Significant Research Achievements of ICAR-RCER (2012-17)

ICAR Research Complex for Eastern Region
ICAR Parisar, P.O.: Bihar Veterinary College
Patna-800 014 (Bihar)

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Foreword

The Eastern Region of India is endowed with rich natural resources and has diverse agro-climatic conditions, which offers unique scope and opportunities for the cultivation of various crops, livestock and fisheries. Despite having rich natural resources like fertile soil, adequate rainfall and sufficient ground-water and bright solar radiation, its potential could not be harnessed in terms of improving agricultural and water productivity, poverty alleviation and livelihood improvement and hence this region is referred to as "Low Productivity-High Potential" zone. There is a large gap between the potential and productivity of major crops, horticulture, fisheries etc. Moreover, this region is also experiencing frequent flood and drought-like situation. Identification of research gaps and constraints in productivity of important agri-horti crops, livestock and fishery, crop diversification, minimization of production losses, processing and value addition, location-specific production technologies, however, would play an important role in improving productivity and thereby socio-economic upliftment of resource poor farmers of the region.

ICAR Research Complex for Eastern Region (ICAR-RCER), Patna has made significant contributions in different areas of crops, livestock, fisheries, horticulture, aquatic crops and natural resource management. The present document presents the compilation of major research achievements carried out by the institute during 2012-2017.

I compliment the Director and his editorial team for bringing out the salient research achievements generated during 2012-2017 in the form of a book entitled "*Significant research achievements of ICAR RCER, Patna (2012-17)*", which I believe, will help the scientific community, researchers, extension workers, planners and stakeholders to plan their future strategies.

(S.K. Chaudhari)

Preface

The Eastern Region of India is bestowed with enormous natural resources and has diverse agro-climatic conditions, which offers inimitable opportunities for the cultivation of various crops, rearing of livestock and aquaculture activities, and providing livelihood opportunities to millions of people. However, overall productivity per unit area and development is still low compared to other parts of the country. Moreover, this region is also experiencing frequent flood and drought-like situations. Among various other issues, lack of location-specific farming system model and production technologies, low cropping intensity, fragmentation of land, poor irrigation facilities, lacks in quality planting materials, animal breeds, feeds and fodder, and adequate animal health care mechanism as well as dissemination of scientific knowledge to farmers, are hampering agriculture and allied sector significantly.

ICAR Research Complex for Eastern Region (ICAR-RCER), Patna, is a multi-commodity and multi-disciplinary institute, established, with an objective to address diverse issues relating to land and water resources management, crop husbandry, horticulture, agroforestry, aquatic crops, fishery, livestock and poultry, agro-processing and socio-economic aspects for achieving food and nutrition self sufficiency in the Eastern Region. The institute has made significant contributions in various areas, and has become one of the most important ICAR institutes in the whole Eastern Region.

During the period (2012-2017), the Institute has made significant contributions in research and extension related activities in different agri-horti crops, livestock & fisheries, agroforestry, aquatic crops, and water management besides socio-economic aspects through different institutional and externally funded projects in networking mode. To showcase the information and to have a database of different achievements of the Institute during 2012-17, this document contains the compilation of major research findings of the institute in the form of E-book. The editors express their sincere thanks to all the concerned scientists for providing information that has helped to compilation of this E-book.

The authors believe that this E-book will be a very good source of reference material on agriculture and allied areas of the Eastern Region, and will be useful to researchers, students, entrepreneurs and policymakers

Editors

Contents

1. Introduction

The Eastern Region comprises of seven states *viz*., Assam, Bihar, Chhattisgarh, Eastern Uttar Pradesh, Jharkhand, Odisha, and West Bengal (Fig. 1.1), can be divided into three distinct physiographical parts, namely (i) plains of Eastern UP, Bihar, West Bengal and Assam; (ii) hilly and plateau regions in Eastern UP, Bihar, Jharkhand, West Bengal, Odisha, Chhattisgarh, and Assam; and (iii) coastal plains of West Bengal and Odisha. The Eastern Region covers about 21.85% geographical area of the country and supports 34% human and 32% livestock population of India. The region is bestowed with rich natural resources and has great potential for intensive and diversified crop production to improve agricultural productivity, poverty alleviation, and livelihood improvement besides livestock and fisheries development. Agriculture is the mainstay of eastern India's economy, but agricultural productivity and per capita income of the farmers are very low. It is also inhabited by resource-poor people with small holding. In order to ensure the food security of the nation, the Eastern Region has been targeted for ushering a Second Green Revolution, which can be accomplished through holistic management of land, water, agri-horti crops, livestock, fishery and human resources.

The region's climate is tropical, hot, and humid except in hilly areas with high rainfall. Agriculture in this region is, by and large, complex, diverse and risk-prone, with the vast area being rainfed, facing various constraints for resources, infrastructure, technology outreach, and institutional mechanisms. Though major rainfall (about 80%) used to be received during *Kharif*, it has large spatial and temporal variation, leading to immense uncertainty and instability in agricultural productivity and production. The occurrence of long drought spells during critical growth

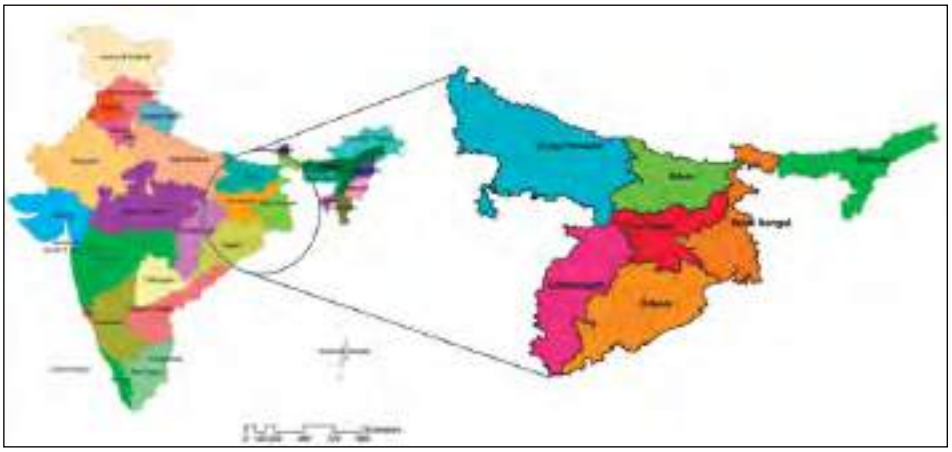


Fig. 1.1. Geographical spread of Eastern States

periods of crops is quite common in the region. Further, heavy spells of rains lead to water congestion and flooding, making crop cultivation almost impossible, during the *Kharif* season. The region receives substantially high precipitation but surface and groundwater resources are utilized to a minimum level and, a large proportion of the cultivated area does not receive any irrigation water. The farmers still depend on the vagaries of the monsoon for crop production. Because of the above-mentioned scenario and production, productivity gaps of different enterprises the potential of this region could not be exploited. Therefore, on the initiation of the Govt. of India, ICAR decided to establish ICAR Research Complex for Eastern Region (ICAR-RCER) with its headquater at Patna.

ICAR-RCER was established on the 22nd February, 2001 having the merger of Directorate of Water Management, Patna with the Complex. On April 1st, 2001, Central Horticultural Experimental Station, Ranchi and Central Tobacco Research Station, Pusa were also merged in the complex. The ICAR-RCER is a multi-commodity and multi-disciplinary institute, which has basically a broad-based approach to address diverse agricultural issues relating to land and water resources management, crop husbandry, horticulture, agro-forestry, aquatic crops, fishery, livestock and poultry, agro-processing, extension and socio-economic aspects in holistic manner for enhancing research capability and providing a backstopping for improvement in agricultural productivity and sustainability.

Geographically, the Institute is located at 25º 35'30" N latitude, 85º 05'03" E longitude and at an altitude 52 m above mean sea level. The complex has broad based mandate in view of emerging opportunities of research in frontier areas, initiatives for regional cooperation, globalization, and cost competitiveness. In order to achieve 4 percent growth rate in agriculture, emphasis is being given on multi-disciplinary research in a program matrix. Network and consortium approach are envisaged to achieve mission of the complex through partnership and collaboration with SAUs, ICAR Institutes, CGIAR institutions and NGOs. To justify its existence and to address the poor and small and marginal farmers with better scientific knowledge, institute has formulated a details programme, a brief note is given below.

Vision

The vision is to pre-position the institute with desired competitiveness for developing the kind of technologies needed to address the multiple vulnerabilities confronting agriculture and allied fields today and likely to confront tomorrow and thereby contribute towards production, profitability and sustainability in agriculture, particularly in view of Look East Policy of Govt. of India, for ensuring food security in the country.

Mission

- Transforming *Low Productivity-High Potential* Eastern Region into *high productivity* region for food, nutritional and livelihood security in a manner that is environmentally sustainable, socially acceptable and monetarily profitable.
- Utilization of vast seasonally waterlogged and perennial water bodies for multiple uses of water and aquatic crops besides, poverty alleviation and women empowerment through employment generating activities.
- Promote network and consortia research in the Eastern Region.

Mandate of the Institute

- Strategic and adaptive research for efficient integrated management of natural resources to enhance productivity of agricultural production systems in Eastern Region.
- Transform low productivity-high potential Eastern Region into high productivity region for food, nutritional and livelihood security.
- Utilization of seasonally waterlogged and perennial water bodies for multiple uses of water.
- Promote network and consortia research in the Eastern Region.

Modalities to Achieve the Mandate are:

- Facilitate and promote coordination and dissemination of appropriate agricultural technologies through network/consortia approach involving ICAR Institutes, SAUs and other agencies for generating location-specific agricultural production technologies through sustainable use of natural resources.
- Provide credible scientific support and to act as a centre for vocational as well as advanced training to promote agricultural production technologies.
- Act as repository of available information and its dissemination on all aspects of agricultural production systems.
- Collaborate with relevant national and international agencies in liaison with state and central government departments for technology dissemination.
- Provide need-based consultancy and advisory support for promoting agriculture, horticulture and livestock in the region.

- Socio-economic evaluation and impact assessment of agricultural technologies.
- To achieve the mandate as stated above, the Institute has following six major programmes.

Research Programme

(a) Farming System Research including Climate Resilient Agriculture

(b) Genetic Resource Management and Improvement of Field, Horticultural and Aquatic crops

(c) Improved Production and Protection Technologies for Agri-Horti Crops

(d) Integrated Land & Water Management

(e) Livestock & Fisheries Management

(f) Socio-Economics, Extension and Policy Research

To achieve its targets the Institute is having headquarter at Patna, two research stations and two KVKs as mentioned below:

ICAR-RCER Headquarter at Patna

Research Complex for Eastern Region has 03 research farms in Patna. Main campus of the institute is spread over 65 acres. The other research farm of 42.57 acres, located at Sabajpura, is around 8 km from the main campus. Institute also has 11 acres of farm land at WALMI, Phulwari Sharif, which is 10 km away from the main campus.

ICAR-RCER Farming System Research Centre for Hill & Plateau Region, Ranchi Jharkhand

It has 189.29 acres of farm land located at Plandu, Ranchi and 236.54 acres of research farm at Churu, Ranchi, Jharkhand.

ICAR-RCER Research Centre for Makhana, Darbhanga, Bihar

It has 25 acres of research farm at Darbhanga, Bihar.

ICAR-RCER Krishi Vigyan Kendra at Buxar, Bihar and at Ramgarh, Jharkhand

The Krishi Vigyan Kendra Buxar has 25.64 acres of farm land. Here front-line demonstration and on-farm trials at farmer's field on improved technologies and refinement of the existing technologies were regularly conducted so as to suit the need of the farmer. Apart from that they also organized on and off line campus training programme for the farmers, rural women, and youth.

From the time of inception, the institute has made significant contributions in research and extension related aspects on different crops, livestock & fisheries, agro-forestry, aquatic crops, and water management besides, socio-economic aspects through different institutional and externally funded projects. However, most of the information are available in a scattered manner and not in a public domain for the access of the research activities. Hence, an attempt has been made to compile the divisional level research information in a book form for the access to the researchers, students, entrepreneurs and policymakers.

2. Prevailing Weather Condition at Patna and Ranchi Centre during 2012-17

Agro-meteorological Observation

An agro-meteorology observatory was established at Patna in 2012 with a manual and automatic data recording system (Fig. 2.1). At Patna, weather parameters *viz.* air temperature, humidity, rainfall, sunshine hours and pan evaporation at hourly interval were recorded. The different annual meteorological parameters such as maximum-minimum temperature, annual rainfall, rainy days, relative humidity (RH) and sunshine hours were recorded at Patna and Ranchi stations during the 2012-17 are presented in Table 2.1 & 2.2.

As per the annual temperature is concerned there was not much variations among the years (Fig. 2.2) both in terms of maximum and minimum temperature, however, there were variations among the months. The maximum temperature (39.1°C) was

Fig. 2.1. Agro-meteorological observatory at ICAR-RCER, Patna

Table 2.1 Annual average weather parameters during 2012-17 at meteorology observatory of ICAR-RCER, Patna

Year	Annual Max Temp (°C) / Month-Max. Temp	Annual Min Temp(°C) / Month-Max. Temp	Annual RH (%)	Annual rainfall (mm)	Annual Rainy days	Sunshine hrs/day
2012	30.2 (May-37.2)	20.2 (Jan-6.5)	65.9	995.5	26	6.4
2013	30.3 (May-36.3)	20.0 (Jan-7.7)	69.4	844.7	45	5.00
2014	30.0 (May-38.1)	19.9 (Dec-10.1)	70.04	1071.4	54	5.04
2015	30.5 (May-37.9)	20.4 (Dec-10.5)	69.24	703.7	39	4.91
2016	30.8 (Apr-39.1)	20.4 (Jan-8.7)	68.4	1053.3	49	4.23
2017	30.7 (Apr-36.1)	20.6 (Jan-10.4)	67.7	887.6	45	4.5

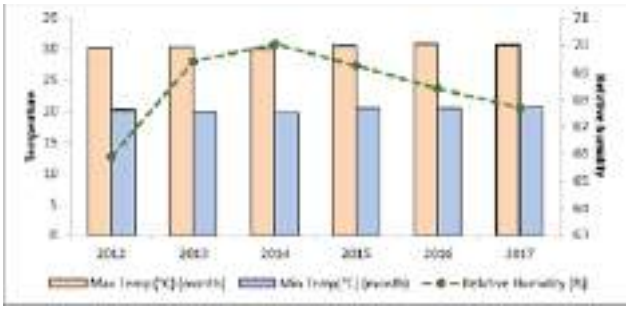


Fig. 2.2. Annual average temperature variations and relative humidity during the year 2012-17 at meteorology observatory of ICAR-RCER, Patna

Table 2.2 Annual average weather parameters during the year 2012-17 at meteorology observatory of ICAR-RCER, FSRCHPR Ranchi

Year	Annual Max Temp (°C) / Month- Max. temp	Annual Min Temp(°C) / Month- Min. temp	Annual Relative Humidity (%)	Annual rainfall (mm)	Annual Rainy days
2012	29.9 (May-38.1)	18.7 (Dec-9.4)	85.4	1259.2	79
2013	28.5 (May-37.7)	18.2 (Dec-7.5)	84.7	1016	70
2014	29.5 (April-36.1)	19.9 (Dec-7.6)	86.5	920	-
2015	30.0 (May-37.3)	18.7 (Jan-9.4)	88.3	1092	72
2016	30.3 (Apr-39.1)	18.9 (Jan-8.9)	87.4	964	-
2017	30.5 (May-38.4)	19.5 (Jan-9.6)	88.2	1386	-

recorded in April 2016 and similarly minimum temperature 6.5°C in January 2012. The annual average relative humidity and sunshine ranges between 65-70% and 4.2-5.0 hrs, respectively. The annual average relative humidity in Patna was maximum in 2014 (70.04%) and minimum during 2012 (65.9%).

Annual average rainfall recorded at the ICAR RCER; Patna centre is presented in Fig. 2.3. At Patna, the normal annual rainfall is around 1127.3mm. The total annual precipitation received during 2012, 2013, 2014, 2015, 2016 and 2017 were 955.5, 844.7, 1071.4, 703.7, 1053.3, 887.6 mm respectively which were 11.7%, 25.0%, 5.0%, 37.6%, 6.6%, 21.3% deficient than that of normal average rainfall.

The distribution of rainfall over time and intensity in the rainy season was very erratic. For example, during 2013, good rainfall was received in non monsoon months (February and October), while, the monsoon rainfall (June-September) was very low (575 mm) as compared to normal (951.9 mm).

As per the annual temperature, variations between maximum and minimum during the same period (2012-17) was very less at Ranchi (Fig. 2.4), however, there were variations among the months. The maximum temperature 39.1°C was recorded in April 2016 and similarly minimum temperature (7.5 °C) in the month of December 2013. Here compared to Patna, the fluctuations in annual average relative humidity

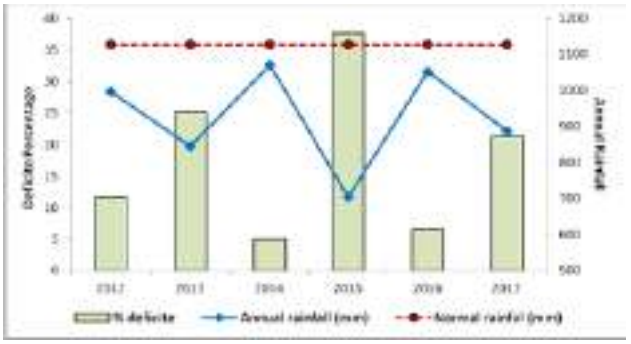


Fig. 2.3. Annual average rainfall pattern at ICAR-RCER, Patna during 2012-17

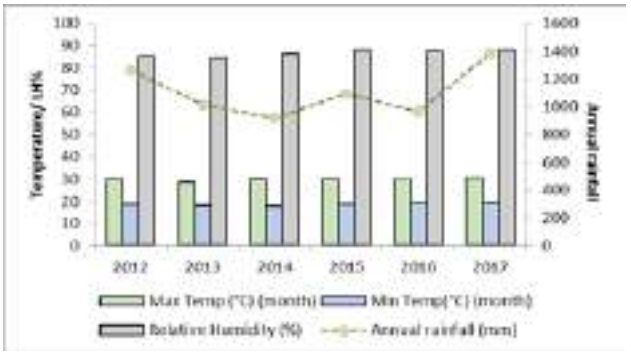


Fig. 2.4. Annual average temperature variations and relative humidity during the year 2012-17 at meteorology observatory of ICAR-RCER, Ranchi

were very narrow (85-89%) and much higher compared to Patna, and maximum in during 2017 (88.20%) and minimum in 2013 (84.70%) (Fig. 2.4).

Annual total rainfall except for the year 2012 and 2017, which was normal for that region, were deficient at the rate of 29.5%, 12.9%, 21.8%, 16.7% corresponding to 2013, 2014, 2015 and 2016 respectively. At Ranchi centre also the annual rainfall recorded was not uniform and as recorded at Patna centre, the pattern was erratic during 2012-2017.

During 2013 in Ranchi centre also received 38, 35 and 58% less rainfall in July, August and September, respectively. However, October had almost double rainfall than normal. Similarly, the total annual rainfall during 2014 was 920 mm of which about 87.1% (801 mm) was received during the monsoon months.

3. Division of Crop Research

Upland drought-prone rice

Total 276 rice genotypes were evaluated during 2012-2017 for reproductive stage drought, multi-stage drought, irrigated and aerobic conditions and participatory varietal trials. A total number of 51 AICRIP trials were also conducted for various ecologies. Total 42 advanced breeding lines were nominated under different breeding trials and 21 entries were promoted to 2nd and 3rd year of testing. Three VIC proposals (IET 24003, IET 24692 and IET 24306) were submitted for identification and release. IET 24003 was found promising identified for Chhattisgarh and M.P., and IET 24692 was found promising for Jharkhand. IET 24003 (Swarna Shreya) was later released and notified by the CVRC for Chhattisgarh, Jharkhand and Bihar (Fig. 3.1).

Fig. 3.1. IET 24003 (Swarna Shreya)

Diversification of rice-wheat cropping system with vegetables

Rice-cauliflower- leafy onion-greengram produced significantly higher rice equivalent yield (38.42 t/ha), net returns (Rs. 3,51,601/ha) and benefit:cost ratio (2.56) followed by rice-broccoli-spinach-greengram (28.13 t/ha, B:C: 2.25) and rice-tomato-greengram (25.34 t/ha, B:C: 2.40).

Evaluation of vegetable varieties under different irrigation methods

In tomato, three varieties *i.e.* Swarna Lalima, Swarna Naveen & local variety were grown under the surface and two levels of drip irrigation (IW: CPE=1.0 & IW: CPE = 0.7). Mulched crop attained 50% flowering stage five days earlier than non mulched crop and produced 29% and 25.4% higher yield non mulched crop under drip ir-

rigation. A saving of 51-65 % of irrigation water was found under drip irrigation.

In brinjal, three varieties *i.e.* Swarna Pratibha, Swarna Shobha & local variety were grown under surface and two levels of drip irrigation (IW:CPE=1.0 & IW:CPE=0.7). Mulched crop attained 50% flowering stage three days earlier than non mulched crop and produced 30.3% and 13.2% higher yield over non mulched crop under drip irrigation. Fruit yield of brinjal variety Swarna Shobha (33.9 t/ha) was significantly higher than Swarna Pratibha (30 t/ha) and local variety (29.3 t/ha). A savings of 63 and 75 % of irrigation water was found under drip irrigation compared to surface irrigation.

