall.
- Small area under assured irrigation.
- High percolation, resulting in heavy nitrogen losses in red sandy-loam soils, particularly *Bhata* soils.

B. Input related factors
- Delayed and prolonged *biasi*/transplanting.
- Low coverage under high yielding varieties (HYVs).
- Little attention to timely weed control.
- Inadequate supply of quality seed.
- Little attention to disease/pest control.

C. Social factors
- Low literacy.
- Large proportion of marginal and tribal farmers.
- Practices of animal grazing on agricultural lands.
- Low risk bearing capacity of farmers of the region.

Pearl millet-Wheat

The pearl millet-wheat is one of the most important cropping systems of the country and spreads over (i) arid eco-region comprising, western plain, Kachch and part of Kathiawar Peninsula having desert and saline soils and representing Gujarat, Rajasthan and Haryana; (ii) semi-arid eco-region comprising northern plains of Haryana, western Uttar Pradesh (Agra region) and central highlands including Aravallis, Banswara, Jaipur and Tonk districts of Rajasthan with alluvium derived soil and Gujarat plains and Kathiawar Peninsula – Gujarat state, having medium and deep black soil. Following issues are some of the concerns of sustainability:

1. Over mining of nutrients
2. Depleting soil fertility
3. Imbalance in fertilizer use
4. Decreasing response to nutrients
5. Lowering groundwater table
6. Build up of diseases/pests and weeds.

In pearl millet-wheat system, farmers are now realizing the need to replace pearl millet with more remunerative crops. Therefore, diversification may prove to be of paramount importance in several farming situations, not only in mitigating problems of soil health, but also from economics point of view.

Pearl millet – Mustard

Pearl millet during Kharif and rapeseed during Rabi have been the most important crops of dryland and/or areas with limited water availability under marginal land condition of north-west, west and central parts of India. In several parts of Haryana, Rajasthan, Uttar Pradesh and Madhya Pradesh where mono-cropping of pearl millet and mustard was most common, increase in irrigation facilities has made it possible to grow these crops in sequence. Although, exact statistics is not available but the area under pearl millet-mustard crop sequence is increasing year after year. Following are some of the concerns related to pearl millet-mustard sequential cropping system:-

1. Delayed sowing of mustard after harvesting pearl millet in October
2. Pearl millet in an exhaustive cereal crop and it depletes soil of essential nutrients
3. Non-application of sulphur in this area by farmers.
4. Shortage of farm machinery by the farmers in this area.
5. Build up of diseases by continuous cultivation of pearl millet – mustard sequence.

Maize-Wheat

Among maize-wheat growing areas, maize is the principal crop of Kharif season in northern hills of the country but plains of northern states like Uttar Pradesh, Rajasthan, Madhya Pradesh and Bihar also have sizeable acreage under this crop.

Results of national demonstrations and lab to land demonstrations clearly revealed that this system has a potential to produce 8-10 t/ha per year. However, experimental findings from various research stations revealed that a productivity of more than 10.5 t/ha per year (6.0 t+ 4.5t) may be realized under sub-montane conditions of Jammu. Likewise, a productivity of 7-8 t/ha per year at Palampur, 6.28 t/ha per year (2.00 + 4.28 t) at Indore and more than 7 t/ha per year at Ludhiana has been recorded in maize-wheat system. Maximum yield research in maize-wheat sequence at Palampur has shown a potential of 14.21 t/ha per year by optimization of various resources like plant population, manures and fertilizers.

Poor maize-wheat yield has been reported from Andhra Pradesh, Assam, Gujarat, Madhya Pradesh, Maharashtra, Rajasthan, Tripura, Eastern Uttar Pradesh and Tamil Nadu. There are number of reasons for poor yield but the most significant are:

1. Sowing time
2. Poor plant population
3. Poor weed management
4. Poor use of organic and inorganic fertilizers.

5. Large area under rain fed.

As most of the area in maize-wheat system is in rain fed conditions when uncertainty of rainfall is a major limitation. This also acts as a deterrent to farmers to adopt intensive input use, leading to deterioration of soil health and depletion of major plant nutrients from soil. Farmers in general, tend to grow low yielding traditional varieties. Maize is a widely spaced crop and its cultivation on slopping fields leads to soil erosion, especially when sowing is not done across the slope, maize in very sensitive to water logging and drought. Any delay in weed control in maize can reduce the yield of the system significantly.