Sustainable crop intensification through the development of suitable plant types in cool-season pulses under rice-fallow and makhana-fallow cropping systems of Eastern India

Four advance breeding lines each in chickpea (DBGC 1, DBGC 2, DBGC 3 and DBGC 4) and lentil (DBGL 62, DBGL 105, DBGL 135 and DBGL 138) were developed (Fig. 3.2). These genotypes showed moderate to complete resistant reaction to Fusarium wilt in the wilt-sick nursery at TCA, Dholi. In grass pea, low ODAP lines were procured from ICARDA, and were evaluated under moisture deficit conditions. One white-flowered low ODAP containing line 'RCEGP 17-2' was selected as a spontaneous mutant in grass pea. Besides, three "cleistogamous" lines (RCEA 14-1, RCEA 14-5 and RCEA 14-6) were also developed in pigeon-pea.

Fig. 3.2. An NDT "cleisto" line

Assessment of chickpea genotypes for drought and heat stress tolerance

Two genotypes, namely DBGC 1 and DBGC 4, performed well under limited moisture conditions. For heat stress, DBGC 4, DBGC 3, DBGC 1 and Pusa 3043 appeared to be tolerant to heat stress. Grain yield/plot showed a significant positive association with biological yield/plot, plant height, biological yield/plant, seed yield/plant and ascorbic acid, whereas proline content did not show any correlation with any agronomical or other physiological traits in either positive or negative direction.

Creation of seed hubs for increasing indigenous production of pulses in India

Two pulse seed hubs, one at ICAR RCER, Patna and the other at Krishi Vigyan Kendra, Buxar, were established. The quantity of seeds produced in various pulses is mentioned in the Table 3.1.

Table 3.1. Quality seeds produced under Pulse Seed Hub during 2016-17

Centre	Crop	Variety	Area	Quantity quintal
Patna	Lentil	HUL 57	10.0 ha	80
		KLS 218	1.0 ha	12
	Field pea	HUDP 15	1.5 acre	09
Darbhanga	Lentil	HUL 57	1.0 ha	3.4
Ranchi	Chickpea	Pusa 547	1.0 ha	10
	Field pea	Swarna Mukti	1.0 acre	01
	Lentil	HUL 57	1.0 acre	01

Integrated Farming System Research

Two IFS models were developed for small and marginal farmers of Bihar (Fig. 3.3). The 1-acre model comprises of integration of crops (3500 m2) + Goat (20+1 nos.) + Poultry (200 birds/cycle of 35-40 days) and mushroom for the irrigated midland situation. With an initial investment cost of Rs.1,02,220/-, this model fetches a net annual return of Rs. 89,413 with B:C ratio of 1.7 and income sustainability index of 77.2.

- The 2-acre model integrates crops (6500 m^2) + livestock (2 cows + 2 calves) + fish/duck (1000 m^2) for lowland situation. With an initial investment of Rs.2,05,500/-, this model fetches a net annual return of Rs. 1,42,244 with B:C ratio of 1.8 and an income sustainability index of 79.8.
- In a 2-acre IFS model, recycling of various farm wastes within the system added 56.5 kg N, 39.6 kg P and 42.7 kg K to the soil valued Rs. 4,826/year. In one acre model, 44.0 kg N, 29.5 kg P and 31.2 kg K were added to the soil valued Rs. 3,175/year.
- Total carbon sequestration (2011-17) under Crop + Goat + poultry and crop + livestock + dairy IFS model was 1.04 Mg C/1 acre and 5.6Mg C/ 2 acre, respectively.

Fig. 3.3. IFS Model

- Detailed energy budgeting of different IFS components under both the models were also carried out. The energy output: input ratio varied from 2.54 in 2 acres to 3.18 in 1 acre model.
- The developed IFS models were validated in different farmers' fields of Nalanda, Vaishali, Darbhanga, Buxar, Gaya, Betiah, Patna, Bhagalpur districts, and were found promising. After its validation, the technology was pushed over to State Agriculture Department for its dissemination on a large scale.

Department of Agril., Govt. of Bihar has selected a total 1068 farmer (two farmers from each block) from 534 blocks for its adoption and also provided a subsidy of Rs. 10,000/farmer to integrate any of enterprise with their crop.

Management of high-intensity rain events in crops in the flood-prone region of middle IGP for *Kharif* crops and low temperature in Boro rice in Eastern IGP (NICRA)

In *Boro* rice, cold injury (Fig. 3.4) to rice seedlings in a nursery is the major problem. Out of sixteen genotypes evaluated for cold tolerance, TP30752 (IRTON 103) was observed to be highly cold-tolerant at seedling stage. Among cultivated boro rice varieties IR64, Naveen, Rajendra Bhagawati and IET4094 exhibit a moderate level of cold tolerance at the seedling stage.

- Polythene covering of nursery beds in night times during December and January months has increased the soil temperature by 2-3^{0}C as compared to normal conditions and increased the germination and early vigour of seedlings and reduced the seedling mortality.
- Rice genotypes Arize 6444 Gold (7.62 t/ha), CRL 193 (7.45 t/ha), Arize 6129 (6.95 t/ha), RCPR 31 (6.91 t/ha) and Sahbhagi dhan (6.78 t/ha) have been found promising.

Fig. 3.4. Cold injury in boro rice seedlings

Characterization of wheat genotypes for terminal heat stress tolerance

- Delayed sowing of wheat due to late harvesting of long duration rice varieties sown in Eastern Indo-Gangetic Plains (EIGP), results in yield loss associated with high temperatures

- The average temperature during the anthesis stage of late (LS) and very late sowing (VLS) conditions were 2.7°C and 5.2°C higher than that of the timely sowing (TS) condition, which caused an average yield reduction of 18% under LS and 34% under VLS conditions as compared to the TS condition.
- Occurrence of heat stress under late sown during anthesis accelerated pollen mortality due to deprived starch synthesis and mobilisation, affecting the final grain yield.
- Wheat genotypes showed heat tolerance by maintaining pollen viability thus grain yield through enhanced redox homeostasis in developing anthers and flag leaves.
- Promising genotypes for late sown heat stress *viz*., NW1014, Halna, WH730 and GW273 were identified.

Impact of elevated CO_2 and temperature on the performance of rice and wheat genotypes

Wheat and rice were grown with two levels of carbon dioxide, *i.e.* ambient (400 ppm) and elevated (500 ± 20 ppm) and two levels of temperature, *i.e.* ambient, and ambient >2 ^{0}C inside the open-top chambers (Fig. 3.5). The study revealed that elevated CO_2 improved wheat photosynthetic rate, membrane stability index (MSI), leaf area (LA), plant height and grain yield (26.9%) as compared to ambient, while the activity of antioxidant enzymes (catalase and peroxidase) were decreased.

Fig. 3.5. Open-top chambers

However, the elevation of temperature by 2°C decreased the photosynthetic rate, LA, and grain yield (11.7%), but CAT and POX activity were increased compared to ambient condition. Rice genotypes performed better under elevated CO_2, such as growth and in yield attributing traits, depending on the genotypes. However, the beneficial direct impact of elevated CO_2 on crop yield can be counteracted by elevated temperatures. Rice genotype IR83376-B-B-24-2 was highly responsive, while IR64 showed moderate response toward elevated CO_2.

Physiological traits like relative water content (RWC %), membrane stability index (MSI %), chlorophyll content, the photosynthetic rate was improved under elevated CO_2. However, responses of these traits were negative with elevated temperature. SOD and CAT activity was decreased with elevated CO_2 while it increased under elevated temperature. No significant difference in TBARS content was observed under the combined elevation of both CO_2 and temperature as compared to ambient conditions. The results indicated that elevated CO_2 had positive effects, whereas elevated temperature had negative effects and with a simultaneous elevation of CO_2 and temperature, elevated CO_2 nullified the negative effects of elevated temperature on photosynthetic characteristics and yield components.

Conservation Agriculture in rice-fallows

In Bihar, *Utera* cropping (broadcasting seeds in standing rice 10–12 days before crop harvest) of winter pulses (lathyrus and lentil) resulted in significantly higher system productivity and profitability than mustard, linseed and chickpea in the transplanted rice-fallow system. Seeding of winter pulses under ZT with mulch (rice straw @ 5.0 t/ha) proved to be more productive and profitable than ZT without mulch. Lentil varieties Arun, Vaibhav, IPL 01 and Pusa Massor 5; and Linseed varieties RLC 143 and Uma were found promising for rice-fallows under zero-till conditions (Fig. 3.6).

Fig. 3.6. Conservation Agriculture in rice-fallows

- Although the productivity of direct-seeded rice (DSR) was less than the puddle transplanted rice (PTR), the yield of succeeding winter crops was significantly higher in DSR than in the PTR.
- In Jharkhand (Ranchi) and Chhattisgarh (Jashpur), rice varieties Naveen and Lalat were promising, though the productivity at Jashpur was low. Rice-mustard-cowpea, rice-bottle gourd, and rice-linseed systems with rice residue mulch on soil surface were more productive and profitable.
- Long-term (2009-10 to 2017-18) effects of CA practices in rice-based cropping systems have been evaluated under CSISA platform research. From 2010 till 2015, rice grain yields in S3 (ZT DSR-ZT wheat-ZT greengram) and S4 (ZT DSR-

ZT mustard-ZT maize) were higher or on a par with S1 (Puddled transplant rice-conventional till wheat) and S2 (Puddled transplant rice-ZT wheat-ZT greengram). However, from 2016 onwards, the rice yields were reduced in full CA systems. The effect was more pronounced in S4 than the S3 due to a severe rice mealybug outbreak.

- Rice mealybug could become a potential threat to rice under CA system in the future. Therefore, appropriate strategies for its management including control of grassy weeds in crops and field bunds, crop residue management and crop rotation need to be developed to succeed rice-based conservation agriculture systems. After 6-7 years of continuous Zero-tillage, deep tillage is necessary to sustain the productivity of the rice-wheat cropping system
- The present experiment also established that CA practice enhanced carbon stock up to 0-30 cm depth of soil. The S3 scenario proved to be highly efficient in enhancing carbon sequestration and labile carbon in the system. Macro and waterstable aggregates and infiltration rate increased to a large extent in full CA. Improvement in soil physical condition did not effectively translate into rice or wheat yields, but the system productivity increased largely.

Integrated weed management in Direct-seeded rice

- The advanced rice breeding line 'IR 84899B183CRA19-1' and the released variety 'CR Dhan 40' had the superior weed-suppressing ability, while 'IR 83387BB27-4' had higher weed tolerant ability.
- Pre-emergence application of pendimethalin 1.0 kg/ha *fb* post-emergence application of bispyribac-sodium 30 g/ha and hand-weeding at 45 DAS significantly reduced the weed infestation and resulted in higher yield and profits in dry direct-seeded rainfed upland rice.
- The study also indicates that plant height and leaf area index is the major weed competitive traits that can be explored for direct-seeded rice.

Integrated nutrient management in DSR

- The highest grain yield (4.79 t/ha) of direct-seeded upland rice was recorded with 30 kg seed rate/ha along with application of full dose of P and K and $ZnSO_4$ as basal, 1/3 N at first shower/ enough moisture availability preferably after first weeding, 1/3 N at maximum tillering and 1/3 N at PI.
- Maximum grain yield (4.04 t/ha) of rainfed transplanted rice was recorded with application of 20 kg K_2O/ha (as basal) + one foliar spray with KNO_3 (@1.0% solution) at PI stage (Fig. 3.7).

Fig. 3.7. Integrated nutrient management in DSR

- Seed treatment with selective *Trichoderma* strains S2 (*Trichoderma harzianum*) increased the grain yield of 'Sahbhagi Dhan' (2.94 t/ha) as compared to farmers practice (2.36 t/ha) by improving root and shoot length of rice seedlings.

Management of flood-prone rice

- Under submergence-prone ecology, application of 20kg K_2O/ha as basal + 20 kg at PI as top dressing or 40kg K_2O/ha as basal application + 1% KNO_3 at PI (foliar spray) was found better with grain yield of 4.35-4.46 t/ha (Fig. 3.8).

Fig. 3.8. Management of flood-prone rice

- Rice varieties with *Sub1* gene had better submergence tolerance than the susceptible check variety Swarna; with Samba Mahsuri-Sub1exhibiting the highest plant survival (96%) under 16 days submergence.
- Under submergence-prone ecology, an additional dose of 10 kg/ha each of nitrogen and potassium applied at 5 days after de-submergence enhance the plant survival and grain yield of rice variety 'Swarna sub-1'.

Diversification of rice-wheat system with millets

- Pearl millet (Proagro-9001 and 9450) with 85-90 days maturity duration and productivity of 4.5-4.8 t/ha could be grown under rainfed upland conditions of Bihar.

- Barnyard millet (1.92 t/ha), proso millet (1.14 t/ha), little millet (1.17 t/ha) and foxtail millet (0.98 t/ha) could also be included successfully in cropping system during spring-summer season.
- Rice-wheat system may be diversified with soybean, dual purpose maize as green cob and fodder and millets like sorghum, and pearl millet during rainy season and maize, pigeonpea and mustard during winter season (Fig. 3.9)
- Maize (cob)-pigeonpea (ZT) was the most remunerative system (Net returns Rs. 3,19,215/ha) fb Sorghum (F)-Mustard (ZT)-Urd (ZT) (NR Rs. 2,26,119/ha).

Fig 3.9. Diversification of rice-wheat system

Transplanting of winter maize

Due to the late harvesting of rice sowing of winter maize gets delayed, resulting in severe yield loss. Transplanting of maize crop shortened its life cycle by 18-22 days which provides an opportunity to go for a third crop in a sequence like moong/veg. crop/green manure crop etc. Transplanting of 5-6 weeks older maize seedling resulted in better plant stand if transplanted in the last week of December *i.e.* after harvesting of rice (Fig. 3.10). Around 10 kg of seed can be saved by using transplanting of maize crop. For transplanting in an area of one ha 500 m^2 area is required for raising seedlings.

Fig. 3.10. Transplanting of winter maize

The fertilizer scheduling in the transplanted crop was standardized (120: 60:80 kg of N, P and K) in three splits *i.e.* at Knee height stage, pre-tasseling and grain filling stage.Transplanted crop saved about 6-12 cm of irrigation water over traditional maize farming. BBF system of planting was found best and was followed by ridge and furrow system of transplanting.

4. Division of Land and Water Management

Application of micro irrigation in system of rice-wheat intensification

The performance of different irrigation methods on water productivity in the system of rice and wheat intensification (SRI and SWI) was studied. SRI under micro-irrigation system (LEWA and micro-sprinkler) resulted in significantly higher (128 and 123 %) grain yield of rice as compared to farmers' practices of rice transplanting under check basin irrigation (3.80 t/ha). However, the grain yield variation between LEWA and micro-sprinkler irrigation under different establishment methods was insignificant (Fig. 4.1 & 4.2). A combination of SRI and micro-irrigation (LEWA and micro-sprinkler) significantly increased water productivity by 153 and 156 % respectively, compared to check basins under framers' practices of rice establishment (0.34 kg/m^3). There was a mean saving of 27 and 39% water observed in LEWA and micro-sprinkler irrigation, respectively as compared to check basin irrigation (340 mm) in rice crop.

Fig. 4.1. LEWA irrigation in SRI

Fig. 4.2. Layout of the experiment during *Kharif*

In case of wheat, SWI in combination with micro-irrigation system (LEWA and micro-sprinkler) recorded significantly higher (132 and 131%) grain yield (Fig. 4.3) in comparison to farmers' practices of wheat establishment under check basin irrigation (3.10 t/ha). Whereas, a combination of SWI and micro-irrigation (LEWA and micro-sprinkler) significantly increased water productivity by 190 and 233 % respectively in comparison to check basin under framers' practices of wheat establishments (1.07 kg/m^3). There was a mean saving of 23 and 36% water observed in LEWA and micro-

Fig. 4.3. Micro irrigation in wheat

sprinkler irrigation respectively as compared to check basin irrigation (249 mm) in wheat crop. It has been clearly established that SRI and SWI in combination with micro-irrigation played crucial role in enhancing the grain yield and water productivity of rice and wheat.

Optimization of water productivity of aerobic rice-based cropping system

In rice-based cropping system, rice grain equivalent yield (RGEY) and water productivity (WP) of rice-maize-mungbean cropping system were found to behighest, *i.e.* 13.00 t/ha and 1.11 kg/m^3, respectively, while significantly the lowest RGEY was recorded with rice-wheat-mungbean cropping system. The requirement of irrigation water was similar in the case of rice-wheat-mungbean and rice-maize-mungbean cropping systems. The rice-maize-mungbean cropping system recorded 41 and 37 percent higher RGEY over rice-wheat-mungbean and rice-mustard-mungbean cropping systems, respectively. Rice-maize-mungbean (Fig. 4.4) system also recorded the highest water productivity, which was 46.1 percent higher than rice-wheat system.

Fig. 4.4. Rice-maize-mungbean cropping system

Improved cultural practices and scaling up of rice intensification in Bihar

Improved cultural techniques in the form of irrigation have been attempted. Irrigation given either through micro-irrigation or through surface irrigation (maintaining saturation throughout), has saved water by 38 and 28% respectively over 1" standing water. Weed management through cono weeder twice at 15 and 30 DAT has been found most effective and economical in SRI method of rice establishment (Fig. 4.5).

Fig. 4.5. Weed management through cono weeder

Rice-fallow management

Direct seeded rice variety *Lalat* yielded 2.0 to 2.5 t/ha during rainy season. Soil moisture (%) variation (depth: 0-60 cm) at fortnightly interval during *rabi* crop in village Kuchhu and Ormanjhi was recorded to know the residual moisture content. During winter season, the highest water use efficiency of linseed and mustard were recorded as 3.67 and 5.01 kg/ha/mm with two and three irrigations respectively. Linseed was found promising oil seed crop in comparison to mustard as it matures 2 weeks earlier than mustard under rice fallow system.

Solar power utilization in agriculture

Developed a solar photovoltaic groundwater pumping and irrigation model coupled with pressured irrigation option for Eastern Region (Fig. 4.6). This model comprised of pumping unit, water storage tank and delivery unit. Groundwater volume ranged from 104 -120 m^3 per day can be abstracted in the months of Dec to Jan; and 140 - 160 m^3 per day in remaining months on a bright day. System can irrigate 0.25-0.30 ha of cropped area per day by surface method.

Fig. 4.6. Solar photovoltaic groundwater pumping system model for small farms

System offers pressure head of 1.2 - 1.6 kg/cm^2 for 3-4 hrs on a bright day to facilitate pressured irrigation. The water storage tank is used for fish and duck farming.

Dissolved oxygen concentration is one of the critical parameter in a fish pond. A sprinkler type solar aerator was developed with 0.9 kWp solar array and 0.75kW induction motor pump and installed in a fishpond of dimension 30 m x 40 m with 1.5 m standing water depth (Fig. 4.7). For 6 to 7 hrs day time operation increased dissolved oxygen concentration by 23-28% over control value of 4.0 - 4.4 ppm sub-layers of water column. Moreover, due water circulation in aerating pond, water temperature decreased compared to non-aerated condition, seen as favorable condition during summer seasons. The fish growth was high, as fish weight increased by 150-175 g compared to control value of 100 -125g over a month period.

Fig. 4.7. A sprinkler type solar aerator for fish pond

Developed a solar watering system for animal shed with water source from a nearby pond. This supplies pressured water at 1.0-1.5 kg/cm^2 which facilitates good washing for both animal and shed (Fig. 4.8).

Fig. 4.8. Solar watering system for animal sheds

Developed a solar humidifier for animal shed to protect animals from high thermal heat index with working pressure of 9.5-6.0 kg/cm^2, as thermal environment is a major factor that negatively affects the milk production, hormone management and fertility of dairy cattle in a significant way. Its refinement is underway.

Consortia Research Platform on farm mechanization and precision farming at ICAR RCER, Patna

A Farm Machinery Resource Centre was established at ICAR RCER Patna which was inaugurated and dedicated to the farmers by Hon'ble Union Agriculture and Farmers Welfare Minister, Shri Radha Mohan Singh on 28.06.2016 at ICAR RCER, Patna (Fig. 4.9). In addition, a custom hiring centre for farm machinery and implements was set-up at KVK Buxar. A total of 87 farmers were trained under this project.

Fig. 4.9. Inauguration of farm machinery resource centre

Design and ergonomic evaluation of gender-neutral marker and weeder for SRI

Field testing of conoweeder in sandy loam soil with submerged water has been conducted at Sikorna village, Katihar District, Bihar during boro rice season, 2016 was done (Fig. 4.10). The result showed that the field capacity and weeding efficiency were found to be 0.0147 ha/h and 79%, respectively. Comparative analysis between two manual operated weeders *i.e.* star and SWI weeder was done in System of Wheat Intensification (SWI). The result indicated that working efficiency increased by 28% using the star weeder.

Fig. 4.10. SRI weeder in farmers' field

Off-season vegetable production in low-cost greenhouse

An even span greenhouse with floor area of 20 m^2 (5 × 4 m) was designed and established at ICAR RCER, Patna for production of off-season vegetables.

Tomato *var.* Swarna Anmol (Fig. 4.11) was grown in green house and open conditions. The result indicated an increase of 39% tomato production in greenhouse as compared to open field

Fig. 4.11. Tomato *var.* Swarna Anmol

conditions. The higher yield was achieved in greenhouse 39 t/ha as compared to open field condition 28 t/ha.

Brinjal: Higher yield was achieved in greenhouse (21 t/ha) than open condition (16 t/ha). In greenhouse, brinjal can be raised 10-15 days earlier as compared to open conditions.

Capsicum: The result indicated that the yield was 25.66 % times more as compared to open field conditions. Higher yield was achieved in greenhouse (0.18 t/ha) than open condition (0.14 t/ha) (Fig. 4.12).

Fig. 4.12. Capsicum in greenhouse

Performance evaluation of hand-held crop cutter used in rice and wheat harvesting

The results showed that the field capacity (Paddy cutter: 0.041 ha/hr and manual operation: 0.01 ha/hr) of crop cutter was 2.44 times higher than the manual operation for rice. The labour requirement was 32 and 149 man-hr/ha for crop cutter and manual operation, respectively for rice. The cost of operation/ha was estimated Rs. 2,464/- for crop cutter and Rs.5,597/- for manual, respectively for rice.

Field capacity (Paddy cutter: 0.029 ha/hr and manual operation: 0.013 ha/hr) of crop cutter was observed 2.23 times greater than manual harvesting in wheat. Labour requirement was observed 23 and 116 man-hr/ha for crop cutter and manual operation, respectively for wheat. The cost of operation/ha was calculated to be Rs.2,340/ in case of crop cutter and Rs. 3,750/- for manual operation for wheat.

Comparative performance of different weeding tools in winter maize

It was found that *khurpi* was recorded the highest weed control efficiency (93%) followed by grubber (83%), spade (76%) and single wheel hoe (72%). The highest human energy was also attained in case of *khurpi* (568 MJ/ha) followed by spade (327 MJ/ha), grubber (213 MJ/ha) and single wheel hoe (167 MJ/ha). The highest embodied energy was noticed in single wheel hoe (93 MJ) followed by spade (45 MJ), grubber (20 MJ) and *khurpi* (11 MJ). The field capacity of single wheel hoe was

observed maximum (0.008 ha/hr) where as spade was minimum (0.0002 ha/hr). Hence, the wheel hoe was found to be the most efficient and cost-effective weeding tool in winter maize (*Zea mays* L.) (Table 4.1).

Table 4.1 Comparative performance of different weeders in maize

Particulars	Single wheel hoe	Double wheel hoe	Prototype weeder	Power weeder
Field capacity (ha/h)	0.0057	0.0089	0.012	0.048
Plant damage (%)	3.61	1.94	3.21	5.84
Avg. working speed (kmph)	0.36±0.05	0.69±0.06	0.52±0.06	1.5±0.3
Avg. depth of weeding(mm)	24±4	24±2	24±4	35±5
Weeding efficiency	75	82	85	86

Refinement of LEWA for its better performance

In order to cater the need of small and marginal farmers, modified LEWA irrigation system was developed with its novel design. Modified LEWA device has higher structural strength. All the components are made of poly propylene except the two washers which are made of Teflon. Leakage from the device was successfully reduced (almost nil) within the operating pressure of 0.4 to 0.8 kg/cm^2. It has higher uniformity coefficient (75%) than previous LEWA (65%) and the device do not come out from riser (at higher maximum designed pressure of 0.8 kg/cm^2) due to its design of thread and coupling system. After a satisfactory lab testing of modified LEWA irrigation system based on above mentioned parameters, it was successfully demonstrated in vegetable crops of tribal dominant Karar village in 0.25 acre (Fig. 4.13).

Fig. 4.13. Demonstration of modified LEWA in vegetable crops at farmers' field

Evaluation of different weeding technologies for rice (Direct Seeded) -maize cropping system

A manual weeder was designed and developed. Prototype of the manual weeder is shown in Fig. 4.14. Field capacity of the prototype weeder was computed as 0.012 ha/hr. Average depth of weeding and weeding efficiency of the manual weeder were computed 24mm and 85%, respectively.

Fig. 4.14. Prototype of the manual weeder

Evaluation of irrigation system and improvement strategies for higher water productivity in Sone canal command

A pond of size 25x20x2 m was designed and excavated in Bharatpur sub-distributary of Sone canal command. In addition, two ponds were also excavated on participatory mode of size 60 x 20 x 2.5 m. Pond water was used for fish production Jasar (*Pangasus spp*) variety of fish, recorded a yield of 4.6 t/ha in 115 days. Installation of 2 hp solar water pump and 3 hp electrical submersible pump was done. It has been evaluated that solar water pump reduces cost of paddy nursery raising (Rs 1,310 per ha) by 3.7 and 1.3 times than that of diesel and electric pumps, respectively. For tube well irrigation the farmers were advised to use layflate tube/flexible plastic pipe in place of earthen channel which increased conveyance efficiency up to 95 %.

Evaluation of developed decision tools in participatory model

Since canal water is available at much cheaper rates, water users don't prefer ground water utilization unless they feel that their production will reduce drastically in the absence of water. Interactions with farmers indicated that there is good scope of ground water development and utilization in Bihar because here all blocks are under safe zone. Analysis based on data fed in Decision Support Tool (DST) clearly shows that yield of crops like rice and wheat may improve substantially provided timeliness is maintained and conjunctive use practice is widely adopted by farmers as and when required (Fig. 4.15).

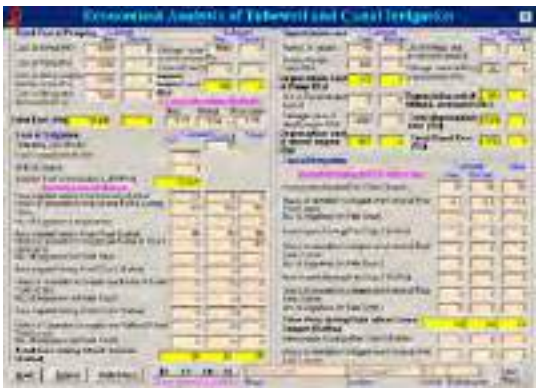


Fig. 4.15. Developed DST

Crop diversification with faba bean to improve land and water productivity

Under crop diversification with faba bean, irrigated rice yield ranged from 6.67 to 6.72t/ha. During rabi season faba bean yield recorded 4.19 and 2.14 t/ha under irrigated and rainfed condition, respectively. Faba bean yield under faba bean + lentil intercropping system was 2.12 and 1.37 t/ha under irrigated and rainfed condition. Faba bean performance under faba bean + maize intercropping system was 1.39 and 0.94 t/ha under irrigated and rainfed condition respectively. Faba bean performance under faba bean + potato intercropping system was 1.82 and 1.37 t/ha under irrigated and rainfed conditions respectively. Maize green cob yield was recorded

64.5 and 31.8t/ha under irrigated and rainfed condition respectively. Potato yield was recorded 21.4 and 11.9t/ha under irrigated and rainfed conditions respectively. Lentil yield was recorded 0.95 and 0.45t/ha under irrigated and rainfed conditions respectively. During summer ladies' finger and cowpea green pod yield recorded 8.15t and 7.93 t/ha. Similarly, green gram seed yield was 1.78 to 1.8.4 t/ha (Fig. 4.16).

Fig. 4.16. Faba bean seed production

Effect of sowing time on wheat performance

Three wheat genotypes (HD 2967, HD 2933 and HD 2824) were tested under five different dates of planting (starting from 1st November to 30th December with a fortnight interval). HD 2967 proved grain yield of wheat superior to other tested cultivars (*i.e.* HD 2933, HD 2824) (Fig. 4.17). Maximum and minimum (*i.e.* 4.67 and 3.18 t/ha) was produced by HD 2967 and HD 2733 when it was sown on 1st November and 30th December, respectively. Maximum (2.29 kg/m^3) and minimum (1.61 kg/m^3) water productivity was recorded with November 01 and December 30 planting and the highest water productivity (1.99 kg/m^3) was obtained in case of HD 2967.

Fig. 4.17. Effect of sowing time on wheat performance

Faba bean varietal technology

"Swarna Gaurav" (IC No. 0595986) variety was developed by ICAR Research complex for Eastern Region Patna and has been recommended by Bihar State Varietal Release Committee (SVRC) for cultivation in the Bihar state. This variety attains height of 77- 105 cm and plant type is bushy. The seed yield potential of this variety is 5.0 to 5.5 t/ ha. The sweetness of the mature seeds is 10.34 TSS.

Fig. 4.18. Faba Bean Swarna Gaurav

The developed variety is also rich in minerals like iron, manganese and zinc. “Swarna Suraksha” was also developed by ICAR Research complex for Eastern Region Patna and Bihar State Varietal Release Committee (SVRC) recommended for its cultivation under rainfed as well as irrigated ecology. This variety attains height of 70- 90 cm, plant type is bushy. It is a medium duration cultivar which matures in 110-115 days. The seed yield potential of this variety is 3.0 and 4.3 t/ ha under rainfed and irrigated conditions respectively (Fig. 4.18).

Evaluation and optimization of Integrated Farming System

Evaluation and optimization of developed IFS at farmer’s field Anantpur village, Nalanda was done. From the analysis of the data collected on IFS, it was recommended that area should be less in cereal crop whereas mushroom spawn production, horti-culture crop and the area of fish production should be increased and IFS components such as goatry, vermicompost, duckery may be included for getting more profit.

5. Division of Livestock and Fisheries Management

Appraisal and inventorization of natural resources

Characterization of lesser-known breeds of farm animals in Eastern India

Under this theme, characteristics and production performances of indigenous populations reared in the Eastern Region were studied. The populations included Bachaur (Fig. 5.1), Purnea (Fig. 5.2) and Gangatiri (Fig. 5.3) cattle and Diara buffaloes. Apart from their performances, the socio-economic conditions of farmers rearing these indigenous populations and the role of these populations in influencing the socio-economic status were also studied.

Fig. 5.1. (a) Bachaur bull (b) Bachaur cow (c) Bachaur bullock

Fig. 5.2. (a) Purnea bull (b) Purnea cow (c) Purnea calf

Fig. 5.3. (a) Gangatiri bull (b) Gangatiri cow (c) Gangatiri calf

Among the draught breeds of India, it was found that the Bachaur cows were reasonably good milkers with an average lactation yield of 752.10±5.82 kg and peak yield of 4.70±0.07 kg per day. The breed is reported to be regular in reproduction cycle with the age at first calving and calving interval of 31.55±0.35 months and 14.44±0.22 months, respectively in its breeding tract.

Study on Purnea cattle revealed that selected animals were found to yield 5 to 6 litre of milk per day. It was also found that these cattle were offered only dry fodder, apart from little green grasses based on availability. The lactation yield and lactation length of these cattle were found to be 658.77±5.87 kg and 183.81±8.77 days, respectively.

The study conducted in the Itarhi block of Buxar district along with Krishi Vigyan Kendra, Buxar revealed that the milk production in Gangatiri cattle ranged from 2 to 6 litres in farmers' management. The age at first mating in the bulls was found to be 3 to 3½ years whereas the age at first calving in Gangatiri cows was reported to be 3½ to 4 years.

Diara buffaloes (Fig. 5.4) were found to be medium-sized animals with prominent forehead and loosely curved horns. They are smaller than the heavy-sized breeds like Murrah, Jaffarabadi and Nili-Ravi. The height, length and girth of female Diara buffaloes were 94.96±0.58 cm, 92.96±0.49 cm and 115.93±0.81 cm up to 1 year of age and 133.60±0.69 cm, 138.36±0.74 cm and 200.79±0.95 cm above 7 years of age, respectively. Estimated adult body weights of Diara buffaloes pooled over ages were found to be 494.99±27.15 kg in males and 483.21±3.58 kg in females.

Fig. 5.4. (a) Diara bull (b) Diara female (c) Diara calf

Improvement of livestock production

Management of Sahiwal breed

Sahiwal breed of cattle was introduced in the institute farm to study the production potential and heat tolerance ability of Sahiwal in the Eastern Indo-Gangetic Plains (Fig. 5.5). The daily milk yield of Sahiwal cattle was recorded at 9.3 kg. Average daily body weight gain of male calves' upto 4 months of age was recorded at 227 g/day

Fig. 5.5. Sahiwal breed Management

as compared to body weight gain of 203 g/day in case of HF x Indigenous crossbred calves.

Buffalo improvement

In order to improve the productivity of buffaloes, the institute is maintaining a herd of Murrah buffaloes with adult an herd strength of 20 animals. The objective of the project is to assist in selection of elite Murrah bulls for improving milk productivity. Subsequently, Network Project on Buffalo Improvement was initiated in ICAR Research Complex for Eastern Region, Patna with the funding from network main centre, ICAR-Central Institute for Research on Buffaloes, Hisar. The total herd strength of Murrah buffaloes during 2016-17 was 72 which include 37 adults, 15 heifers and 20 calves. The average lactation yield, lactation length, service period and inter-calving period of the herd during the year 2016-17 were found to be 1645.53 ± 5.24 kg, 312.76 ± 4.17 days, 168.35 ± 7.17 days and 412.16 ± 3.07 days, respectively. Over the years there was marginal improvement in the performance of the buffalo stock. Just to have a comparison, during 2019, there were 93 buffaloes were maintained (in 2014-15

Fig. 5.6. Network Project on Buffalo Improvement

there were 37 nos only) in the institute farm out of which 53 are breedable stocks. The total lactation milk yield, standard lactation milk yield, the average peak yield, lactation length, and service period of Murrah buffalo observed during 2019 were 2450.12±126.21 kg, 2015.18±110.12 kg 12.88±0.50 kg and 341.25±20.25 days and 130.56±10.01 days respectively.

Management of heat stress in buffalo

The ambient temperature and Thermo humidity index (THI) prevailing during the experimental period is given in Table 5.1.

Table 5.1 Ambient temperature and Thermo Humidity Index (THI)

Season	Maximum Temp.	Minimum Temp.	THI
Spring	30.37±2.36	23.65±3.46	68.56±6.94
Summer	39.17±2.38	28.82±1.32	84.74±7.32
Winter	22.81±1.42	10.24±1.57	53.86±4.38

THI was found to be highest in summer and lowest in winter. The Livestock Weather Safety Index (LCI 1970) is commonly used as a benchmark to assign heat stress levels to normal, alert, danger and emergency categories. In this index, THI≤74 is classified as normal, 75-78 as alert and 79-83 as danger and THI ≥84 as emergency. Therefore, based on this index buffaloes reared in summer falls under emergency category indicating a stressful condition of the animal.

Effect heat stress on rectal temperature, respiration rate and pulse rate

Rectal temperature, respiration rate and pulse rate measured during experimental period are presented in Table 5.2.

Table 5.2 Effect of season various physiological parameters

Season	Rectal Temperature		Respiration rate	Pulse Rate
	Morning	Evening		
Spring	99.83±0.07	100.15±0.17	13.25±0.46^{b}	63.79±1.03^{b}
Summer	101.1±0.03	101.18±0.02	18.97±0.59^{c}	69.98±0.81^{c}
Winter	99.13±0.04	99.37±0.08	10.91±0.50^{a}	58.52±2.21^{a}

This study reveals that seasons are having a significant effect ($p<0.5$) on respiration and pulse rate. Bothe are having highest in summer and lowest in winter indicating stress in summer. However, we didn't find any significant effect of season on the rectal temperature in the studied population.

Similarly, blood profile and hormone level (Cortisol, T3 and T4) (Table 5.3) were also measured in different seasons to study the effect of heat stress in Murrah buf-

falo. Heat stress activates the hypothalamo-pituitary-adrenal cortical axis (HPA) and sympatho—adrenal medullary axis. This leads to an increase in plasma concentration of cortisol and decrease concentrations of triiodothyronine (T3) and thyroxine (T4) in plasma and milk of heat-stressed animals. Hence, Cortisol, T3 and T4 level were measured.

Table 5.3 Hormonal profile of Murrah buffalo

Parameter (ng/ml)	Summer	Pre-winter	Winter
Cortisol	5.34±0.7	4.43±1.7	4.03±1.8
T3 (ng/ml)	1.92±0.20	2.15±0.6	2.72±0.8
T4 (ng/ml)	32.25±1.1	32.86±1.1	35.39±1.1

Effect of roughage to concentrate ratio

To study the effect of roughage: concentrate ratio in buffalo calves, 12 calves (197-331 kg body weight, 6-8 months age) were selected and divided into 3 groups in RBD. Group 1 was fed wheat straw and concentrate at the ratio of 1:3 on DM basis while group 2 and 3 were fed at the ratio of 1:1 and 3:1, respectively, during 3 months in summer. The calves in group 2 attained higher body weight growth (556 g/d) than group 1 (527 g/d) and group 3 (472 g/d). The digestibility of DM and OM was also found higher in group 2 followed by group 1 and 3.

Effect of sodium bicarbonate supplementation in summer on milk yield in buffalo

Sodium bicarbonate feeding is beneficial in lactating buffalo due to its buffering capacity in the rumen as it maintains a normal rumen environment by lowering the incidence of acidosis effectively, which is commonly occurring during hot weather. For the study, 8 lactating buffalo (454.6 ± 28.3 kg b. wt, 3-4 months lactation length, 2-3 parity) were selected and divided into two groups. Group 1 was fed standard a diet (wheat straw, concentrate and Sorghum fodder) and buffaloes in group 2 were fed standard diet with supplementation of sodium bicarbonate @ 30g/d dividing into equal doses in the morning and afternoon. The trial was conducted during summer (mean temperature 42.3˚C and RH 56.8%). The milk yield of buffaloes in Group 2, yielded higher milk (6.85 ± 1.4 kg *vs* 7.33 ± 1.1 kg) over control. The fat percentage also found slightly higher in sodium bicarbonate supplemented buffalo milk (6.2± 0.03 kg *vs* 6.28 ± 0.2 kg).

Effect of mustard oil supplementation in summer on milk yield in buffalo

Eight lactating buffalo (462.7± 36.8 kg body weight, 3-4 months lactation length, 2-3 parity) were selected and divided into two groups. Group 1 was fed standard diet

whereas Group 2 were fed standard diet with supplementation of Mustard oil@ 150 ml/d. This study revealed that mustard oil supplementation (150 ml/d) has significant effect (P≤0.05) on milk yield in summer. Treatment group has higher milk yield (6.16 ± 2.87 kg/d) than the control group (5.12 ± 1.87 kg/d)

Goat improvement

Exploring growth hormone and prolificacy gene for improvement of growth performance traits in Black Bengal Goat

Two fragments 245 and 472 bp fragment of growth hormone gene was amplified and allelic variants were identified. The least squire analysis revealed that 245 bp genotypes had significant effect (P≤0.05) on birth weight whereas 472 bp fragment's genotypes had significant effect (P≤0.05) on body weight. Animals having AC genotype had 47% more birth weight than the animal having CC genotype. Similarly, animals having AC genotype had 65% more body weight than the animal having CC genotype at both 6 months and 9 months of age. The BMPR1B locus in Black Bengal Goats revealed two genotypes- GG and GA and consequently two allelic variants A (wild) and G (mutant). Animal having homozygous mutant genotype (Fec B) *i.e.* GG gives 2.1 kids per kidding whereas carrier animal *i.e.* heterozygous animal (GA) gives 1.6 kids. Twinning % in homozygous mutant (67.66%) was much higher than the heterozygous carrier (54.755%) animals.

Study on high prolific goat germplasm

Bengal goats are known for their fecundity rate as most of the goats give mostly twins and triplets whereas quadruplets are reported sporadically. Increasing the herd horizontally by increasing the herd size could be one of the ways of improving total biomass productivity of the farm.

In order to collect the baseline information, an initial survey was undertaken to study the production and reproduction performances of Black Bengal goats in Katihar and Purnea districts of Bihar. The result showed that the body weights of Black Bengal goats at the age of 3, 6, 9 and 12 months ranged from 3.2 to 4.1 kg, 5.3 to 6.26 kg, 9.85 to 10.2 kg and 12.9 to 13.5 kg, respectively. With respect to reproduction traits, the age at 1st kidding, and kidding interval varied from 395 to 440 days and 200 to 290 days respectively. Total distribution of types of birth of high prolific Bengal type goats were 75% singlet and 25% twins in primiparous goats, and 5% twins, 45% triplets, 40% quadruplets and 10% quintuplets in multiparous Black Bengal goats (Fig. 5.7). It was

Fig. 5.7. Quintuplets in institute goat farm

found that there was no selection practiced towards any special traits in male and female Black Bengal goats in the surveyed villages. Women members of farmers' family played a proactive role (90%) in the rearing of goats whereas involvement of male members of the family was just 10%.

Multiplication and production profiling of improved pig farming system

A piggery unit was established at Research Centre, Ranchi comprising 25 numbers of pigs of T & D breed (Fig. 5.8). The average birth weights of male and female were found to be 1.10 ± 0.08 and 1.07 ± 0.03 kg, respectively. During the study, it was found that sex did not influence the birth weight significantly. T&D breeds had significantly ($P<0.05$) heavier birth weights than Desi pigs (0.64 ± 0.04). Average daily gains of male & female pig were found to be 0.65 ± 0.06 and 0.58 ± 0.05 kg, respectively up to 4 months of age.