Declining yield trends in maize-wheat system under long term experiments have indicated that the system suffers due to emerging deficiencies of multiple nutrients. Continuously over-mining of nutrients from soil and imbalance on use of fertilizers in maize-wheat system are some of the many reasons for such decline.

Sorghum-Wheat

Sorghum-wheat is one of the most prevalent cropping system in Western regions of the Country, comprising eastern parts of Rajasthan, western and central parts of Madhya Pradesh, Western Marathwada and Vidarbha regions of Maharashtra, Sourthern Gujarat, Northern parts of Karnataka and Telangana region of Andhra Pradesh.

Out of the two component crops of the system, productivity of sorghum faces wide fluctuations due to some problems. Stiga, a parasitic weed is one of such problems hampering the productivity of sorghum. Top shoot borer and shoot fly are major insects affecting plant population and reducing yield levels considerably. Fluctuating market prices, usually discourage the sorghum growers, however, sorghum cultivation is indispensable as it is the most important source of fodder for cattle in this area.

Sugarcane-Wheat

Sugarcane is grown in about 3.4 million hectare. In north India (Uttar Pradesh, Punjab, Haryana and Bihar), which account for 68 per cent of the total area under sugarcane, sugarcane-ratoon-wheat is the most important crop sequence. The system is also gaining importance in Jorhat, Sibsagar and Sonitpur districts of Assam; Ahmedanagar and Kolhapur district of Maharashtra and Belgaum district of Karnataka. The other states where the system covers considerable area under sugarcane-wheat are Haryana, Punjab, Madhya Pradesh and Rajasthan.

Problems in sugarcane-wheat system are:

i. Late planting of sugarcane as well as wheat.
ii. Imbalance and inadequate use of nutrients. Since majority of farmers apply only N in sugar cane and the use of P and K is limited. The emerging deficiencies of P, K, S and micro-nutrients are limiting system productivity directly and through interactions with other nutrients.
iii. Poor nitrogen use efficiency in sugarcane.
iv. Low productivity of ratoon due to poor sprouting of winter harvested sugarcane in north India.
v. Build up of *Trianthema partulacastrum and Cyprus rotundus in sugarcane.*
vi. Stubble of sugarcane pose tillage problem for succeeding crops and need to be managed properly.

Cotton-Wheat

Cotton is widely grown in alluvial soils of north India (Punjab, Haryana, Rajasthan and Western Uttar Pradesh) and black cotton soils of central India (Andhra Pradesh, Tamil Nadu and Karnataka). With the availability of short duration varieties of cotton, cotton-wheat cropping system has become dominant in North. About 70-80 per cent area of cotton is covered under this system. In Central region also, wherever irrigation is available, cotton-wheat is practiced. The major issues of concern in cotton-wheat cropping system are:

i. Delayed planting of succeeding wheat after harvest of cotton.
ii. Stubbles of cotton create problem of tillage operations and poor tilth for wheat.
iii. Susceptibility of high yielding varieties of cotton to boll worm and white fly and consequently high cost on their control leading to unsustainability.
iv. Poor nitrogen use efficiency in cotton results in low productivity of the system.
v. Appropriate technology for intercropping in widely spaced cotton is needed to be developed.

Soybean – Wheat

Soybean-wheat cropping system has emerged as an important cropping system only after 1980 with the introduction of soybean as a Kharif crop in wheat growing areas of the country particularly under irrigated ecosystem.