Fig. 5.8 T & D breed of pigs at Research Centre, Ranchi

Fig. 5.9. Experimental pig

An experiment was conducted to test the efficacy of replacement of maize feed with boiled sweet potato for Tamworth x Deshi crossbred pig (Fig. 5.9) for 75 days. Sweet potato *(Ipomoea batatas)* grown in institute farm recorded an average yield of 41.6 t/ha and used for the experiment. Chemical analysis indicated that raw sweet potato contains about 66% moisture, 1.13% protein, 0.97%fat, 4.2% fibre, 6.1% sugar and 0.45% ash. Crossbred (T & D) pigs were under feeding regime with dried sweet potato with replacement of maize in concentrate feed. Four treatments each comprising of six pigs of 80 days age with an average body weight of 28 kg (3 female and 3 male) were selected and experiment was conducted on the replacement of maize with sundried sweet potato (SSP) at the rate of T1 (0%, Control), T2 (25%), T3 (35%) and T4 (50%), respectively. The feed was offered twice daily at the rate of 2.25 kg/pig/day, on dry matter basis. During 75 days trial, it was observed that maximum weight gain was in T3 followed by T4, T1 and T2. The same trend was followed in average daily gain also. The maximum weight gain with 35% SSP may be due to the maximum availability of digestible carbohydrate in the diet along with protein. It may be inferred that sundried sweet

potato up to 35% may be incorporated in pig feed to achieve maximum weight gain for replacement of maize.

Poultry and duck improvement

Multiplication and production profiling of improved poultry germplasm under backyard farming system

Study was conducted to determine the effect of different climatic parameters on production performance of F1 generation Vanaraja poultry birds under deep litter system of rearing.

Effect of Temperature Humidity Index (THI)

Effect of temperature and humidity on growth and other biological traits on Vanaraja birds was studied. The overall average temperature, relative humidity, Temperature Humidity Index in different months inside the shed ranged from 16.67±0.23 to 33.08±0.28, from 46.60±2.40 to 90.20±1.12 and from 64.84±0.30 to 85.94±0.38, respectively. The live weight of Vanaraja ranged from 2.07±0.051 to 2.79±0.045 kg at the ageof 20 to 52 weeks. Vanaraja birds have good genetic potential to lay a greater number of superior quality eggs in the THI of 81 to 85 (month of April & May). However, the egg production, fertility, hatchability on total fertile egg set were just ranged from 24.71±2.03 to 28.67±1.63, 62.68±4.35 to 68.59±3.06 and 55.20±8.49 to 64.32±3.03 respectively, which was significantly lower at Temperature Humidity Index ranged from 85.53±0.18 to 85.94±0.38 (May to August). However, there was a negligible effect of Temperature Humidity Index (>85) on egg quality. Supplementation of critical inputs like brooding temperature, balanced feeding, vaccination, anti-stress, medication during early stage of brooding and growing period showed <5 % mortality.

Comparative performance of Vanaraja, Gramapriya and Kadaknath

Comparative performance of *Vanaraja, Gramapriya* and *Kadaknath* was evaluated in the institute farm (Fig. 5.10). It was observed lower age of sexual maturity in *Gramapriya* and *Vanaraja* as compared to *Kadaknath*. Age at first laying of

Fig. 5.10. (a)*Vanaraja* ***(b) Gramapriya*** ***(c) Kadaknath***

Vanaraja, Gramapriya and *Kadaknath* was 133, 119 and 140 days respectively. Egg weight of *Vanaraja*, *Gramapriya* and *Kadaknath* varies from 40-58, 39-56 and 35-45 g respectively. The live weight of *Vanaraja, Gramapriya* and *Kadaknath* chicks ranged from 37.25±0.80 -1061.38±64.93, 34.57 - 699.29±25.88 and 32.8±0.83 - 442.2±2.22 g respectively at the age of 0 to 8 weeks. The hatchability percentage in *Vanaraja*, *Gramapriya* and *Kadaknath* on total egg set basis were 85.45, 84.74 and 82% respectively. The mortality percentage upto 28 weeks of age was more in *Gramapriya* (8%) than *Vanaraja* (6%) and *Kadaknath* (1%). The total number of egg and egg weight at respective week of age were higher in improved varieties than local *Kadaknath* birds. The hen day egg production upto 40 weeks of age for *Vanaraja* and *Gramapriya* were 85.45 and 84.74 respectively whereas in *Kadaknath* upto 28 weeks of age it was 35 %. Peak production in *Vanaraja* (53.18%) and *Gramapriya* (86.16%) was at the age of 28-32 and 36 to 40 weeks of age.

The average daily gain upto 8 week of age (g/day) was found to be higher in *Vanaraja* (15.55 g/day) as compare to *Gramapriya* (10 g/day) and *Kadaknath* (6.58 g/day). Egg production upto 55 weeks of age was higher (151.39 egg /bird) in *Gramapriya* followed by *Vanaraja* (103.87 egg /bird) and *Kadaknath* (98.02 egg /bird). The age at first laying & egg weights of *Vanaraja*, *Gramapriya* and *Kadaknath* were 133 days & 41.45±0.99 g, 123 days & 39.57±1.32g and 165 days & 33.57±1.32g, respectively. There was negligible effect of summer temperature and humidity on egg quality trait of *Vanaraja Gramapriya* and *Kadaknath*. Injection of Vitamin A increases the egg production by 2% in *Vanaraja* and *Gramapriya*. Mortality rate in summer reduces to 10 % after Vitamin E supplement.

Around 63,000 (nos.) of germplasm of *Vanaraja, Gramapriya* and *Kadaknath* were distributed to farmers in the form of fertile eggs, chicks and growers to see the performance at farmers' field. There was 80 % hatchability in *Vanaraja* bird under natural method of incubation by local desi bird. The study revealed that the *Vanaraja* poultry birds are preferred by farmer for their improved dual purpose, less mortality, coloured plumage with better growth rate, good eggs production and larger egg size.

Promotion of backyard poultry system through motivation and training cum exposure visits for increasing livelihood of farmers of Bihar. Disseminated advanced poultry (*Vanaraja* & *Gramapriya*) and their rearing technology to the farmers.

Characterization and evaluation of duck germplasm in Eastern Region

To study the different duck rearing practices and characterization of local germplasm, the study was conducted in different states of Eastern Region *viz*. four districts of Odisha (Cuttack, Baleswar, Puri and Maurbhanj); three districts of Bihar (Katihar, Purnea and Araria); six districts of Jharkhand (Palamu, Garhwa, Lohardaga, Latehar, Simdega and Khuti) (Fig. 5.11).




Fig. 5.11. (a) Odisha desi duck germplasm (b) Bihar desi duck germplasm (c) Jharkhand desi duck germplasm (d) WB desi duck germplasm

The study revealed that the ducks were raised under semi-intensive management system and mostly depends on scavenging for their nutritional needs. The ducks are raised both for meat and eggs. About 86-89% of the farmers provide some kind of separate shed for their birds, usually constructed mainly from simple locally available materials in their backyard like bamboo-straw, soil and brick with plastic shed. 11-13% of farmers did not possess any shed and kept the ducks in their house only by tin-shed and soil.

The annual average egg production per duck was very poor (80-90). The flock size is usually small, 7.27±0.49 to 9.51±0.67. In both drake and duck body carriage was slightly upright and Bill shape was horizontal. Indigenous ducks have multi-colored plumage. Varieties of ducks in respect to plumage colour *viz.* white, brown, fawn, white or penciled, white and black/brown mix have been seen. The average adult body weight of Odisha, Bihar, Jharkhand & West Bengal of drake and duck were 1.80±0.02 & 1.40±0.07, 1.06 ±0.084 & 1.71±0.01, 1.41±0.02& 1.37±0.08 and 0.950±0.079 & 1.58±0.02 kg, respectively.

Comparative evaluation of *Khaki Campbell*, *White Pekin* and *Desi duck* germplasm of Odisha, Jharkhand, Bihar, West Bengal were being recorded in Institute duck shed (Table 5.4). Hen day egg production (%) up to 30th week of age recorded was higher

Table 5.4 Comparative performance of desi duck germplasm

Traits	Odisha Desi	Bihar Desi	Jharkhand Desi	W. Bengal Desi
Hatchability %	60	55	60	45
Day old body weight (g)	37±0.37	35.8±0.29	35.9±0.34	35.8±0.28
Average daily gain up to 12 weeks (g/day)	8.49	5.64	5.75	6.08
Mortality % up to 3 months of age	8.5%	5.5 %	5.2%	6.05 %
Age at first lay (days)	165	163	175	165
Body weight at first lay (g)	1140±0.20	1120±0.2	1420±0.2	1390±0.11
Average annual egg production (nos.)	75-80	35-42	45-55	80-95
Egg weight (g)	52.90±2.4	46.60±0.37	46.93±0.32	47.28±0.4

in *Khaki Campbell* (45 %) followed by *Desi Duck* germplasm of Odisha (35%), Jharkhand (28%) and Bihar (27%). Egg weight was higher for *Khaki Campbell*. Hatchability percentage was higher *for Khaki Campbell* (70 %) followed by *White Pekin* (65%), *Odisha Desi* (60 %), *Jharkhand Desi* (60 %) and *Bihar desi* (55%). For the promotion of duck rearing practices, around 6,342 (nos.) germplasm of duck were distributed to farmers in the form of fertile eggs, duckling and growers.

Feed supplement and growth promoter

Effect of phytase supplementation on the performance of croass breed pig and divyan red poultry

To study the phytase supplementation on growth performance and nutrient digestibility of rice polish-based feeding, a feeding experiment for a period of 80 days was conducted on CB (Hampshire x Ghunghroo) male finisher pigs (16; 40.63±1.30kg BW) having 50% exotic inheritance at NRC on Pig, Rani, Guwahati. The study revealed that the levels of inclusion of rice polish with different doses of phytase enzyme supplementation did not exhibit any significant effects on the performance of finisher pigs. However, the highest average daily gain (ADG) with better feed conversion ratio (FCR) and lower feeding cost per kg gain was recorded in pigs fed on rice polish at 50% level with one lac unit of phytase enzyme. Thus, it is concluded that rice polish can be fed up to 50% with 20g phytase (one lac unit/100kg feed) to finisher pig for maximum growth performance.

Fig. 5.12. Feeding trial in pigs

To study the growth performance of birds fed ration supplemented with phytase under deep litter a feeding experiment for the period of 85 days was conducted on 40 days old Divyan red poultry (421±4.58g BW). The results revealed that supplementation of phytase in diets improved daily growth rate of 18.38% with an improvement of 15.12% in FCR value in chicks than control group. However, the overall growth performance

Fig. 5.13. Broiler chicken rearing

of Divyan red poultry under a confined condition in deep litter system was very poor and un-economical. Thus, it is recommended in broader aspect that this bird may only be reared under backyard farming system with zero inputs by resource poors for their livelihood. In another study on broiler chicken, supplementation of phytase enzyme @ 20g/100 kg feed improved average daily gain by 2.25% and feed conversion ratio by 5.62% over a control group

Integrated Farming System and Water Productivity

Optimization of production efficiency in livestock–fish integrated farming system

Integrated fish farming system (IFFS) is a diversified and coordinated method of farming system, where agriculture, horticulture and animal husbandry are integrated along with fish culture in order to achieve higher production and economic sustainability. The main objective of this system of farming is to recycle wastes or by-products (faeces, urine and spoiled feeds) generated from one unit as inputs to fish culture in the form of fertilizer and feed to achieve higher productivity and to reduce the cost of production. As because IFFS takes a holistic approach to upgrade the socioeconomic condition of residing people, it is a popular model among the small and marginal farmers that involves profitable, waste recycling and energy conservation. The study on integrated fish farming was carried in the institute farm and among different fish based integrated farming models - highest production was achieved in cattle fish integration (Fig. 5.14) (5.05t/ha) followed by pig-fish and buffalo-fish (3.57 t/ha) integration. Supplementary feed-based control showed marginally higher production of 5.31t /ha. Data indicates that the fish rearing with the concentrate feed was able to increase a fish yield only by 300 kg/ha as compared to the productivity of cattle-fish integration.

Fig. 5.14. Integrated cattle-fish farming

Plankton analysis

The plankton densities were also estimated from different integration. Results revealed that the annual average plankton density was recorded to be highest in fish-pig integration (1194.44 no./lit) among all integrations followed by fish-cattle (1105.56 no./lit.) and fish-duck (1050.00 no./lit.) integrations etc. subsequently, the lowest plankton population was recorded in fish-buffalo integration *i.e.* 888.89 no./lit.

A suitable plankton population enriches the systems with oxygen through photosynthesis during day light hours and lowers the levels of carbon-di-oxide, ammonia, nitrite, hydrogen sulphide, methane etc. Abundance of zooplankton is more generally associated with the application of organic manure. Rotifers, Copepods etc., are the best natural fish food organism in freshwater fishpond. Following is some of the representative species of plankton recorded during sampling (Fig. 5.15).

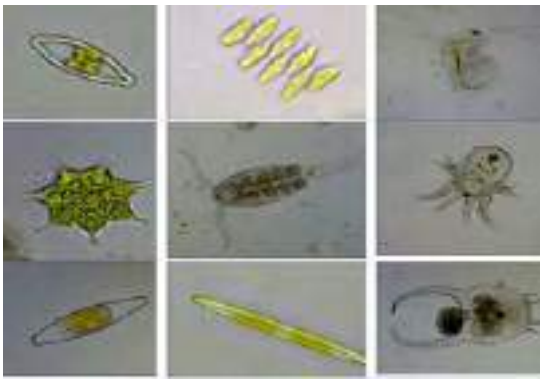


Fig. 5.15. Natural Phyto and Zooplankton species diversity from fish pond

The temperature and pH of pond water from all the integrations ranged between 24.3-24.78 ^{0}C and 7.47-8.12 and no abrupt changes in pH have been recorded so far. Dissolved oxygen was almost maintained between 5.7 - 7.67 ppm, which is ideal for fish survival and growth. Other water quality parameters like ammonia (NH_3-N) content were maximum in fish-buffalo, fish-pig as well as in feed-based integration (0.02 ppm), nitrite (NO_2-N) was also highest in feed based (0.02 ppm) farming followed by fish-goat (0.018 ppm). Phosphate (PO_4^{-2}) level was highest in fish-cattle (0.53 ppm) followed by feed-based farming (0.37 ppm). The alkalinity and hardness are also recorded within the acceptable limit in all the ponds. Based on the estimation, it can be concluded that livestock-based integration has not significantly deteriorated water quality parameters.

Primary productivity and water quality management play vital role in integrated aquaculture system. Gross primary productivity (GPP) was recorded highest in fish-goat integration (0.18g C $m^{-3}h^{-1}$) followed by cattle- fish integration (0.16g C $m^{-3}h^{-1}$). Net primary productivity (NPP) was highest in fish-pig integration (0.10 g C m^{-3} h^{-1}) followed by cattle-fish integration (0.07 g C m^{-3} h^{-1}), while the respiratory quotient was higher in fish-goat integration (0.13 g C m^{-3} h^{-1}). Overall condition was more congenial in cattle –fish integration compared to other integration.

Aquaculture Production and Management

Grow-out technology of freshwater prawn culture

The standardization of grow-out technology on polyculture of freshwater prawns (Fig. 5.16) under multiple water use system has been carried out. Freshwater prawn was stocked @30,000 PL/ha and results have shown that prawn after 240 days of rearing in polyculture attained an average weight of 94 g and size of 184 mm. Stocking densities of catla, rohu, bata and grass carp were 10,000 fingerlings/ha in 1:1:1:1 ratio. In Polyculture, prawn yield was 300kg/ha/8 months and survival rate was 50 %, along with fish yield of 3321kg/ha. Prawn was cultured in semi-intensive systems involving stocking of PL-20 at 4-20/m^2 in ponds. Predators and competitors were controlled and water quality, health and growth rate were monitored. Grow-out technology of giant freshwater prawn, *Macrobrachium rosenbergii* aims at a sustainable production of 1.5t/ha/crop. This technology involves an initial nursery phase for a period of two months followed by a grow-out phase of six months. The grow-out pond is often stocked with post-larvae, which usually lead to poor survival and hence low yield. Therefore, a nursery phase of 45-60 days is advocated prior to the grow-out phase for successful farming of scampi. Mixture of groundnut oil cake and fish meal in the proportion 1:1 is used as supplementary feed.

Fig. 5.16. Freshwater prawn *M. rosenbergii*

Diversification of fish farming system

The objective of the study is to standardize the breeding protocol and rearing practices of *Labeo bata* and to evaluate the performances in different fish farming system. *Labeo bata*, locally called as Bata belongs to the Family Cyprinidae. The most identifying characteristic of the fish is the presence of small black spot on 5^{th} and 6^{th} scales on the lateral line. Breeding trials of *Labeo bata* was taken

Fig. 5.17. Minor carp *Labeo bata*

up and the best dose of inducing agent, ovaprim, for female was 0.3 ml and for male 0.1 ml /kg body weight, respectively. The hatching of larvae took place between 5-6 hours after ovulation at 27-28°C in all the breeding trials. The highest percentage of hatching was recorded at 84.00% and the lowest at 39.67%. Approximately 20 lakhs fish spawn seed have been produced for further rearing them to stunted fingerling. Regular water quality and sampling were done to monitor and assess the growth and maturation of *L. bata.* Average fish production was 3.625 t/ha.

Breeding and culture of magur

Clarias batrachus (desi magur) brood fishes were raised in 0.01 ha earthen pond for gonadal development and maturation. Magur was regularly fed at the rate of 2% of their body weight with commercial sinking pelleted feed containing 22% crude protein. During the breeding season, both males and females were collected from the brood stock pond and maintained separately in cement cistern for breeding purpose. To facilitate magur breeding a flow through magur hatchery was designed and used for breeding and early rearing of magur (Fig. 5.18). As the eggs are adhesive in nature, the eggs distributed through out the plastic tub including sticking to the wall of the plastic tubs.

Fig. 5.18. Flow-through magur hatchery

Induced breeding operation techniques were followed and fishes (male and female) were injected with hormone (oaprim). After 18 hr of operation female were striped and on an average about 6,000-7,000 eggs were obtained from a fully ripped female. Detailed embryonic developmental stages of magur larvae are illustrated in Fig. 5.19 & 5.20.

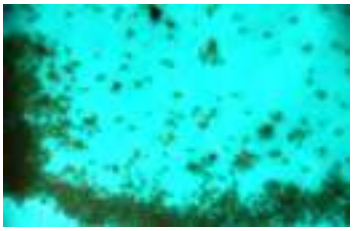
The fertilization percentage obtained varied from 89 to 96% with an average of 93.16% whereas the hatching percentage varied between 23 and 75% with an average of 55.10%. An average of 21.55% survival was achieved from spawn to fry stage with a maximum of 34%. Hatchery water temperature, pH, dissolved oxygen and total alkalinity were in the ranges of 26-32°C, 7.4-8.1, 6.5-7.1 mg/l and 160-190 mg/l, respectively. Hatching time varied between 23 hours and 26 hours at a temperature range of 29°C–34.5°C and water pH range of 7.6-8.1. The maximum survival percentage from spawn to fry was 34%. After hatching to at least 16-20 days they were maintained in the hatchery itself and were transferred to 2 × 0.5 × 0.3 cm3 size FRP tanks for another 30 days. More than 1000 early fry and fingerlings with average length (75 mm ± 9 mm) and average weight (5.1 ± 0.10 g) were obtained after first sampling. After those fishes (8-10 cm size) were released to the nursery pond

Male and female sex

Eggs release by female

Mixing of eggs with milt

Fertilized eggs



Just hatch out magur

Magur with egg yolk

Fig. 5.19. Artificial breeding procedure of magur

for further rearing and fed with eggs yolk suspension along with crumbled powder feed having 20% protein and boiled poultry eggs. Natural breeding of magur was also successfully attempted after suitably modifying the breeding ground with 70-80 cm depth. About 20 breeding pits were dug on upper portion of the breeding pond. Several earthen pots, aquatics weeds and hideouts were provided for facilitating good breeding response. Water level in the breeding ground was maintained at 15-20 cm above the breeding pits. The breeding and spawning response of magur in natural site was found to be good. Magur fry and fingerlings recovered from natural breeding ground were being reared for further maturity and development.

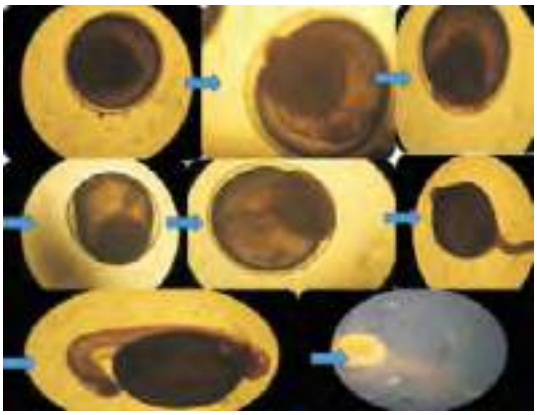


Fig. 5.20. Embryonic development of fertilized eggs of magur

Rice–fish integrated farming system

Rice-fish farming was carried out in the seasonally waterlogged areas in WALMI campus of ICAR-RCER, Patna to assess the potentiality of this system for augmentation of overall water productivity (Fig. 5.21). For the experiment five paddy fields

Fig. 5.21. Integrated rice-cum-fish culture

(0.1 ha) of uniform topography were selected where centre 10% area has been used as a fish refuge (1.2 m depth). In the periphery, rice was transplanted in the already prepared field and a total of 50 numbers (25 each) of stunted rohu (*Labeo rohita*) (104.7±2.65g) and Catla (*Catla catla*) (95.1±3.22g) were stocked in the refuge area. Rice was harvested after 120 days and net fish production was recorded after the culture period of 180 days. At the end of five months, rohu attained growth of 545.1 ± 24g and catla 589.5± 42.6g. Average productivity of 5 five refuges was 1.70 t ha-1 of fish and recovery was around 78%.

In another study raised beds and furrows was made alternatively in the low-lying areas by deepening in one area and depositing the excavated soil to other areas. The raised broad bed areas are used for cultivating seasonal vegetable or fodder crops. The depressed portion was used for fish cultivation. Total 9 trenches were made and fishes were grown in those trenches. A total of 200 fishes rohu (130 numbers) (49.7±3.91 g) and catla 70 numbers (47.5 ± 4.36 g) were stocked. At the end of 4 months, 81% recovery was recorded and 29.5 kg production was obtained with an average body weight of rohu: 158.5±8.6 g) and catla 172.2±12.53 g).

Buffalo magur integration

Successful culture of *Clarias batrachus* was carried out in buffalo wallowing tank (Fig. 5.22). The fishes were stocked @ 30000/ha with 75% survival rate. The average body weight of *Clarias batrachus* varied from 100-120 g with the highest body weight of 495 g and total yield was obtained 2.5 t/ha without feeding for a culture period of 7 months.

Fig. 5.22. Magur fish in wallowing tank

Use of solar operated sprinkler in fish pond

In view of immense solar energy potential in Eastern Region of India, a spray type solar aerator was developed and evaluated for dissolved oxygen concentration in a fish pond of size 20 x 30 x 1.5 m at Patna. It was designed with a one horse power DC surface pump and 900WP solar panel. It sprays less oxygenated pond water high into the air through a perforated pipe. This aerator not only increases the dissolved oxygen concentration of pond water, but also breaks the thermal stratifications which obstruct inter-mixing of more oxygenated top layers of pond water with the low oxygenated sub-surface layers. The inter-mixing of top saturated layers with low oxygenated sub-surface water layers facilitates increase in dissolved oxygen concentration of subsurface layers. If this aerator was operated for 6 to 7 hrs in a day, then an increase of 20-22% in oxygen concentration in sub-surface layer (0.5 m from surface) and 40-50% increase in deeper layer (1.0 m from surface), were observed compared to the controlled conditions, *i.e.* 4.24 and 3.37 ppm, respectively. Average weight gain of *Labeo rohita*, was higher at aerated pond compared to the control (Fig. 5.23). Percentage of weight gain and specific growth of *Labeo rohita* was 211.4 %, 119.8%, 1.51% and 1.05% respectively. Survival percentage was lower in the controlled pond (73%) as compared to treatment pond (84%). However, no significant difference in dissolved oxygen concentration was observed in surface layers due to the fact that the top layer is always at higher concentration.

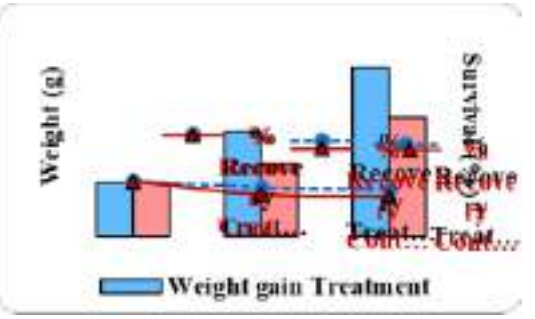


Fig. 5.23. Performance of solar operated sprinkler aerator on growth and survival of *L rohita*

Improving the livelihood security in salt-affected watersheds of Muzaffarpur&Sheohar districts of Bihar through fish culture (NAIP)

There was tremendous scope for fish culture in both the districts. Initially, water and soil parameters were analyzed from Kushar village of Sheohar district and Motipur (Fig. 5.24) village of Muzaffarpur district project sites.

The pH and Ec of the soil and water are within the acceptable limit both for fish culture as well as agriculture operation. Other important parameters like nitrogen, potassium, phosphorous as well as iron, copper, zinc, calcium, magnesium, sodium and potassium were also analyzed. Under interaction with the farmers of Motipur, it was found that knowledge level in fish farming was not adequate in spite of having several ponds in the adopted villages of both the districts. After continuous interac-

Fig. 5.24. Fish pond before and after intervention at Motipur

tions and through awareness campaign few farmers repaired and renovate their existing pond and started fish culture activities (Fig. 5.24).

To popularize the composite fish culture practice, duck cum fish culture was demonstrated in three sites in the farmer's field. The low-cost duck house was made from locally available materials. At the end of culture practice average production in duck –fish integration was estimated to about 2.826±0.20 t/ha. Similarly fish production from few adopted farmers ponds also recorded improvement in fish production compared to traditional system (0.7 t/ha) to about 1.7 t/ha).

Fig. 5.25. Duck cum fish culture at Motipur village

Surveillance and monitoring of animal diseases

Animal Diseases

A total 12 districts were surveyed in all the four agro-climatic zones of Bihar for sero-surveillance of goats viral diseases and 855 sample collected from goats (Fig. 5.26). The overall prevalence of PPR in Bihar was 34.39%. Sero-surveillance of PPR antibody indicated very low prevalence in kids of age group <5 months. The highest circulating PPR Antibody was recorded in non-pregnant goats and there was non-significant dif-

Fig. 5.26. Disease sample collection

ference between male and female goats. The sero-epidemiology of Blue tongue (BTV) antibody indicates prevalence of 14.68% (range 10.71 to 20.93% in different districts). No significant difference was found between genders for BTV sero-positivity.

Few goats were positive for both BTV and PPR. CAE antibody was not found in goats of Bihar and only 2 cases were found sero positive for antibody of CAE. History indicated purchase of goats from state of Rajasthan and breed found positive were of Sirohi breed.

Study was conducted to study the subclinical mastitis in crossbred cattle of peri-urban areas of Bihar, Jharkhand and Eastern UP. Screening was done based on modified California Test, followed by bacterial isolation and culture sensitivity testing. The prevalence of subclinical mastitis was 38.57% and 39.42% in the peri-urban cattle of Bihar and Jharkhand respectively. The prevalence of subclinical mastitis was 27.27% animal wise and 8.18% udder wise in the peri-urban cattle of Eastern Uttar Pradesh. The pattern of incidence of SCM teat wise was maximum in left hind followed by left fore and then right hind and right fore. Culture sensitivity results indicated maximum sensitivity to Cefoperazone CPZ75 (63.7%), gentamicin G10 (36.36%); intermediate sensitivity to Ampicillin AMP10 (72.72%); Amoxycillin AMX10 (54.54%); streptomycin S10 (54.5%) and resistant to Penicillin P10 (100%) against *Staphylococcus aureus*. The result of the clinical trial of feeding 100 gm dry powdered curry leaves and 30 gm dried powder of methi seed for 10 days orally as supportive therapyorally in CB cattle with SCM provides evidence of ameliorative potential with respect to its use as an adjunct therapy. The observed outcome may be attributed to its anti-oxidant as evident from its levels in milk and blood and possible anti-inflammatory potential.

Fig. 5.27. Microbiological analysis

Formulation of area specific mineral mixture based on soil-plant-animal continuum in Bihar

The deficiency of zinc, phosphorus, molybdenum and sulphur was found during estimation of soil, feeds & fodder and animal blood samples randomly collected from 14 districts in four agro-climatic zones of Bihar. A specific region based mineral mixture was prepared for Bihar (Fig. 5.28). It was named as “Swarna Min” which contains calcium 25.46, phosphorus 13.20, iron 0.16, copper 0.12, manganese 0.16, zinc 0.99, cobalt 0.02, iodine 0.04 and sulfur 1.04 percent.

The performance of area-specific mineral mixture was evaluated in farmers’ field and institute farm. A serum mineral profile of buffalo was estimated after feed-

ing Swarna Min and mineral mixture available commercially (Table 5.5). It has been observed that concentration of Fe, Cu, Mn, Zn, Ca and P was higher in Swarna Min fed group as compared to serum of buffalo fed with mineral mixture available commercially in the market. On-farm trial on the effect of feeding mineral mixture was conducted and presented in Table 5.6.

Fig. 5.28. Mineal mixture 'Swarna min'

Table 5.5 Serum mineral profile of buffalo

Parameters	Critical level	Swarna Min	Commercial mineral mixture
Fe (ppm)	<1.00	3.25-3.55	3.12-3.86
Mn (ppm)	<0.20	0.31-0.39	0.14-0.21
Zn (ppm)	<1.00	0.82-0.92	0.50-0.62
Cu (ppm)	<0.65	0.81-1.26	0.89-1.09
Ca (g/dl)	8.00	9.20-9.33	8.07-8.19
P (g/dl)	4.00	4.96-4.98	3.75-3.99

Table 5.6. On-farm evaluation of mineral mixture 'Swarna min'

Place	Type of animal	Initial milk yield	Final milk yield	Percent increase
Badipur, Patna	Crossbred cattle	12.5	13.1	4.8
Khajuri, Patna	Crossbred cattle	28.8	29.1	1.04
Nawada	Crossbred cattle	16.4	16.9	3.05
Sonpur, Vaishali	Crossbred cattle	8.8	9.6	9.1
Jandah, Vaishali	Crossbred cattle	11.2	11.9	6.25
Dal Singh Sarai, Samstipur	Crossbred cattle	17.9	18.4	2.8
Dal Singh Sarai, Samstipur	Buffalo	8.4	8.9	5.9
Dal Singh Sarai, Samstipur	Buffalo	6.2	6.9	11.3
Bikramganj, Sasaram	Buffalo	9.1	9.7	6.6

It has been observed that supplementation of Swarna Min improved the milk yield of crossbred cattle and buffalo at 4.50 and 7.93%, respectively depending on the status of supplementation of commercial mineral mixture before trial. In another experiment, comparison with the commercial mineral mixture, supplementation of 'Swarna Min' resulted in higher milk production in lactating crossbred cows by 14.1%, while 4.8% by commercially available mineral mixtures. Formulation of mineral mixture for Jharkhand is in progress. The Swarna Min was released for further use

by farmers of Bihar by Hon'ble Agriculture Minister, Govt. of India on 22nd February 2015 during Agri-expo of CPRS Regional Station, Patna.

Fodder production

Round the year fodder production technology

Annual cereal and legume fodder were grown in 3.5 ha land for round the year production. Multi cut sudan as cereal and cow pea (Bundel-2), rice bean (RBS-16) and soybeans (NRC-37) as legumes were grown during rainy season. Cereal fodder was grown under 85% areas whereas, legumes under 15% areas only. The cereal fodder oat under 40% area and legume fodder berseem under 60% areas was grown on the same land during winter season. The yield of perennial ground nut legume fodder, transplanted two years back, was recorded at 57.00±3.00 t/ha in three cuttings with inter-cutting gap of 55 days having DM and CP contents of 32.24 and 14.36 percent, respectively.

Fig. 5.29. Round the year fodder production

Season-wise total biomass yield with compositions is presented in Table 5.7. It is estimated that total biomass production of 67.90 t during rainy season and 51.99 t during winter season from one ha land area is sufficient to meet the fodder requirements of 14 crossbred cows round the year. Thus, it can be concluded that this type of fodder production system is beneficial for balance feeding of ruminants.

Table 5.7 Season-wise production of various fodders

Particulars	Total fodder yield (t/ha)	DM (%)	CP (% DM)
Rainy season			
Sudan in 3 cuts at 60, 105 & 145d	74.78±2.92	14.48	8.72
Cow pea at 90 days	29.06±4.06	12.77	15.18
Rice bean at 90 days	35.67±1.52	17.19	15.30
Soybean at 90 days	22.15±0.65	26.53	19.45
Winter season			
Berseem in 4 cuts at 50, 85, 115 & 145 days	67.84±1.22	11.65	15.83
Oat in 2 cuts at 50 & 105d	28.23±0.64	14.18	11.14

Productivity of various fodder crops

Different cultivars of promising fodders *viz.* Oat (*var*. Kent and JHO-822), Maize (*var.* Hybrid), Annual Rye (*Lolium multiflorum*), multicut wheat (*var.* VL-829), Berseem (*var*. Hybrid and Wardan) and Aankathi (*Viciahirsuta*) were grown during *Rabi* season

and Multi cut Sudan (*var*. MP Chari) during *Kharif* season to study the productivity and nutritive value of forages.

The forage productivity along with dry matter (DM) and crude protein (CP) contents of different forage crops are given below. There were no significant differences in fodder and protein yields in different varieties of oat and berseem (Table 5.8). However, maximum cumulative forage and protein yields were recorded in Annual Rye grass.

Fig. 5.30. Multicut wheat (VL 829)

Table 5.8 Forage productivity with protein content

Fodder crops	Forage yield (t/ha)	DM (%)	Av. CP (g/100g DM)	CP Yield (t/ha)
Multicut Sudan (2 cuts at 55, 115d)	96.00 ± 2.08	17.75	8.75	1.49
Berseem (4 cuts at 50, 80, 110, 140d)	56.63 ± 0.21	12.36	19.27	1.35
Hybrid Wardan	56.86 ± 0.64	12.51	19.31	1.35
Oat (2 cuts at 60,105d)	27.27 ± 0.92	16.05	11.00	0.48
Kent JHO-822	28.33 ± 0.55	14.77	11.49	0.48
Maize hybrid (at 100d)	58.67 ± 1.33	12.94	8.65	0.66
Annual Rye (4 cuts at 60,80, 100, 120d)	72.82 ± 1.38	13.85	17.12	1.71
Multicut Wheat (VL-829) at 70d	7.20 ± 0.23	15.28	17.46	0.19
Aankathi at 75d	10.33 ± 0.72	20.64	26.85	0.57

Feed-food crop cultivation

Dual purpose wheat (VL 829) (Fig. 5.31) was cultivated to study the fodder and grain yield. The wheat forage was harvested on 70th day after sowing at the base height of 10 cm. Irrigation was provided immediately after forage harvesting and urea was broadcasted @60 kg/ha. Similarly, multi-cut Sudan gave good forage yield

Fig. 5.31. Promising rabi forage crops

during *kharif* season (96 t/ha). Thus, it is concluded that Berseem and/or Annual Rye grass may be the best option for fodder production during *rabi* season and multi cut Sudan during *kharif* considering the forage yield.

Assessing productivity and quality of fodder with carrying capacity under different land-use system

Relative performance of annual fodder crops *viz*. multicut sorghum, local sorghum, pearl millet, maize and cowpea were evaluated during *kharif* 2016 (Fig. 5.32). Annual fodder crops were sown in main field during May-June, 2016, while Napier grass root slips were transplanted on bunds during June, 2015. Fodder yield of different crops was recorded and its nutrients were analyzed (Table 5.9).

Table 5.9 Fodder productivity with nutrient conent

Crop	Harvesting days after sawing	Cumulative fodder yield	Av. DM (%)	Nutrients (g/100g DM)			
				CP	EE	CF	TA
Hybrid Napier *var.* CO3	50, 90, 140, 200, 320	300.33± 8.37	16.45	10.18	1.28	32.01	14.67
Multicut Sorghum *var.* Hybrid Gagan	70,110	55.60± 1.06	22.96	8.64	1.38	36.93	7.52
Maize *var.* African tall	70	35.63± 1.17	14.18	9.30	1.19	33.66	9.18
Pearl millet *var.* Bajra local	70	32.63± 1.43	22.07	8.10	1.12	38.73	9.21
Sorghum *var.* Jowar local	70,110	36.10± 0.13	22.08	7.85	1.19	34.18	9.44
Cowpea *var.* Bundel-2	70	28.67± 0.37	14.53	13.12	2.24	24.53	9.91

Fig. 5.32. Annual fodder crops

Cumulative annual fodder yield from Napier *var.* CO3 from bunds was recorded as 300 t/ha. Hence, from bund area (400 m2) of one acre land, 12 t green fodder was harvested which was sufficient to meet the requirement of two adult cattle round the year (25 kg/d/animal). Fodder productivity and nutrient contents of different annual cereal fodder were almost similar. However, performance of multi-cut

Table 5.10 Nutritive value of forage crops in cattle heifers

Forage crops	DMI (kg/100kg B. Wt.)	DMD (%)	CPD (%)	DCP (%)
Berseem (Wardan)	2.71 ± 0.09	78.36 ± 1.77	74.01 ± 1.19	14.29 ± 0.23
Oat (JHO-822)	2.43 ± 0.05	84.61 ± 1.25	65.87 ± 1.91	7.57 ± 0.22
Wheat (VL-829)	2.61 ± 0.03	77.99 ± 0.59	72.84 ± 0.09	12.72 ± 0.01
Annual Rye	2.84 ± 0.11	84.31 ± 1.55	77.27 ± 2.25	13.23 ± 0.38
Maize Hybrid	2.13 ± 0.05	66.60 ± 2.13	46.07 ± 3.68	3.99 ± 0.32
Multicut Sudan	2.09± 0.07	65.47 ± 0.51	43.83 ± 0.89	3.84 ± 0.08

sorghum was better due to more numbers of cuttings. Fodder productivity of legume fodder (cowpea) was recorded as 28.67 t/ha with almost 50% higher protein content in comparison to annual cereal fodder. Hence, it is recommended to grow multicut sorghum and cowpea in combination (3:1 ratio of area) during *kharif* season which can provide good quality fodder of 49 t/ha. It can meet up the fodder requirement of 16 adult cattle for balanced feeding @ 20 kg green fodder per day per animal for 150 days.

Nutritive value of various forage crops

Digestibility trials were conducted in crossbred heifers to study the nutritive value of berseem, oat, wheat, annual rye, maize and sudan forage crops. The individual forage was provided as sole feed to heifers for 21 days as an adaptation period and a digestibility trial was conducted for the period of four days. A set of another digestion trial was also conducted in buffalo calves using berseem and oat fodder to study the comparative nutritive values in cow and buffalo calves.

Significantly maximum dry matter intake (DMI) and crude protein digestibility (CPD) were recorded in heifers fed annual rye which was at par with wheat and berseem fodder (Table 5.10). However, maximum digestible crude protein (DCP) value was obtained in berseem fodder. The nutritive value of maize and sudan forage in terms of DMI, CPD and DCP was recorded the lowest and seems to be poor, hence supplementation of legume fodder is required for balance feeding.

The nutritive value of berseem and oat in cow and buffalo calves indicated that berseem forage had significantly ($P<0.01$) higher DMI, CPD and DCP values than oat forage. Similarly, the DMI, DMD, CPD and DCP intake values were significantly ($P < 0.01$) higher in cow calves than buffalo calves. It is concluded that the nutritive value of berseem forage is better than the oat. The oat forage requires supplementation of legume forage to make balance nutrient contents. The forage intake and their nutrients digestibility are better in cattle calves than buffalo calves.

6. Division of Socio Economic and Extension

Growth & instability in production of principal crops in Bihar

Thirty years secondary data since 1982 on area, production and yield of principal food grains crops in Bihar were collected to study the growth and instability in production of food grains. In Bihar, rice, wheat maize and pulses are principal crops and jointly constitute about 82 percent of gross cropped area but area under food grains declined during last 30 years. The decline in pulses area was more pronounced, particularly during 1984-94 due to shift of pulses area to wheat crop. Wheat and maize recorded steady growth in area during period under study. Rice also faced a setback in area expansion during the period. Despite decline in area under food grains, production observed increasing trend due to substantial increase in production of maize and wheat, which was made possible due to increase in area and productivity of these two crops in Bihar. Productivity of all food grain crops including pulses increased during all the three specified periods. Food grain production could achieve less than 1% increase in 1984-94 and 1994-2004 but recorded production growth of 6.76% during 2004-14.

Weather based forecasting for agricultural growth in eastern India

The project is based on 24 years secondary data on crop statistics and weather parameters during the crucial stages of crop growth. A total of 48 monthly weather indicators were computed. Since, a particular crop in general is of 4 to 5 months duration, a particular crop study was based on 20 to 25 indicators. The critical period of crop growth being influenced by the weather variables was identified with the help of stepwise regression in the major crops of Howrah districts of West Bengal, Bhubaneswar and Jharsuguda districts of Odisha, and Gorakhpur district of UP. It was observed that the effect of weather variables is different in different crops. While using the Artificial Neural Network analysis consisting of influencing weather variables and the crop yield, it was found that the ANN model fitted the data well and the actual by predicted plot of all the crops were

Fig. 6.1. Field visit at Darbhanga

approximated to 99% synchronization. The study indicated that in Howrah district the 10 mm increase in January precipitation reduces the wheat yield by 2.5% and increase the potato yield by 1.9%. In the rest of the month the change was minor. With 0.1 ºC increase in maximum temperature in January and February months, potato yield decreases the by 1.3% and wheat yield decreases the by 0.75% respectively

Changes in economical status and employment scenario of household of Bihar and Jharkhand

The study was conducted Patna and Darbhanga districts of Bihar and Ranchi and Dumka district of Jharkhand. Total 8 villages were selected from four districts and data of forty households from each village (10 each from labor, small, medium and large farm categories households) was collected. Per capita Income increased more rapidly in rural Jharkhand than rural Bihar but rural population below poverty line is more in Jharkhand. Role of institutional support in providing modern technology and poor access to formal credit system were the main constraints in agricultural development in villages under study in Bihar and Jharkhand. Poverty declined continuously over the years in Bihar and Jharkhand but more decline was observed in Bihar. There was an increase in employment for male in both farm and non-farm sectors, but increase was higher in non-farm sector. The role of non- farm sector in providing rural employment has increased and it may be one of potential pathways for alleviating poverty in Bihar. Farm mechanization increased considerably in the study villages of Bihar. But agricultural mechanization is still at lower level in Jharkhand.