Constraints limiting the soybean production and productivity viz. a relatively recent introduction of soybean as a crop, limited genetic diversity, short growing period available in Indian latitudes, hindered agronomy/availability of inputs at farm level, rain fed nature of crop and water scarcity at critical stage of plant growth, insect pests and diseases, quality improvement problems, inadequate mechanization and partial adoption of technology by farmers have been identified.

The realized and realizable yield potential have shown

that the nation-wide average realized yield obtained by adopting improved technology is about 2 t/ha in soybean as against one t/ha obtained under farmers' practices. It is, however, to be noted that yield level of 3 to 3.5 t/ha in individual farmer's fields is not so uncommon in southern Maharashtra, Malwa plateau and some areas of Rajasthan.

7. LEGUME BASED CROPPING SYSTEMS

Legume crops (pulses and oilseeds) are popular for their suitability in different cropping systems. Recent advances in the development of large number of varieties of pulse and oilseed crops, varying largely for maturity duration, have made it possible to include them in irrigated crop sequences. The popular cropping systems are pigeon pea-wheat in Madhya Pradesh and groundnut-wheat in Gujarat, Maharashtra and Madhya Pradesh and groundnut-sorghum in Andhra Pradesh and Karnataka.

The major issues in legume based cropping systems are:

i. No technological breakthrough has been achieved so far in respect of yield barriers, particularly in legumes.
ii. Susceptibility of the pulses to aberrant weather conditions especially water logging and adverse soils making them highly unstable in performance.
iii. High susceptibility to diseases and pests.
iv. Low harvest index, flower drop, indeterminate growth habit and very poor response to fertilizers and water in most of the grain legumes.
v. Nutrient needs of the system have to be worked out considering N-fixation capacity of legume crops.

Yield Gaps

The yield gaps of some of the important cropping systems are given in the following tables:

Table 4. Yield gap of oilseed based cropping systems between farmer's method and improved method under different agro-ecosystems

Agro-eco-system/ Centre	Cropping system (Average over years)	System yield, (rice equivalent, t/ha) Farmer's Method	Improved Method	Yield gap (rice equip-ment, t/ha)
Arid			Rapeseed & Mustard based	
Jodhpur	Pearlmillet-Mustard (4)	4.46	6.02	1.56
			Sunflower based	
N. Kannada	Maize-Sunflower (2)	6.90	8.10	1.20
Semi Arid				
Aligarh	Maize-Mustard (5)	4.30	6.50	2.20
Badaun	Rice-Mustard (2)	4.61	6.55	1.94
			Groundnut based	
Beed	Sorghum-Groundnut (2)	5.70	6.30	0.80
			Sunflower based	
Beed	Sorghum-Sunflower (4)	5.50	6.43	0.73
			Soybean based	
Ujjain	Soybean-Wheat (2)	8.90	12.90	4.00
Sub-humid			Groundnut based	
Mayurbhanj	Rice-Groundnut (4)	6.95	11.00	4.05
Coastal			Groundnut based	
Puri	Rice-Groundnut	6.90	11.30	4.40

Source : Yadav, R.L., Prasad Kamta and Singh, A.K. (Editors), 1998. Predominant Cropping Systems of India: Technologies and Strategies, pp. 237. Project Directorate for Cropping Systems Research, Modipuram, Meerut-250110, India.

Table 5. Yield Gap Analysis in Wheat in various States/Agro-climatic regions (q/ha)