Fig. 6.2. Interaction with farm households

Sustainable livelihood improvement through need based farming system models in disadvantaged districts of Bihar

- Study was conducted in 7 clusters of 4 disadvantaged districts– Vaishali, Samastipur, Darbhanga and Munger of Bihar covering around 1600 households. The project was implemented in consortium mode in association with CIFRI, Barrackpore; CPRS, Patna; RAU, Pusa; BAIF, Bihar.
- Half acre integrated farming system model was developed in Chakramdas village of Vaishali district which included crop, buffalo, duck cum fish culture and

backyard vegetable production. The cost benefit analysis showed six fold increase in net income (Rs 55,578/-) over traditional cropping system (Rs 7,528/).

- One acre IFS model was developed in the same village with agri-horticrop-goat-poultry as the village is dominated by rice-wheat cropping system followed by fruits and vegetable production. The net return from the system was achieved at Rs 59,428/- and gross return of Rs 235,072/-.
- Farming system model by integration of fish and singhara with makhana was developed in 50 ha of land in Darbhanga district. The net benefit from the system was recorded at Rs 52,435 as compared to traditional system (makhana production alone) of Rs 20,614. The makhana contributed the major share of around 40% followed by fish at 22.5%.
- 12 cropping systems were tested and demonstrated in the 234 farmers' field in an area of 42 ha. With the inclusion of one more crop, cropping intensity of the area increased from 200% to 264% which resulted in increase in farmer's income by 31 to 158% with an increase in employment up to 13.7%.

Fig. 6.3. Makhan + fish integration

Fig. 6.4. Field Day at Sukhet (Madhubani) under SRFSI project

- Potato seed production was taken in Vaishali cluster covering an area of 13.1 ha and involving 240 small and marginal farmers. A total of 284.4 t foundation seed was produced s with average productivity of 21.7 t/ ha.

- In Munger cluster, a total of 2024 numbers of breedable cattle were inseminated artificially with improved semen which resulted in improved milk production (2700 liters/ lactation). Selected Black Bengal bucks (22 nos) were distributed in the cluster to improve the existing stock of Black Bengal goats which have lower growth rate and body weight. By this method, more than 3000 numbers of natural breeding were carried out. Similarly, crossbred cows were introduced to 55 landless households in the cluster which resulted in an increase of 60% income per household per year over an income of Rs 22,400 per household per year.

Sustainable and resilient farming system intensification in Eastern Gangetic Plain

The overall aim of the project is to reduce poverty in the Easter Gangetic Plains by improving the productivity, profitability and sustainability of smallholder agriculture. The project was implemented in five nodes of Madhubani district of Bihar in collaboration with CIMMYT.

Fig. 6.5. Field Day at Korahiya under SRFSI project

Fig. 6.6. Animal based farming system at Rewa Maheswar (Assam)

- Farmers participatory trials revealed that there was saving of water and manpower in zero tillage in comparison to conventional sown wheat.
- Water and labour productivity under different establishment methods in wheat revealed that there is an increase of 42% and 36 % water and labour productivity respectively under zero tillage in comparison to traditional sown wheat.
- In case of rice, ZTDSR is more labour productive (95 %) and there is 46 % labour savings in comparison to transplanted rice. 1207 farmers got direct benefit in terms of field trials, training, exposure visits, field days etc through the project activities in Madhubani. Out scaling of ZT wheat was done in 14.34 ha area by 63 farmers of Madhubani district.

Tribal farming system in Eastern India

Cluster based participatory technological intervention is being implemented by ICAR-RCER, Patna at tribal dominated areas of Ranchi, Bhadrak, Kamrup and Jalpaiguri districts of Jharkhand, Odisha, Assam and West Bengal states, respectively with collaboration of SAUs, IINRG, Ranchi, R.K. Mission and local Panchayats. Total targeted beneficiary was around 500 households. Livelihood approach was adopted by the institute focusing on capacity building of stakeholders, working with them in participatory mode, analyzing people's existing strength and utilization of available resources Women and youths was involved in capacity building and implementation of livelihood interventions. Participatory technology demonstrations on improved vegetable cultivation, scientific lac cultivation, rice fallow management, protected cultivation, restoration of degraded land through agroforestry and multi-tier horticulture, high density orchards, backyard poultry, mushroom cultivation, feed and health management in animals was conducted.

Fig. 6.7. Performance of bottle gourd at Uttar Simlabari (Alipurduar)

Risk proneness studies of major crops of Eastern India

This study is based on historical crop-statistics on area and production for past more than 30 years data obtained from Directorate of Economics and Statistics of the Governments of Odisha, Chhattisgarh, Uttar Pradesh, Bihar and Jharkhand. Using the probability of crop failure, the districts of the respective states have been classified as low, medium and high risky area for a particular crop. The validity of the premium was decided by the profitability over the years. On the basis of extent of short fall in yield the districts were classified as low, medium and high risky for growing a particular crop. The study indicated that the district wise risk is more appropriate than the state wise risk determination. The crop insurance premium rate for all the crops under study have been determined for the crops having high and medium risk in the districts. In case of sugar cane MPD method for premium determination have been used as the yield did not followed normal distribution. The premium rate varied from 1.7% to 13.4% in rice crop and 1.9% to 3.6% for wheat crop depending upon districts and the type of crop at 90% indemnity level. The probability of crop failure for the major crops of Odisha, Chhattisgarh and eastern part of UP has been deter-

mined and it was observed that these probability ranges from 2 to 18 %. In case of wheat the number of shortfalls varied from 2 to 8 and for maize 0 to 9 and for other crops from 0 to 8. In the state of Chhattisgarh, rice, wheat, maize, niger, groundnut and arahar crops were taken for risk analysis study. The number of shortfalls varied from 0 to 7 depending upon crops grown in different districts of Chhattisgarh state. Similarly, in Eastern UP, the data were available for 35 years. *Kharif* Rice, wheat, lentil, potato and sugarcane crops were taken for risk analysis study. The number of shortfalls varied from 8 to 18 depending upon crops grown in different districts of eastern UP. The instability of rice and wheat crops in different districts of Eastern Region of India was estimated using popularly known CDV Index. It was observed that rice yield is unstable or moderately unstable in almost seventy percent districts of Eastern Region. The seventy percent districts contain most of the districts of Bihar, Jharkhand, Odisha and Chhattisgarh. Similarly, wheat yield is unstable or moderately unstable in almost forty seven percent of districts. These districts mostly lie in Odisha state in addition to few districts in rest of the states.

7. Farming System Research Centre for Hill and Plateau Region, Ranchi

Farming System Research Including Climate Resilient Agricultur

Development of location specific Integrated Farming System models for rainfed ecosystem of Eastern Plateau Hill region

A 0.75 Acre IFS model (Crop + Horti + Dairy) (Fig 7.1) has been developed in which livestock (2 cows + 2 calf), fruits *viz* Guava and Papaya (8.5% area) are integrated with cereals, pulses and oil seed (64 % area), vegetables (6% area) and fodder (15.3% area) under rainfed ecosystem to enhance the productivity and to improve the livelihood and socio-economic status of people of eastern plateau and hill region. During the 7th year of the system, the total fruit yield was 485 kg which is sufficient for fulfilling the daily dietary requirement of 11.07 persons. The surplus production gave net income of Rs. 7,550/- per year. The total milk production was 1,040.25 lit from two cows which is sufficient for the 14.25 persons. So, the milk and fruit production were in surplus in the IFS and gave net income of Rs. 11000/- from selling of milk. The cereals, pulses and oilseeds obtained from IFS were 250.83 kg, 33.4 kg and 16.35 kg respectively which were sufficient for fulfilling the daily dietary requirement of 1.32, 1.83 and 1.0 person respectively. Vegetable production from bathua, mustard, tuber crops and badhal flowers was sufficient for fulfilling the daily dietary requirement of 3.61 persons. The total FYM production was recorded as 9.49 t/year and cow urine production as recorded as 3 464.37 litres/year from two cows and three calves. A total of 2 kg Tephrosia seed was produced and total fuel wood produced from the system was 212.3 kg. The total fodder production was 4.01t/year. The total FYM production was recorded as 3.84t/year, vermicompost production from the unit was estimated as 1.34 t/year and cow urine production was recorded as 3464.37 litres/year from two cows and two calves. Estimation of soil fertility status

Fig. 7.1. Different components of IFS model

of the system indicated an increase in the value of average soil organic carbon from 0.31% to 0.66% in a period of 7 years.

Understanding the changes in host-pest interactions and dynamics in mango under climate change scenarios

To understand pest dynamics on mango, observation of pests dynamics data on Real Time basis was recorded at weekly interval from 120 mango orchards in six different mango growing belts *viz*. Ranchi in Jharkhand, Lucknow in Uttar Pradesh, Vengurla in Maharastra, Paria in Gujarat, Sangareddy in Telangana and Bangalore in Karnataka. Mango pests population dynamics could not be explained only through weather parameters, and host phenology was also found to have important role to determine the pest population. General understanding from pest population data and weather parameters showed that major pests *i.e.* thrips and hoppers were positively correlated with minimum and maximum temperatures. Natural enemies were directly correlated with presence of their hosts.

Documentation of outbreaks in respect to weather aberrations

Subzero temperature (-0.2 to -1.20 ºC) (lowest since last 40 years) during 9th and 10th January, 2013 in Northern (Rohilkhand and Avadh) Plain resulted in 100% leaf necrosis with drying of 5-20 cm of terminal shoots. This happened along with more foggy days and heavy rains during February, 2013 which delayed the bud burst and panicle development in particular year. Again in 2015, high incidence of blossom blight was observed in Uttar Pradesh and Jharkhand mango orchards. The incidence of disease was started due to abrupt changes in weather phenomena specially rainfall. Outbreak of mango hopper, *Idioscopus nitidulus* was noticed in about 70% mango orchards of Sindhudurg and Ratnagiri district during year 2013. This was due to late cessation of rain in the area which leads to intermittent vegetative flushes and flowering.

Heavy incidence of mango hoppers and thrips was recorded in south Gujarat during year 2014 on Hafoos and Kesar mango varieties. High temperature during day time and cold nights have played major role to outbreak the population. This fluctuation in minimum-maximum temperatures also lead to poor pollinator's activity ultimately leading to low pollination.

Identification of insect pest and pathogen shifts and emergence of new pests

During RTPD observations, pyralid fruit borer, *Citripestis eutraphera* (Meyrick) was recorded (Fig. 7.2) as new pests in Indian main land on immature mango fruits causing serious damage in several villages of rural Bangalore and other parts of Karnataka during April-June, 2013.

Fig. 7.2. Pyralid fruit borer, Citripestis eutraphera (Meyrick) recorded as new pests in Indian main land on immature mango

With respect to shift in pest status, shoot gall psylla, *Psylla cistellata,* was major problem in Tarai area of Uttar Pradesh and part of Bihar, Jharkhand and West Bengal. During the survey, the pest was observed and documented from plain areas of Uttar Pradesh orchards**.** Similarly, caterpillars (*Euproctis fraterna, Porthesia scintillans*) and flower webbers *(Dudua aprobola)* was recorded on panicles in Northern Telangana region of Andhra Pradesh, Chotanagpur plateau and hill region and Deccan plateau of Karnataka and inflorescence midge was recorded in Deccan plateau (Telengana) and Western Ghat of Maharastra as major pest which were not considered as major pests of mango earlier.

In respect to shift in pest behavior, infestation of shoot borer, *Chlumatia transversa* was recorded on panicles under Deccan (Karnataka) Plateau conditions during RTPD study period which is not a common pest of mango panicles. Similarly, damage of early emerged panicles was recorded due to high incidence of leaf webber, *Orthaga* spp. in the Deccan (Telengana and Karnataka) Plateau and Eastern (Chhotanagpur) Plateau region.

Develop models for forewarning of mango pest/disease

The artificial neural network (ANN) technique was evaluated for its applicability for Incidence of mango hoppers under increasing temperature scenarios in Konkan region of Maharashtra and Valsad region of Gujarat. ANN based model could simulate the pest population dynamics with reasonable degree of accuracy. Hence, ANN models can be used to predict the pest incidence, one to two week in advance in some regions.

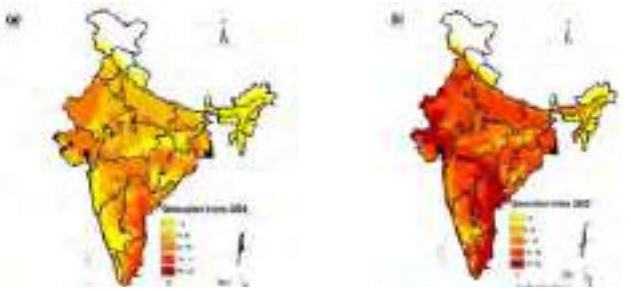
Prediction of pest status under climate change scenarios

Temperature-based phenology model was developed for *Bactrocera zonata* (Diptera: Tephritidae), a potential pest of mango, by constructing thermal reaction norms for cohorts of single life stages, at both constant and fluctuating temperatures within the ecologically relevant range (15-35°C) for its development. Major area of mango cultivation are predicted as optically suitable for estblishment, abundance and

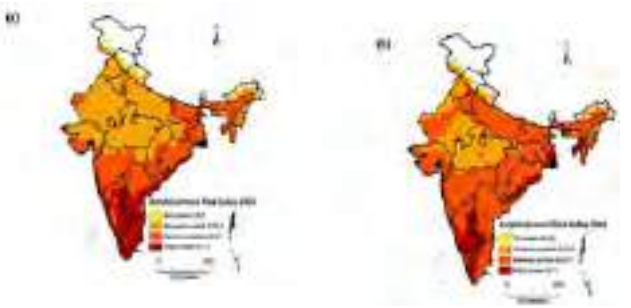
spread of *B. zonata*. *B. zonata* was predicted to complete average of 8-10 generations (GI) per year under the current climatic conditions in most of the mango production areas (Fig. 7.3).

Due to climate change *B. zonata* was expected to complete additional two more generation per year in most of the mango growing belt of the country. the temperature increases due to future climate change will take marginally suitable region in to fold of *B. zonata* incidence and population dynamics.

In case of *Bactrocera dorsalis* (Hendel) another study was conducted to estimate the number of generations in relation to changing temperature for eight different geographically isolated major mango growing locations of India for baseline (1961 to 1990), present (1991 to 2015), near future (2021 to 2050) and distant future (2071 to 2098) of projections of A1B from the regional circulation model (RCM) Providing Regional Climates for Impacts Studies (PRECIS) model. The near and future climate change periods indicate faster accumulation of degree days which will make it to possible for one or two additional generations with shortened mean life cycle (5 to 7 days less) compared to baseline and present periods at majority of locations.



Change in number of generations per year of B. zonata in India based on generation index (GI)



Change in establishment and future distribution of B. zonata in India based on establishment risk index

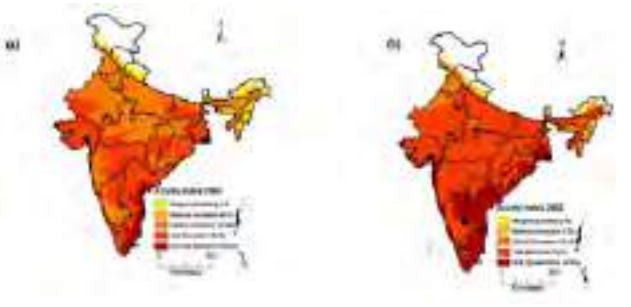


Fig. 7.3. Change in establishment and future distribution of B. zonata in India based on Activity index

Development of adaptation strategies for pest management under climate change scenarios

A total of 100 mango genotypes were screened for tolerance against different pest and diseases. Based on six years of data, incidence of leaf hopper in Hybrid- 10, Chandrakiran and and Swarnagudi was consistently low. Similarly, with respect to shoot gall psylla infestation, consistently low incidence was recorded in the genotypes Mulgoa hill, Himayuddin, Sammar Bahist Chausa, Lat Sinduria and Lucknow Selection. These resistant genotypes/varieties can be successfully used for development of resistant varieties.

Among the agro-techniques, centre opening of canopy by pruning was found to be effective in minimizing the incidence of mango hopper, powdery mildew and sooty mould.

Carbon sequestration potential of fruit orchard in Eastern Plateau and Hill Region

The study was undertken to estimate the carbon sequestration potential in different fruit orchards under eastern platue and hill region. The mango orchard registered highest total soil organic carbon (62.5 Mg ha^{-1}) among the different orchards of 6-year-old. The mango, guava and litchi orchards caused an enrichment of total soil organic carbon (C_{tot}) by 17.2, 12.6 and 11%, respectively over the control. The mango orchard registered highest significant increase of 20.7, 13.5 and 17.4 % in very labile carbon (C *frac*$_1$), labile carbon (C *frac*$_2$), less labile carbon (C *frac*$_3$) and non-labile carbon (C *frac*$_4$), respectively over control. There is greater accumulation of all the C-fractions in the surface soil (0-0.30 m). The maximum total active carbon pool was 36.2 Mg C ha^{-1} in mango orchard which was resulted in 1.2 times higher than control. The passive pool of carbon constituted about 42.4 % of C_{tot} and registered maximum in the mango orchard. The maximum microbial biomass carbon (C_{mic}) was 370 mg C kg^{-1} in guava orchard and constituted 4.2 % of C_{tot}. The mango orchard registered highest carbon build up rate of 1.53 Mg C ha^{-1} yr^{-1} and resulted in 17.3 % carbon build up over control. Among the carbon fractions, C *frac*$_1$ was highly correlated (r = 0.567**) with $C_{mic.}$

Predictive models (Richard's model) for dry biomass and carbon stock estimation were developed in litchi orchard based on destructive sampling of 2, 4, 6, 8, 10 yr old. Using the models, the carbon mitigation potential in litchi plants was estimated which varied from 0.05 (2yr) to 1.26 (10 yr) Mg ha^{-1} with corresponding CO_2 mitigation potential of 0.19 to 4.63 Mg ha^{-1}. Similarly, in mango, highest predicted total biomass carbon in 10-year-old mango orchard with average collar diameter of 14.33 cm was estimated to be 3.87 Mg ha^{-1}. The carbon mitigation potential of 10-year-old mango orchard was highest of 3.0 Mg ha^{-1} with a corresponding carbon dioxide mitigation of 11.04 Mg ha^{-1} in hot and sub-humid climate.

Rates of decomposition and nutrient mineralization of leaf litter from different orchards

The leaf dry matter decomposition of mango, litchi and guava was estimated to be 1.55, 3.75 and 8.07 years with decay constants of 3.22, 1.33 and 0.62 year^{-1}, respectively. Leaf litter from litchi showed noticeable slow decay rate and is worthy to be used for organic matter build up in hot and dry sub-humid climate. High content of lignin (33 %) in litchi leaf litter had a higher significant negative correlation with decomposition rate followed by lignocelluloses and cellulose and resulted in slow decomposition rate compared to guava and mango leaf litter. The decomposition of leaf litter of orchards grown under hot and dry sub-humid climate may be governed mostly by the initial lignin rather than N content. The N, P and K availability in mango leaf litter (1.17 t/ha) was prolonged for 1.23, 1.22 and 1.07 years, respectively with N, P and K release of 1000, 88 and 800 g/ha/month (2.5g: 0.22g: 2g NPK/plant with 400 plants/ha) in 7-year-old orchard. The N, P and K availability in litchi leaf litter was prolonged for 4.13, 4.56 and 3.06 years, respectively.

Recycling of farm residue and biomass through vermicomposting

The farm residue and biomass namely banana leaf, cucumber vine, tomato vine, muskmelon vine, ridgegourd vine, bottle gourd vine, watermelon vine were recycled through vermicomposting (Fig. 7.4). During the pre-digestion period, the temperature of the crop residues varied from 40-45^{o}C, which gradually decreased and at-

Banana leaf | Cucumber vine | Tomato vine

Muskmelon vine | Ridge gourd vine | Bottle gourd vine

Fig. 7.4. Recycling of farm residue and biomass through vermicomposting

tained stable temperature of 25-30°C after one month of digestion. The pre-digested residues were subjected to vermicomposting after one month of decomposition. The vermicomposting recovery (%) varied from 20-30% among the crop residues. The highest recovery of vermicomposting was 30.5% in muskmelon with composting period of 73 days, while, banana leaf took highest composting period of 102 days with 23.6% recovery. The N- content of vermicompost was highest of 2% in banana leaf, muskmelon vine and ridge gourd vine. Similarly, the P-content of vermicompost was highest of 0.5% in ridge gourd vine, while, the K-content was highest of 1% in muskmelon vine.