Particulars	Punjab (Semi-arid)	Haryana (Arid)	West Bengal (Humid)	Madhya Pradesh (Semi-arid)	Gujarat (Arid & Semi-arid)	Himachal Pradesh (Humid)	Rajasthan (Arid & Semi-arid)	Bihar (Sub-humid)	Uttar Pradesh (Semi-arid & Sub-humid)
A. Potential/ Experimental Yield (1998-99)	48.06	47.05	50.25	43.4	48.51	48.92	38.89	36.96	47.69
B. On-farm Yield (1998-99)	47.82	41.98	30.77	24.28	34.43	44.35	32.80	32.45	42.81
C. State Average yield (1998-99)	43.32	39.16	21.17	17.9	24.27	17.10	24.87	19.92	25.10
Yield gap (I) A-B. (Potential–On-farm)	0.24	5.07	19.48	19.12	14.08	4.57	6.09	4.51	4.88
Yield gap (II) B-C. On-farm – State average	4.50	2.82	9.60	6.38	10.16	27.25	7.93	12.53	17.71
A-C. Total Yield Gap	4.74	7.89	29.08	25.50	24.24	31.82	14.02	17.04	22.59
D. Percentage of total yield gap (%) (A-C) × 100/A	9.86	16.8	57.9	58.8	49.9	65.0	36.0	46.10	47.4

Source: Director, Project Directorate for Cropping Systems Research, Modipuram, Meerut-250 110, India.

Table 6. Yield Gap in Rice in different States/Agro-climatic regions (q/ha)

Particulars	Andhra Pradesh (Semi-arid)	Assam (Humid)	West Bengal (Humid)	Tamil Nadu (Semi-arid)	Karnataka (Arid & Semi-arid)	Punjab (Semi-arid)	Orissa (Sub-humid)	Madhya Pradesh (Semi-arid)	Bihar (Sub-humid)	Uttar Pradesh (Semi-arid & Sub-humid)
A. Potential/ Experimental Yield (1998-99)	83.38	55.08	52.32	55.12	78.16	69.0	60.47	54.84	59.75	73.42
B. On-Farm yield (1998-99)	54.51	37.61	46.10	45.29	46.20	62.85	49.58	47.26	34.40	50.31
C. State Average Yield (1998-99)	27.81	13.45	22.55	34.03	25.29	31.52	12.12	10.13	13.01	35.53
Yield gap (I) A-B. (Potential – On-farm)	28.87	17.47	6.22	9.83	31.96	6.15	10.89	7.58	25.35	23.21
Yield gap (II) B-C. On-farm – State average	26.70	24.16	23.55	11.26	20.91	31.33	37.46	37.13	21.39	14.68
A-C. Total Yield gap	55.57	41.63	29.77	21.09	52.87	37.48	48.35	44.71	46.74	37.89
D. Percentage of total yield gap (%) (A-C) × 100/A	66.6	75.6	56.9	38.3	67.6	54.3	79.9	81.5	78.2	51.6

Source: Director, Project Directorate for Cropping Systems Research, Modipuram, Meerut-250 110, India.

8. HORTICULTURAL CROPS

India has made a good place for itself on the Horticulture Map of the World with a total annual production of horticultural crops touching over 1490 million tones during 1999-00. The horticultural crops cover about 9 per cent of the total area contributing about 24.5 per cent of the gross agricultural output in the country. However, the productivity of fruits and vegetables grown in the country is low as compared to developed countries.

The information with regard to cropping pattern in horticultural crops particularly vegetables and tuber crops is not compiled and readily available. However, the constraints in production in these crops and zones/ states of cultivation of these crops is given briefly.

I. Vegetable Crops

Vegetable crops in India are grown from the sea level to the snowline. The entire country can broadly be divided into six vegetable growing zones:-

1. Temperate Zone	:	Jammu & Kashmir, Himachal Pradesh, upper Uttranchal and Punjab, Darjeeling hill area of West Bengal, Nilgiri hills areas of Tamil Nadu, Arunachal Pradesh and Sikkim.
2. Northwestern subtropical zone	:	Haryana, parts of Punjab, Uttar Pradesh, Madhya Pradesh and Bihar.
3. Northeastern subtropical zone	:	Most parts of Bihar, northern parts of West Bengal, Meghalaya, Assam and Nagaland.
4. Central tropical zone	:	Gujarat, most parts of Madhya Pradesh, Maharashtra, Western part of West Bengal, Tripura, Manipur and part of Mizoram.
5. Southern tropical zone	:	Andhra Pradesh, Karnataka, Tamil Nadu and part of Kerala.
6. Coastal humid tropical zone	:	Coastal areas of Kerala, Andhra Pradesh, West Bengal and Orissa.

Low productivity is the main feature of vegetable cultivation in India as farm yields of most of the vegetables in India are much lower than the average yield of world and developed countries. The productivity gap is more conspicuous in tomato, cabbage, onion, chilli and peas. Preponderance of hybrid varieties and protected cultivation are mainly responsible for high productivity in the developed countries. Average productivity levels of some important vegetables are given in Table 8.

Constraints in vegetables production:-

1. Lack of planning in Production
2. Non-availability of seeds of improved varieties.
3. High cost of basic production elements
4. Inadequate plant protection measures and non-availability of resistant varieties.
5. Weak marketing facilities
6. Transportation limits
7. Post harvest losses
8. Abiotic stresses.

II. Tuber Crops

Tuber crops have good potential as secondary staple food, vegetable and industrial raw material. Many of the crops find favour with tribals as a rich source of carbohydrates. Many promising varieties of important tuber crops have been recommended and suitable agro-techniques and plant protection measures have been standardized. The important crops are Potato, Sweet potato, Colocasia, Cassava and Lesser yam.

These crops except potato are grown in poor soils with less inputs and even under drought and unfavourable conditions.

1. Potato

For getting high production, the potato crop is required to be planted at optimum time using proper cultural, manurial and irrigational practices. Remunerative potato based cropping systems are also required to be developed to ensure stability of crop area and production and good returns to the farmers. The major potato producing belts are as follows:

- Himachal Pradesh (Shimla, Lahaul spiti & Mandi).
- Punjab (Jalandhar, Hoshiarpur, Ludhiana & Patiala) and Haryana (Ambala, Kurukshetra, Hisar, Karnal).
- Uttar Pradesh (Farrukhabad, Etawah, Mainpuri, Barabanki, Allahabad, Badaun, Moradabad, Agra, Aligarh, Mathura, Faizabad).
- Madhya Pradesh (Sidhi, Satana, Rewa, Sarguja, Rajgarh, Sagar, Tikamgarh).
- Gujarat (Khera, Dissa, Banaskantha, Jamnagar, Baroda, Mehsana).
- Orissa (Cuttack, Dhenkamal, Puri & Sambalpur) and West Bengal.
- Maharashtra (Pune, Satara, Kolhapur, Nasik).
- Karnataka (Belgaum, Dharwad, Hassan and Kolar).
- Andhra Pradesh (Medak and Chitture).
- Tamil Nadu (Dhindigulanna, The Nilgiris).

The State-wise area, production and productivity of potato are given in Table 9.

The information relating to remunerative crop

Table 7. Area, production and productivity state-wise under various vegetable crops