Diversification of rainfed upland rice system in Eastern Plateau and Hill Region

Under rainfed upland condition of Eastern Plateau and Hill Region, an experiment on diversification of direct sown upland rice area was conducted with crops like black gram, horse gram, pigeon pea and vegetable cowpea as sole crop or in combination with rice or finger millet. The sole crop of vegetable cowpea recorded the maximum rice equivalent yield of 13.19 t/ha followed by that of pigeon pea (9.41 t/ha), horse gram (6.15 t/ha), black gram (6.10 t/ha) and finger millet (4.21 t/ha). So, diversification of rainfed upland rice system with vegetable, pulses and millets was found to be more profitable in Eastern Plateau and Hill Region. The BC ratio of cultivation of vegetable cowpea was maximum (3.69) followed by that of pigeon pea (2.35), whereas cultivation of rainfed upland rice was found to be non-remunerative (BC ratio 0.58). Negative balance in content of soil nitrogen, phosphorus and potassium was recorded in diversified rice production system. After crop harvest, actual balance of nitrogen in soil ranged from -11.7 kg/ha in (Rice+Black gram) production system to -31.7 kg/ha in sole crop production system of horse gram. Actual balance of phosphorus in soil ranged from -5.8 kg/ha in sole crop production system of horse gram to -25.6 kg/ha in sole crop production system of finger millet whereas actual balance of potassium in soil ranged from -4.8 kg/ha in (Rice+Black gram) production system to -48.9 kg/ha in sole crop production system of pigeon pea.

7.2 Genetic Resource Management and Improvement of Horticultural crops

Evaluation of advance breeding lines and maintenance breeding in Solanaceous and Cucurbitaceous vegetable crops

Describpted in Table 7.1

Table 7.1 The following varieties/ hybrids of vegetable crops were developed and released:

Sr	Crop	Variety/Hybrid	Details
1.	Brinjal	Swarna Abhilamb	CVRC, 2007, Gazette No.655
2.		Swarna Mohit(F_1)	Identified for release by CVRC 2008
3.		Swarna Neelima (F_1)	CVRC, 2008, Gazette No.999
4.		HABR-21	Identified for release during 31st AICRP group meeting held at CSKHPKV, Palampur (2013)
5.	Tomato	Swarna Vijaya (F_1)	CVRC, 2008, Gazette No.999
6.		Swarna Deepti (F_1)	IVRC, 2011
7.		Swarna Anmol (F_1)	Identified for release through SVRC, Govt of Jharkhand, 2015
8.		Swarna Kanchan (Processing type)	Identified for release through SVRC, Govt of Jharkhand, 2015
9.		Swarna Ratan (Cherry type)	Identified for release through SVRC, Govt of Jharkhand, 2015
10.	Chilli	Swarna Praphulya	Identified for release through SVRC, Govt of Jharkhand, 2015
11.		Swarna Tejaswi (pickle type)	Identified for release through SVRC, Govt of Jharkhand, 2015
12.	Capsicum	Swarna Atulya	Identified for release through SVRC, Govt of Jharkhand, 2015
13.	Ridge gourd	Swarna Sawani (Satputia)	Identified for release through SVRC, Govt of Jharkhand, 2015
14.	Bottle gourd	Swarna Sneha	Identified for release through SVRC, Govt of Jharkhand, 2015
15.	Bitter gourd	Swarna Yamini	Identified for release through SVRC, Govt of Jharkhand, 2015
16.	Pointed gourd	Swarna Suruchi	IVRC, 2011
17.	Pumpkin	Swarna Amrit	Identified for release by CVRC 2009

Genetic enhancement of tomato for nematode and bacterial wilt resistance through molecular markers

The objective of this study was to identify resistant genotypes for both bacterial wilt and root knot nematode and comparing of molecular markers for efficient and rapid screening. Twenty genotypes of tomato were screened under artificial conditions for wilt and root knot nematode. Among them, EC-596747, HAT-296, HAT-305 and Swarna Lalima were resistant for bacterial wilt. HAT-310 and HAT-311 (Fig 7.5) were found tolerant to root knot nematode. Among the crosses made, HAT-311 x Swarna Lalima, HAT-296 x HAT-310, HAT-296 x HAT-311 and EC-596747 x HAT-311 were found tolerant to root knot nematode and HAT-296 x HAT-311, HAT-296 x HAT-310, Swarna Lalima x HAT- 311, Swarna Lalima x HAT- 310 and HAT-296 x HAT-302 were found bacterial wilt resistant. To confirm the genetic resistance, mo-

Fig. 7.5. Swarna Lalima x HAT-311

lecular markers namely REX-1, JB-1, PMi12 and Mi23 for RKN resistance were used to characterise the phenotypically resistant germplasm. Mi23 which is a co-dominant marker produced 380 bp fragments for the homozygous genotype (Mi/Mi) *i.e.* HAT-310 and HAT-311. Tomato plants which lack the Mi-1 locus yielded the 430 bp fragment. Swarna Lalima x HAT-310, EC-596743 x HAT-310, HAT-311 x Swarna Lalima, HAT-296 x HAT-311, EC-596747 x HAT-311, Swarna Lalima x HAT-311 yielded two fragments 380 bp and 430 bp indicating heterozygous nature of resistance. Resistant genotype Swarna Lalima x HAT-311 (50 t/ha) identified from the present study is being tested under multi location trials of AICRP(VC).

Collection, characterization and evaluation of potential wild edibles including tuber crops

Totally 256 germplasm of tuber crops *viz*., *Dioscorea* spp. (56), *Ipomoea batatas* (12), *Maranta arundinacea* (3), *Colocasia* spp. (112), *Amorphophallus* spp. (47), *Alocasia* spp. (7), *Manihot* spp. (7), *Xanthosoma* spp. (5) and *Cucumis melo var. agrestis* (7) were collected throug h 13 surveys in tribal dominated areas of Jharkhand, Chhattisgarh, Odisha, West Bengal and Nagaland. The promising genotypes identified are as follows (Fig 7.6):

- **ACC-161** (a collection from Mardu village under Silli block of Ranchi district of Jharkhand; tuber yield 8.25 t/ha; tuber carbohydrate 17.09 g/100g; total mineral 672.92 mg/100g; anti-oxidant activity 186.89 mg AEAC/100g; beta carotene 7775.28 mg/100g; total sugar 3.86%) in sweet potato**.**
- **ACC-60** (a collection from Sarepahari village under Jama block of Dumka district of Jharkhand; corm yield 748.50 g/plant; 37.42 t/ha; corm carbohydrate 39.29 g/100g; total mineral 1.604g/100g; anti-oxidant activity 284.01 mg AEAC/100g; leaf oxalate 67.47 mg/100g; corm oxalate 45.66 mg/100g; petiole oxalate 10.69 mg/100g) in Taro/Colocasia**.**
- **ACC-136** (a collection from Chirkubera forest under Bandgaon block of West Singhbhum district of Jharkhand; corm yield 2.63 kg/plant; 32.87 t/ha; corm carbohydrate 24.36 g/100g; total mineral 503.09 mg/100g; anti-oxidant activity 50.31 mg AEAC/100g; oxalate 9.22 mg/100g) in Elephant foot yam.
- **ACC-139** (a collection from Chirkubera forest under Bandgaon block of West Singhbhum district of Jharkhand; tuber yield 19.75 t/ha; tuber carbohydrate

30.68 g/100g; total mineral 751.89 mg/100g; anti-oxidant activity 297.71 mg AEAC/100g) in Cassava/tapioca.

- **ACC-28** (a collection from Katud nichetola village under Khunti block of Khunti district of Jharkhand; ORSI value 1.77; aerial tuber yields 9.18 t/ha; tuber carbohydrate 17.01 g/100g; protein 5.05 g/100g; total mineral 1.8 g/100g; anti-oxidant activity 65.64 mg AEAC/100g) in Potato/aerial yam.
- **ACC-34** (a collection from Tunko village under Namkum block of Ranchi district of Jharkhand; tuber yield 42.77 t/ha; tuber carbohydrate 15.61 g/100g; total mineral 642.13 mg/100g; anti-oxidant activity 102.76 mg AEAC/100g) in Greater yam.
- **Lotni** (a variety from Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar; tuber yield 30.77 t/ha; tuber carbohydrate 22.24 g/100g; total mineral 516.50 mg/100g; anti-oxidant activity 187.95 mg AEAC/100g) in Lesser yam.
- **HAYB-1** (A collection from village Khirpai of Pashchim Medinipur district of West Bengal; 52.22 t/ha) in Yam bean.
- **HAWMM-1** (a collection from Jata village under Garhwa block of Garhwa district of Jharkhand; fruit yield 3.32 t/ha; fruit carbohydrate 1.94 g/100g; protein 1.21 g/100g; total mineral 2.99 g/100g; anti-oxidant activity 866.67 mg AEAC/100g) in Wild musk melon.

Taro genotype ACC-60

Potato yam genotype ACC-28

Greater yam ACC-34

Elephant foot yam ACC-136

PCassava ACC-139

Sweet potato ACC-161

Fig. 7.6. Wild edibles including tuber crops

Plant Genetic Resource management of fruits crops

Collection and conservation of germplasm: During the period surveys were conducted in Jharkhand and Bihar to identify the promising fruit germplasm. Promising litchi (04), early vegetable type jackfruit (06), Jamun (02), red flesh guava (12) and custard apple (03) were identified during the period. An early vegetable type Jackfruit Selection from Baradari, Ranchi was registered with NBPGR (IC-0625182).

Evaluation of fruit germplasm/varieties: The fruit germplasm/varieties of mango (160), litchi (35), jackfruit (65), sapota (12), bael (75), tamarind (30) etc. conserved at the centre were evaluated for the quality parameters to identified the most promising germplasm/variety. Based on the fruit yield and quality sapota variety Murabba (pulp 88-90%, TSS 26.5°B) and bael germplasm BS 6/1 (pulp 85-90%, TSS 44.80°B) were identified the most promising for the region.

Development of coloured mango hybrids: Efforts were made to develop mango hybrids with red peel colour having desirable quality. Langra and Amrapali were used as a female parent and Sensation and Vanraj were used as male parents. During the period, total 3925 number of crosses was made and total six hybrids were obtained which have been planted in the field.

Fig. 7.7. Sapota variety Murabba Fruits

Developing national repository and creating facilities for DUS testing in Litchi (Litchi chinensis) (Externally funded, PPV&FRA)

Characterization of reference varieties is the basic need for developing DUS testing guidelines. Systematically collected DUS characterization data and reference variety are the basic needs for DUS testing and IPR issues. So far, for litchi, not much characterization studies have been conducted specifically keeping in view DUS testing of litchi. Since litchi is a tree crop and require several years to come into fruiting and there is need to strengthen DUS related national level information on this most important fruit crop. Keeping this in view the project was undertaken with the objective to develop characteristic database of litchi varieties from DUS point of view and to validate litchi descriptors for their utility for developing DUS guidelines. Based on characterization of 33 litchi genotypes, a total of 25 characters have been identified for DUS testing of litchi and the document on "Guidelines for Conduct of Test for distinctiveness, uniformity and stability of Litchi (*Litchi chinensis* Sonn.)" have been published by PPV&FRA.

Nutritional characterization of underutilized leafy vegetables of Jharkhand

A total of 70 potential underutilized leafy vegetables including fresh leaves, tender shoots, flowers, flower buds, young fronds commonly consumed as vegetables by tribals of Jharkhand, Odisha and West Bengal were collected and identified. The underutilized leafy vegetables are sold in both fresh as well as dried form in tribal markets. Study on the quantification of underutilized leafy vegetables sold in fresh form in the market showed that *Amaranthus viridis* had the highest share (36%) followed by *Amaranthus gangeticus* (33%), *Ipomoea aquatica* (14%), *Basella alba* (5%), *Chenopodium album* (5%). However, among the underutilized leafy vegetables sold in dried form in the markets *Cassia tora* (43%) was found to have the highest share followed by *Vangueria spinosa* (18%), *Ipomoea batatas* (17%), *Antidesma diandrum* (8%) and *Moringa oleifera* (8%). Among the 70 underutilized leafy vegetables, leaves of *Moringa oleifera* showed highest ascorbic acid content (156.92 mg/100g FW), *Amaranthus dubius* recorded highest total carotenoids content (182.81 mg/100gFW), *Cassia tora* recorded highest antioxidant activity (2158.70mg AEAC/100g FW) and *Leucas plukenetii* showed highest total phenol content (855.43 mg GAE/100g FW).The flower of *Indigofera pulchella* contains lowest oxalate content

Fig. 7.8. Guidelines for Conduct of Test for distinctiveness, uniformity and stability of Litchi

Moringa oleifera *Amaranthus dubius* *Cassia tora* *Leucas plukenetii*

Fig. 7.9. Leafy vegetables having high nutritional property

(38.25mg/100g) and lowest nitrate content (86.87mg/100g).An Acceptable Daily Intake (ADI) for nitrate of 3.7 mg/kg b.w./day, equivalent to 222 mg nitrate per day for a 60 kg adult was established by the former Scientific Committee on Food (SCF) and was reconfirmed by the Joint FAO/WHO. Thus, if the daily intake of leafy vegetable is 100 g, then most of the species analyzed contain nitrate in safe limit for human consumption.

Improved Production and Protection Technologies for Agri-Horti Crops

Standardization of Basin Enrichment under High-density Orchards of Bael

The trial is being undertaken to identify the most effective biomass yielding plant to be grown in the alley area of high-density orchard for basin enrichment of bael. During the fifth year of experimentation, the maximum dry biomass yield was recorded in case of weeds (26.7±1.48 t/ha) followed by subabul (18.2±2.26 t/ha) (Fig. 7.10). But there was drastic reduction in the dry biomass yield of Tephrosia which started from the 4th year (Fig. 7.10). However, estimation of cumulative nutrient content which has been recycled into the plant basin during the last five years indicated maximum values with Tephrosia (Nitrogen- 4.17 t/ha, Phosphorus - 0.23t/ha and Potassium-1.50 t/ha) (Fig. 7.11). The significant effects of the treatments on basin enrichment were recorded on organic carbon (%) in the soil at both 0-15 cm and 15-30 cm depths. At 0-15 cm soil depth, all the treatments had resulted in significantly higher

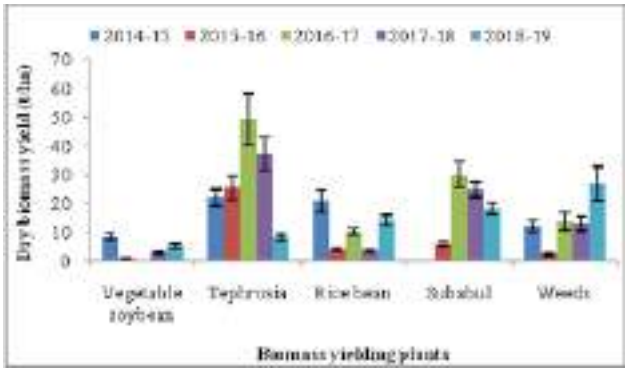


Fig. 7.10. Dry biomass yield of different plantsduring last five years

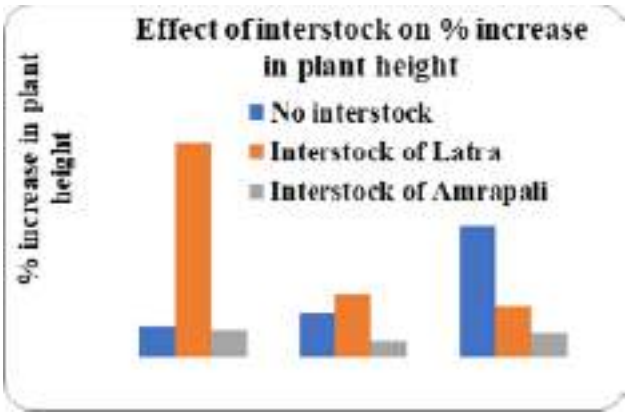


Fig. 7.12. Effect of interstock on plant growth

soil organic carbon content (ranging from 0.56± 0.05 % to 0.79± 0.08 %) over that of control (0.44± 0.06 %), whereas at 15-30 cm soil depth, soil incorporation of Tephrosia biomass resulted in significantly higher organic carbon (0.71± 0.16 %) over control (0.37± 0.07 %). The increase in the soil available phosphorus content at 0-15 cm depth was mainly recorded as maximum in case of mulching of Tephrosia (21.38± 1.23 kg ha^{-1}) and Vvegetable soybean (21.13±1.19 kg ha^{-1}).

Standardization of interstock for induction of dwarfing in vigorous mango cultivars growing under eastern plateau and hill conditions

The mango hybrid Amrapali and and genotype Latra are known for their dwarf tree size. Although fruits of Amrapali and Latra are abundantly available, due their monoembryonic nature limits their use as dwarfing rootstocks. No information was available on behavior of mango *cv* Amrapali and Latra as interstock. Keeping this fact in view we undertook an investigation to test the efficacy of these genotypes to be used as interstocks for reducing the plant size of vigorous but popular mango varieties *viz*. Langra, Himsagar and Bombay Green under eastern plateau and hill conditions.

The present study clearly indicated effects of different interstock on plant growth parameters where interaction between interstock and genotype played important role. After four years of planting reduction in the growth rate of rootstock was recorded in of Mango cv Himsagar on interstock of Amrapali. Reduction in number of flushing and average length of extension growth was found to have contributed towards reduction in the overall plant growth of mango cultivars Himsagar and Bombay Green with interstock of Amrapali. Hence, use of interstock of Amrapali can be an effective strategy for reducing the plant vigour of mango cultivars Himsagar and Bombay Green under the eastern plateau and hill conditions of India.

Biology, seasonal incidence and management of stink bug, *Tessaratoma* sp. on litchi

Biology, morphometrics of life stages and mtCOI (DNA barcodes) based identification has been done and stink bug infesting to litchi in Jharkhand found as *Tessaratoma javanica* (Thunberg) (Hemiptera: Tessaratomidae). mtCOI based 658 bp barcode fragment sequences which facilitating molecular diagnostics of the adults and other life stages of *T. javanica* are available in the GenBank (Accession nos. HQ236466 and AY252948).

Fig. 7.13. Severe infestation of litchi bug

The litchi stink bug, *Tessaratoma javanica* eggs (Fig. 7.14) females were found to start laying eggs from February and peak activity was recorded in the month of March to April during both years. In search natural enemies, three egg parasitoids of litchi stink bug were recorded, two were from the family Eupelmidae and one was from the family Encyrtidae of order Hymenoptera. Among parasitoids recorded, only two were identified up to species level namely *Anastatus bangalorensis* and *Anastatus acherontiae*. Egg parasitization by these two parasitoids were recorded nearly 46.12%, in insecticides free litchi orchard.

Fig. 7.14. Litchi stink bug, Tessaratoma javanica

Bio-intensive integrated pest management module against litchi stink bugs has been standardized. The management module includes, the mechanical destruction of hibernated population using kerosinized water, first spray of lambda cyhalothrin+diclorvos (DDVP) @ 0.5+1.0 ml/litre of water in the last week of December month, second spray of dimethoate @0.05% in second week of February on immigrated population after panicle emergence and before flower opening with mechanical exclusion of parasitoids, third spray of imidacloprid @0.005% at100% fruit setting stage and fourth spray of acephate @ 0.1% at pea stage of fruits, if needed.

Fruit Flies (Tephritidae: Diptera) diversity and their Host Plant Determination from Eastern Region of India

Under this project, extensive surveys were made in Faizabad (U.P.), Varanasi (U.P.), Jaspur (Chhattisgarh), Motihari, Patna, Dharbhanga (Bihar), Murshidabad (W.B.), Cuttack (Odisha) and Ranchi, Lohardaga, Gumla districts of Jharkhand for determination of species of fruit flies in eastern part of India. The survey reports revealed that three fruit flies species *viz., Bactrocera dorsalis*, *B. correcta* and *B. zonata* were in methyl eugenol while *B. cucurbitae* and *B. tau* were in cue-lure para-pheromone traps dominating the respective places. Under the yield loss assessment by fruit flies, percent infestation varies with locations but it was found that infestation ranges vary from 10% to 60 % on vegetables and fruit crops in surveyed places of eastern part of India.

Deltamethrin and Spinosad were found effective against the fruit flies' infestation which can be used for the management of fruit flies in cucurbits.

Integrated Land and Water Management

Evaluation of hydrological response of micro-watersheds in Eastern Plateau and Hill Region

Hydrological processes in a mixed land use watershed are significantly influenced by land use and land cover. Knowledge about the basic hydrological processes occurring in watersheds is important to understand the impact of land cover, morphologic and topographic factors on soil and water resources within the watersheds. For this purpose, two watersheds namely, Plandu in Ranchi district and Keribanda in Hazaribagh district of Jharkhand, having distinct land use land cover (LULC) patterns, were considered in this study. Morphological properties of the watershed like area, slope was determined using ArcGIS package.