State/UTs	Area (in 000'ha)			Production (in 000't)			Productivity (t/ha)		
	91-92	98-99	99-00	91-92	98-99	99-00	91-92	98-99	99-00
Andhra Pradesh	155.2	249.3	230.1	1452.6	3541.2	2839.1	9.4	14.2	12.3
Arunachal Pradesh	17.2	16.7	16.9	79.9	80.9	80.9	4.6	4.8	4.8
Assam	222.4	245.9	255.9	2132.3	2834.8	3089.4	9.6	11.5	12.1
Bihar (including Jharkhand)	843.3	616.6	626.0	8643.1	9418.4	9548.8	10.2	15.3	15.3
Delhi	55.0	45.5	45.7	627.8	621.9	652.0	11.4	14.3	14.3
Goa	NA	7.6	7.6	NA	70.0	70.0	NA	9.2	9.2
Gujarat	114.6	189.9	201.0	1667.9	3255.0	2647.0	14.6	17.1	13.2
Haryana	60.8	120.0	135.0	877.0	1850.0	2094.5	14.4	15.4	15.5
Himachal Pradesh	38.7	45.8	40.6	476.0	606.4	660.9	12.3	13.2	16.3
Jammu & Kashmir	180.3	41.2	41.4	745.0	606.9	584.4	4.1	14.7	14.1
Karnataka	351.1	309.7	361.6	3673.2	4944.9	6796.9	10.5	16.0	18.8
Kerala	202.1	159.7	159.7	3229.1	2857.2	2857.1	16.0	17.9	17.9
Madhya Pradesh (including Chhattisgarh)	176.4	234.0	258.7	2221.0	3276.2	3632.0	12.6	14.0	14.0
Maharashtra	241.1	341.2	385.3	4171.3	4479.5	4828.6	17.3	13.1	12.5
Manipur	11.8	8.5	9.0	50.3	45.0	60.8	4.3	5.3	6.8
Meghalaya	25.9	36.6	29.2	219.2	308.7	252.9	8.5	8.4	8.7
Mizoram	6.0	8.4	8.3	31.8	62.4	56.3	5.3	7.4	6.8
Nagaland	8.2	15.1	20.9	66.9	313.3	235.7	8.2	10.4	11.3
Orissa	710.3	883.9	788.1	7275.0	10087.1	9096.0	10.2	11.4	11.5
Punjab	84.5	117.1	135.4	1450.0	1906.3	2285.0	17.2	16.3	16.9
Rajasthan	62.9	99.3	98.7	307.0	396.1	472.6	4.9	4.0	4.8
Sikkim	7.6	9.4	9.6	46.1	42.2	43.0	6.1	4.5	4.5
Tamil Nadu	889.3	206.7	209.1	3796.9	5704.8	5660.3	4.3	27.6	27.1
Tripura	30.4	18.4	18.4	306.9	232.8	232.8	10.1	12.7	12.7
U.P. (Hills) (Uttranchal)	57.1	91.5	81.9	617.6	840.7	733.2	10.8	9.2	9.0
U.P. (Plains)	576.7	640.7	688.9	9627.3	12680.6	13842.4	16.7	19.8	20.1
West Bengal	456.0	1100.0	1122.3	4680.0	16367.4	17413.8	10.3	14.9	15.5
Andaman & Nicobar	3.4	3.1	3.1	13.2	15.8	15.8	3.9	5.1	5.1
Chandigarh	0.3	0.4	0.1	11.1	11.5	1.2	37.0	28.8	12.0
Dadra & Nagar Haveli	1.5	1.5	1.5	13.6	13.5	13.5	9.1	9.0	9.0
Daman & Diu	0.0	0.1	0.1	1.3	1.0	1.1		10.0	
Lakshadweep	0.4	-	0.3	0.3	-	0.2	0.8	-	0.7
Pondicherry	2.4	2.2	2.6	22.3	33.5	32.6	9.3	15.2	12.5
All India	5592.6	5866.0	5993.0	58532.0	87536.0	90830.7	10.5	14.9	15.2

Source: Horticulture Data Base (2001).

Table 8. Average Productivity Levels (t/ha) of some important vegetables in the world

Crop	Developed	Developing	World	India	
				Onfarm*	Experi-mental**
Tomato	33.73	18.97	25.09	15.60	30.0
Cabbage	25.22	17.67	21.62	15.68	36.0
Melons and cantaloupe	17.0	17.9	16.10	16.8	22.0
Watermelon	12.97	15.85	14.71	12.71	17.60
Cucumber	15.16.	13.99	14.51	6.75	13.60
Brinjal	13.00	12.30	13.70	13.08	25.00
Onion	18.31	11.67	13.79	14.18	34.00
Cauliflower	16.80	10.62	13.62	14.78	26.60
Chilli (green)	15.97	6.77	8.29	2.02	7.50
Beans (green)	7.68	6.24	6.88	2.20	11.50
Peas (green)	7.26	3.74	6.08	7.29	16.50

*Onfarm productivity has been calculated on the basis of area and production (1994-95).

**Experimental productivity is based on average yield of different crops under All India Coordinated trials.

rotations at various locations, promising intercropping systems and remunerative intercrops for different regions is given in Tables 10, 11 and 12.

Future Thrusts

Due to diminishing availability of land resources, the increase in area under potato that occurred in the past is not expected to continue. The possibility of some increase in *Kharif* potato areas in the plateau regions of Bihar, Maharashtra and Karnataka exists provided suitable production technologies are available. Increasing the cropping intensity by identifying suitable, companion crops with potato and the development of remunerative potato based cropping systems can also add to the area under *Rabi* potato.

For increasing the production levels from the present 15.2 million tones to 30 million tones and the productivity from 16.2t/ha to 20 t/ha in the country there is need to pay special attention to the problems of potato growing areas like eastern UP, North Eastern Bihar and the states of Assam and Karnataka which have large areas under the potato crop but their productivity levels are low.

2. Sweet potato

The recommended time of planting of the crop among the different states are given below:

States	Ideal time of Planting
Bihar, Assam, NE region and Uttar Pradesh	As a summer crop it is grown in February (with irrigation). In June sweet potato is raised as upland rainfed crop and in September-October as autumn crop. November is the ideal time for the *diara* land of Bihar where the crop is raised after the recession of flood.
Andhra Pradesh	Kharif and Rabi (with irrigation)
Tamil Nadu	May-September (with irrigation)
Maharashtra	Kharif and Rabi (with irrigation)
Madhya Pradesh	August-September
Karnataka	Kharif and Rabi (with irrigation)
West Bengal	September-October
Chhotanagpur Plateau of Bihar	August-September
In other states	it is grown mostly as Kharif crop during rainy season

Table 9. State-wise area, production and productivity of potato

State/UTs	Area (in 000'ha)			Production (in 000'mt)			Productivity (mt/ha)		
	91-92	98-99	99-00	91-92	98-99	99-00	91-92	98-99	99-00
Assam	61.7	77.0	76.7	473.3	611.1	699.7	7.7	7.9	9.1
Bihar	305.0	191.4	175.5	3250.0	1675	1720.2	10.7	8.8	9.8
Gujarat	16.8	31.6	31.3	412.5	712.9	688.7	24.6	22.6	22.0
Haryana	13.8	17.2	16.5	205.0	276.2	260.0	14.9	16.1	15.8
H.P.	14.7	10.9	10.6	110.0	91.2	140.9	7.5	8.4	13.3
Karnataka	35.4	28.1	32.3	650.0	394.0	460.0	18.4	14.0	14.2
M.P.	31.7	55.1	62.0	368.0	841.3	808.6	11.6	15.3	13.0
Meghalaya	17.6	20.5	18.3	153.2	200.5	143.2	8.7	9.8	7.8
Punjab	46.6	50.3	75.5	923.1	941.9	1563.2	19.8	18.7	20.7
U.P. (plains)	323.0	421.3	463	6145.6	9533.7	10455.3	19.0	22.6	22.6
West Bengal	206.3	318.2	315.8	4531.8	6692.4	7482.3	22.0	21.0	23.7
Others	NA	58.6	63.4	NA	524.5	578.0	–	–	–
Total	1135.1	1280.2	1340.9	18195.0	22494.7	25000.1	16.0	17.6	18.6

Source: Indian Horticulture Data Base (2001).

Table 10. Remunerative crop rotations at various locations

Centre	Recommended rotation	Net Returns (Rs./ha)		
		Ist Yr.	IInd Yr.	III Yr.
Kanpur	Potato-Bajra-Groundnut	43106	63022	—
Deesa	Potato-Bajra-Groundnut	41875	34665	36148
	Potato-Groundnut-Bajra	29250	34500	34926
Ranchi	Potato-Greengram-Groundnut	19058	23385	19590
Chhindwara	Potato-Okra-Soyabean	14981	28620	30125
	Potato-Mung-Maize	19559	20539	29597
Hisar	Onion-Okra	52405	60841	49761
	Potato-Tomato-Okra	46940	38038	38988
Jorhat	Potato-Mung-Paddy (Trans.)	22760	54422	—
	Potato-Summer Paddy (Trans.) Paddy (Trans.)	20633	52900	

Source: 20 Years of Potato Research, 1994 (AICRP), CPRI, Shimla.

Table 11. Promising inter-cropping systems

Centre	Pure Potato	Yield (q/ha) Potato+Intercrop
Kanpur		
Potato + Wheat	270	257 + 25
Potato + Onion(for seed)	270	265 + 3
Pantnagar		
Potato + Wheat	313	304 + 45
Potato + Radish	313	314 + 7
Patna		
Potato + Wheat	223	214 + 15
Potato + Radish	223	206 + 25

Source: 20 Years of Potato Research, 1994 (AICRP), CPRI, Shimla.

3. Colocasia

In Bihar, the crop can be planted successfully in February and June. In areas of Bihar, West Bengal and Eastern U.P., where irrigation is available, February planting is ideal. In Kerala, April-June is the ideal time of planting. February is the planting time in Andhra Pradesh, April in Assam and June in other parts of India.

4. Cassava

In Kerala, cassava is grown as a rainfed crop. Best planting season is April-May with the onset of south-west monsoon. June planting is ideal for Andhra Pradesh, Assam and Jagadalpur under rainfed conditions. Under irrigated conditions of Tamil Nadu, planting in September is found suitable.

Legumes are most suited inter-crop in cassava. Intercropping of blackgram in Tamil Nadu, greengram or blackgram in Andhra Pradesh and French bean in Assam are suitable and profitable. Bunch varieties of groundnut like TMV-2 and TMV-7 are also found to be ideal as an inter crop in cassava.

5. Lesser Yam

Sree Latha is a versatile variety suitable for Bihar, Assam, West Bengal, Kerala and Andhra Pradesh whereas Konkan Kanchan is a variety identified and recommended for Maharashtra.

9. RESEARCH GAP AND FUTURE THRUST

Tuber crops, in general, are low priority crops and are grown in marginal fields by poor farmers. Naturally, crop production techniques involving high inputs may not have much relevance with the majority of farmers hence identification of stress tolerant lines with reasonable yield potential is one of the important

Table 12. Remunerative intercrops for different regions

Centre	Crops	Yield (q/ha)			Net gain (Rs./ha)		
		Potato	Intercrop	Potato+ Intercrop	Potato Pure	Intercrop Pure	Potato + Intercrop
Hisar	Potato+Fennel	287	31.0	280+17.0	54,467	46,130	68,613
	Potato+Onion (for seed)	287	14.0	244+11.0	54,467	104,341	136,868
Faizabad	Potato+Mustard	276	28.7	225+8.5	25,400	27,000	30,123
Chhindwara	Potato+Onion (for bulb)	266	295.5	201+152.7	34,190	42,853	44,843
Kanpur	Potato+Linseed	384	29.0	334+10.0	40,497	15,559	47,174
Ranchi	Potato+Wheat	262	45.0	275+22.0	16,050	10,720	23,895
Rajgurunagar	Potato+Sugarcane	149	1240.0	98+1404.6	9,630	28,352	33,752

Source: 20 Years of Potato Research, 1994 (AICRP), CPRI, Shimla.

mandates in the crop improvement programme.

Short duration lines with good yield potential, quality and tolerance to pests and diseases will be very useful in a cropping system with other economically important crops.

Tuber crops, being vegetatively propagated, the multiplication rate is very low. This coupled with the absence of a proper seed distribution agency poses problems in the propagation and spread of the high yielding varieties released by the state and national agencies. Lack of proper infrastructure for virus elimination and multiplication of CMD free planting material is the real problem which comes in the way of boosting cassava production in non-traditional areas. So, the establishment of an effective seed production and distribution network at the national level is a pre-requisite for boosting production of tuber crops.

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