During the three study years, the peak discharge of Plandu and Keribanda varied from 5.35-8.58 m^3/s and 8.4-11.8 m^3/s, respectively while the water yield varied from 3.70-5.72 MCM and 5.00-6.51 MCM, respectively. The three-year average annual sediment loss in runoff water was 433.8 and 359.5 ton which was equivalent to 0.28 and 0.19 t/ha for Plandu and Keribanda watersheds. This implies that the average soil loss from forested watershed (Keribanda) was 32% less than agricultural watershed (Plandu). The nutrient loss in runoff water varied from 16.25 to 37.1 t/year for Plandu watershed, while it was in the range of 39.6 to 58.0 t/year for Keribanda watershed. Among both the watersheds, the *K* loss was highest during all the three years of study. Comparison of weekly nutrient loads in runoff water showed that nutrient loss was highest in the months of July and August, a period that coincides with maximum agricultural activity.

Estimation of runoff and soil loss from fruit orchards under EPHR

Keeping in view that quantifying and analysing the runoff and sediment loss from different orchard production system could help with the understanding of key hydrological processes within the watershed having vast areas under orchards, this study was aimed at evaluating the response of different orchard production systems in terms of their runoff production and sediment loss potential. Five largely grown fruit orchards of Eastern Region *viz.* litchi+guava, litchi, mango, guava and jackfruit were selected for these assessments.

Percentage of rainfall converted into runoff was varied from 0.8% (litchi) to 4.8% (Guava). The soil loss from orchards was recorded at 31.7, 11.2, 16.3, 33.3 and 19.2 kg/ha from the orchards of litchi+guava, litchi, mango, guava and jackfruit, respectively. Presence of good cover of leaf litter reduced the soil loss from litchi orchards while the higher proportion of the exposed soil surface and lack of proper grass cover increased the soil from guava and Mango+Guava orchards.

Standardization of planting geometry and growth stage-based fertigation patterns for vegetables

- Optimal plant spacing and fertigation are the two management factors that influence yield, nutrient use efficiency and water productivity (WP) of any crop. In this context, a field experiment was conducted to standardize the planting geometry and fertigation practices for drip irrigated chilli, tomato, broccoli and sweet corn in the hot-sub humid region of India.
- *Chilli:* Application of comparatively higher percentage of recommended dose of fertilizer during early reproductive stage (8^{th} to 13^{th} week after transplant) an plating at 40 × 30 cm resulted in highest chilli yield (14.5 t/ha) and water productivity (31.1 kg ha^{-1} mm^{-1}). This treatment also had had highest N recovery of 69.2 and 68.6%; Nitrogen Use Efficiency of 132.6 and 141.3 kg kg^{-1} N, respectively.
- *Tomato:* Significantly higher tomato yields of 87.0 and 89.4 t ha^{-1} were obtained when tomato was planted at 40 x70 cm and 40 x 50 cm spacing in triangulated arrangement in combination with fertigation pattern that applied higher dose of fertilizer during mid-stage of crop growth (7^{th}-11^{th} weeks after transplant). Crop growth was negatively impacted by the plant density. Tomato crop responded well when higher percentage of recommended dose was applied during mid-stage of the crop growth period.
- *Broccoli:* The broccoli crop responded well to the availability of nutrients in the soil during the initial and developmental stage. Higher broccoli yields (313.4 q/ha) were obtained when higher percentage of recommended dose of fertilizer was applied at the developmental stage of crop (8^{th}-11^{th} weeks after transplant) and when crop was planted in triangulated geometry with plant-to-plant and row-to-row spacing of 40 cm and 30 cm, respectively.
- *Sweet corn:* Application of higher percentage of recommended dose of fertiliser during development stage of the crop (10^{th}–12^{th}weeks after transplant) and planting at 15 x 20 cm spacing (plant population of 1, 33, 300 plants per hectare) resulted in maximum cob yield of 213.0 q/ha. This combination of fertigation pattern and planting geometry recorded maximum water productivity of 7.4 kg/ m^3.

Evaluation of vegetable cropping sequences under drip irrigation with mulching in Eastern Hill & Plateau region

The experiment was conducted with three irrigation methods comprising of drip irrigation (DI), drip irrigation with bicolor polythene mulch (DIM) and furrow irrigation (FI). The response of crops *viz*. cabbage, cauliflower and broccoli in *Rabi*;

okra, cowpea and French bean in *Zaid* and tomato, vegetable soybean and capsicum in *Kharif* was evaluated in terms of yield, water productivity and economic water productivity.

During the rabi season the DIM resulted in highest curd yields of 31.25, 26.34 and 10.13 t/ha for cabbage, cauliflower and broccoli, respectively with respective water productivities of 14.83, 12.61 and 4.72 kg/m^3 (Fig. 7.15). During subsequent summer season cowpea, okra and capsicum (Fig. 7.16) were planted on the same beds without disturbing mulch and drip while fields were prepared in furrow irrigation. In case of the summer crop, the DIM resulted in highest fruit yield of 7.87, 10.32 and 2.8 t ha^{-1} for Okra, Cowpea and French bean, respectively. The DIM also showed highest water productivity for these crops.

The seasonal water balance of furrow and drip irrigation methods was assessed under field conditions. The analysis revealed that, deep percolation loss of 139.3 and 30.4 mm was observed under furrow and drip irrigation systems, respectively, which was about 42.2 and 11.2% of the total seasonal water applied to the crop.

Fig. 7.15. Field view of cabbage-cauliflower-broccoli during Rabi season

Fig. 7.16. Field view of okra-cowpea-french-bean during Zaid season

Evaluation of soil fertility status of acid soils of different mango orchards of Eastern Plateau and Hill Region

Different mango orchards with age group of 1-3, 4-5, 6-7 and 9-10 year were evaluated for soil fertility status in Jharkhand state. The soils of different orchards are low in organic carbon, available N, available P and DTPA-Zn; sufficiency in exchangeable K. DTPA-Fe, Mn and Cu were high. The DTPA-extractable Fe was high up to 90 cm depth of soil profile in all the orchards and varied from 18-60 mg kg^{-1} being highest at surface soil. The DTPA-extractable Mn content was high throughout the soil profile depth of 120 cm and varied from 16-86 mg kg^{-1}. The exchangeable Al content varied from 5-108 mg kg^{-1} throughout the depth of soil profile and highest was recorded in surface soil. The toxic effect of Fe and Mn on the establishment of new mango orchard can be overcome by planting the sapling in a pit size of 90 × 90

× 90 cm^3 in eastern plateau and hill region.

Diagnostic and recommendation integrated system (DRIS) help to diagnose plant nutrient needs early in the life of crops than sufficiency range method. The calcium, sulphur, potassium and boron were most limiting nutrient for young age orchard (6-7 year) whereas, Mg, Zn and B was the most limiting nutrient for older age orchard (9-10 year). Boron was found as the most common nutrient limiting mango yield for all ages of orchard. At pH 4.5 to 5.0 the following nutrients were most limiting in the order as, Ca > K > S > Mg > P > N > B > Zn; At pH 5.1 to 5.5 was as, Ca > Mg > B > N > S > Zn > P > K. Most limiting nutrients in mango orchards at pH 5.6 to 6.0 were B, Zn and N whereas the most limiting nutrients at pH 6.1 to 6.5 were Zn, N, B, S and K. The nutrient balance index was highest of 61.16 in 6–7-year-old orchard compared to 9–10-year-old, caused high imbalance of nutrient, and resulted in lowest yield (5.32 t ha^{-1}). The optimum leaf N for mango ranged from 1.21 to 1.40%, whereas the optimum P ranged from 0.13 to 0.15 %. The optimum K ranged from 0.76 to 0.88%.

Socio-Economics, Extension and Policy Research

Participatory management of rice-fallow in eastern plateau and hill region

The Eastern Plateau and Hill Region itself comprises of more than 80% of India's rice-fallow ecosystem area. Keeping this in view a project was implemented in a participatory mode to increase the productivity and profitability of rice fallow in Hundru and Chhotaghagra villages of Ranchi through efficient utilization of available water resources and introduction of improved practices of vegetable cultivation. Results of the field trials revealed that, in the event of delayed rainfall during 2014, 229-269 mm irrigation ensured timely transplanting resulting in significantly higher paddy yields (6.8 to 7.2 t ha^{-1}).

Fig.7.17a. Bumper crop of Direct seeded rice (DSR)

Fig.7.17b. Early harvest of DSR when transplanted paddy still remaining in the field

Fig.7.17c. Early sowing rabi crop in the DSR grown field when paddy stillremaining

Feasibility of short-duration direct sown rice (DSR) was confirmed experimentally (yield 6.2 t ha^{-1}) in 2014 where conventional rice could not be transplanted due to delayed rains. Application of six numbers of supplemental irrigations during mid-season dry spell during 2015 yielded up to 6.0 t ha^{-1} of paddy as against 0.62 t ha^{-1} recorded in unirrigated fields. Improved cultivation practices like, seed covering with polythene sheet + poly tunnel, nursery raising in pro trays and raised beds + plastic mulch significantly improved productivity of rabi crops like bottle gourd (7.38 t ha^{-1}), sponge gourd (8.15t ha^{-1}) and cowpea (7.38t ha^{-1}). In the uplands, establishment of fruit based multi-tier cropping systems and ultra-high density guava orchards with some access to irrigation ensured better land utilization and provided additional source of income to the farmers. Participatory approach on providing access to irrigation water and technological support for vegetable cultivation has sustained adoption of more diverse and intensive cropping, with significant social and economic benefits.

Study on genetic diversity of makhana

Makhana is a very important aquatic crop of North Bihar, grown in thousands of natural water bodies. In these water bodies, it takes on an average 10 months to complete one cycle. Due to its longer growth period, only one crop of makhana in a year is possible in these water bodies. To enhance the production and productivity of makhana is one of the priorities of the institute.



Fig. 7.18. Technology demonstration on vegetable cultivation in farmers' fields

8. Research Centre for Makhana

Germplasm of makhana were collected from 14 sites of Purnea and Kishanganj districts and 2 from Odisha. Through pure line selection first elite strain (Sel-6) of makhana was developed. On the basis of yield potential, strain (Sel-6), first ever variety of makhana "Swarna Vaidehi" have been developed and released by Central Variety Release Committee (Fig. 8.1). The improved variety has the production potential of 3.0 t/ha against 1.4 - 1.6 t/ha local check at the farmer's fields. This variety sowed 60% higher seed yield compared to local check.

Fig. 8.1. Plant and seeds of Swarna Vaidehi

Sequential double cropping systems of Makhana (*Euryale ferox Salisb.*) cultivation in agricultural fields of north Bihar, India

Makhana (*Euryale ferox* Salisb.) is generally grown once in a year in lowlands of most of the makhana growing districts of North Bihar. Due to this full potential of the lowlands could not be harvested by the farmers. To explore the possibility of two crops of makhana per year in the same field, the present study was conducted during 2011 and 2012 at the Research Farm of ICAR–RCER, Research Centre for Makhana, Darbhanga, Bihar. During both the years, the transplantation of first crop was made in the first week of February and its harvesting was made in the last week of June. In the same field the second crop was transplanted in the first week of July and harvested in the last week of October. All standard packages of practices were followed to raise the good experimental crops of makhana. The mean values of seed yield of spring crop of makhana were observed to be 3.04 t/ha while the yield potential of kharif crop was recorded to be 2.23 t/ha. However, the yield potential of kharif crop was not at par with the spring crop, yet it was very high as compared to the

productivity of traditional crop of makhana in pond system (1.0-1.2 t/ha). The net return of these two makhana crops was recorded as Rs. 1,00,305/- and Rs. 80,205/- for spring and kharif crops, respectively. Findings of this study suggest that per year, two crops of makhana could be grown successfully in the field system of makhana cultivation. Apart from Makhana – makhana cropping system other makhana based cropping systems have also been standardized. Like Makhana (March – July) & Rice (July – November); Makhana (April-August) & Wheat (November - April); Makhana (March – July) & Water chestnut (July – November) and Makhana (April – August) & Berseem (November – April).

Dynamics of nutrients under makhana and makhana-based cropping systems grown in Inceptisols of Northern Bihar

Field experiments were conducted to study the impact of makhana-based cropping systems on fertility status of soil. It was observed that the highest amount of available nitrogen (305 kg/ha) and phosphorus (30 kg/ha) was recorded with makhana-chestnut-berseem cropping system followed by makhana-berseem cropping system. Makhana-chestnut cropping system recorded highest potassium content (240 kg/ha) in soil. The lowest quantity of available nitrogen (206 kg/ha), phosphorus (15 kg/ha) and potassium (210 kg/ha) were recorded with makhana-rice-wheat, makhana-rice and makhana-rice-berseem cropping system, respectively. Soils under makhana-chestnut-berseem cropping system recorded highest content of iron (43 mg/kg) and manganese (15.15 mg/kg) while the lowest content of Fe (25 mg/kg) and Mn (8.13 mg/kg) was found with rice-wheat and makhana-rice-wheat cropping system, respectively. The soils under rice-wheat cropping system contained highest concentration of Zn (0.36 mg/kg) which is 16.66% higher than makhana-chestnut-berseem (0.30 mg/kg) while 8.79% higher Cu content was recorded with makhana-rice-berseem than makhana-chestnut-berseem cropping system. Pertaining to effect of cropping on physical properties of soil it

Fig. 8.2. Pond raised of Swarna Vaidehi

Fig. 8.3. Fully grown Swarna Vaidehi

was observed that Makhana-chestnut-berseem cropping had registered highest water holding capacity of soil at its field capacity (46%) and wilting point (25%) followed by makhana-chestnut cropping system 42 and 21% at FC and WP, respectively.

Chemical composition of makhana (*Euryale ferox* Salisb.)

Euryale ferox significantly contributed 34.35 kg/ha N, 56.04 kg/ha P, 53.07 kg/ha K, 27.26 kg/ha Fe and 12.31 kg/ha Mn to the soil system. However, the total uptake of these nutrients made by Euryale ferox was recorded to be 69.42 kg/ha N, 64.44 kg/ha P, 55.59 kg/ha K, 29.27 kg/ha Fe and 12.39 kg/ha Mn (Table 8.1).

Table 8.1. Nutrient contribution through makhana (*Euryale ferox*) plants to the soil

Plant parts	Dry wt. kg/ ha	N kg/ ha	P kg/ha	K kg/ ha	S kg/ha	Fe kg/ ha	Mn kg/ ha	Cu kg/ ha	Zn kg/ha
Leaf	4750	14.72	22.80	19.00	0.95	10.45	4.75	0.038	0.50
Petiole	1690	4.05	7.77	6.42	0.17	3.85	1.67	0.01	0.13
Root	4240	11.87	16.96	23.32	0.42	10.19	4.45	0.04	0.039
Fruit sheath	1548	3.71	8.51	4.33	0.31	2.77	1.44	0.01	0.14
Total	12228	34.35	56.04	53.07	1.85	27.26	12.31	0.10	1.16
Seed	2100	35.07	8.40	2.52	0.84	2.016	0.08	0.02	0.26
Total uptake	14328	69.42	64.44	55.59	2.69	29.27	12.39	0.12	1.42

Development of makhana based integrated farming systems for lowlands and waterlogged areas of North Bihar

Makhana+ fish+water chestnut, fruit plants, vegetables and poultry (in a 16.72 m^2 area over the pond) were integrated to enhance the net income of traditional makhana ponds. In second, model, makhana+fish-water chestnut, makhana rice-barseem, vegetables, fruit plants, and cattle were tried to augment the net income of makhana based agricultural fields. During the second year (2012-13) net return from all the components in pond model was obtained Rs 37,890 with a gross income of Rs 71,970. While, in field-based model net return and gross income from all components were Rs 47,524 and Rs 80,762, respectively. The comparative analysis of two models indicates that the net return in field based integrated model is approximately 25% higher than the pond-based model.

Integration of fish and horticultural components for improving the productivity of makhana *(Euryale ferox Salisb)* ponds

In this system, there were three component combinations namely makhana+fish, makhana+fish+horticultural crops and makhana + water chestnut. The most remuner-

ative component combination was Makhana + fish+horticulture. Under Makhana+fish +horticulture, the average yield of Makhana and fishes obtained were 1.2 and 0.31 t/ha, respectively. The gross and net return from the system, including horticultural crops (consists 20% raised area to grow fruit plants like mango, (Amprali), guava, citrus, papaya, banana and some seasonal green vegetables were estimated as 1, 19,246 and 50,439/-ha, respectively. However, net return on Makhana cultivation alone, Makhana-fish culture and Makhana-water chestnut was obtained as Rs 25,725/-, Rs 37,660/- and Rs 41,745/-, respectively.

Field based integrated Makhana cultivation

Integrated fish and singhara with makhana was developed in 50 ha of land in Darbhanga district (fig. 8.4). The net benefit from the system was recorded at Rs. 52,435/- as compared to traditional system (makhana production alone) of Rs. 20,614/-. The makhana contributed the major share of around 40% followed by fish at 22.5%. Field-based system of makhana cultivation was standardized with other crop like fish, rice, and water chestnut in cropping system mode. The gross return from makhana-fish, makhana-rice and makhana-water chestnut was obtained as Rs. 2,82,810/-, 2,73,480/- and 3,54,340/- per ha, respectively while a gross return of Rs. 1,32,552/- was obtained from makhana cultivation alone. The net return from the above system was recorded at Rs. 1, 21,520/-, 1, 16,322/- and Rs 1, 56,436/- per ha, respectively as compared to Rs. 88,368/- per ha in makhana cultivation alone.

Fig. 8.4. field based integrated makhana

Comparison of fertility status of soils under pond and field-based IFS model

Comparison of fertility status of soils under pond and field Makhana-based IFS model was made. Soils of both pond and field are slightly acidic to alkaline in reaction. The organic carbon content of pond soil (0.58%) was 30% higher than the field soil (0.42%). Pond soil registered 29 percent higher available phosphorus (23 kg/ha) than the field soil (17 kg/ha). The pond soil also recorded 25%, 23%, 19% and 26% higher concentrations of Fe (39 mg/kg), Mn (16 mg/kg), Cu (2.10 mg/kg) and

Zn (0.38 mg/kg), respectively than the field soil [Fe (29.25 mg/kg), Mn (12.32 mg/kg), Cu (1.70 mg/kg) and Zn (0.28 mg/kg)].

Soil Fertility Status of six years old makhana growing pond

The soil nutrient status of six-year-old makhana pond was assessed to understand the nutrient status of the pond. The properties soils of makhana pond ranges like pH 6.65-6.74, EC 0.24-0.28 dS m^{-1}, organic carbon 0.35-0.58%, available nitrogen 232-250 kg ha^{-1}, available phosphorus 17-32 kg ha^{-1} and available potassium 311-632 kg ha^{-1}. The above soil properties revealed that makhana cultivation maintained the soil to slightly acidic to neutral condition which may be due to continuous deposition of organic matter and its decomposition in the soil. The electrical conductivity was also recorded far below the hazardous level. The organic carbon was also got double than its initial contents in the soil. The makhana cultivation was found to be highly beneficial in increasing the content of available phosphorus and potassium contents which is helpful in maintaining the resilient properties of soil.

Integrated nutrient management on the production potential of makhana crop growing under field condition in Northern Bihar

Soil physico-chemical properties, excepting soil reaction and electrical conductivity, all other properties were significantly affected due to INM treatments. Considerable increase in organic carbon value was noticed with 100% NPK + 100% (20 t/ha) compost. A consistent and significant increase in available N, P and K status of soil was observed with successive increase in the doses of NPK fertilizers. This could be attributed partly to the chemical composition of the treatments. However, the availabilities of organic C, available N, P and K were enhanced only at the higher levels of fertilizers combined with the compost.

Pertaining to the effect of INM treatments on micronutrient status of soil, the availability of Fe, Mn, Cu and Zn in soil solutions got increased. The treatment comprising 100% NPK + 100% compost recorded the highest concentration of iron (49 mg/kg), manganese (27 mg/kg), copper (2.51 mg/kg) and zinc (0.92 mg/kg). Application of N, P and K in different combinations brought significant variation in the seed yield. There was increase in seed yield with increasing doses of fertilizers; however, increase was significant only up to 100% NPK + 100% (20 t/ha) compost. Maximum yield (3.2 t/ha) was recorded with application of 100% NPK + 100% (20 t/ha) compost which was statistically at par with application of 100% compost. The increase in yield might be due to the higher availability of nutrients. The treatment 100% NPK + 100% (20 t/ha) compost was also found to be superior in improving the physical properties of soil as compared with other INM treatments.

Evaluation of different genotypes of water chestnut (Trapa bispinosa)

Water chestnut (*Trapa bispinosa*) popularly known as singhara or *paani phal is* mainly grown in Madhya Pradesh, Uttar Pradesh, Bihar and Odisha. On the basis of fruit morphology water chestnut could be divided into thorny.

Since there is no recognized variety of water chestnut, a varietal development programme of water chestnut was initiated. Germplasms of water chestnut was collected from north Bihar, Ranchi, Odisa and Madhya Pardesh. As per study protein, fat, crude fibre and minerals of water chestnut were 4.7, 0.3, 0.6 and 1.1 % respectively. Nutrient content of different tissues like root, leaves and fruits of water chestnut was also studied.

Moreover, water chestnut contributed 7.54 kg/ha/yr N, 14.40 kg/ha/yr P, 16.20 kg/ha/yr K, 3.66 kg/ha/yr Fe and 0.85 kg/ha/yr Mn to the soil system. The total uptake of nutrients made by water chestnut was 21.91 kg/ha N, 21.58 kg/ha P, 17.40 kg/ha K, 1.48 kg/ha S, 3.83 kg/ha Fe, 0.878 kg/ha Mn, 0.035kg/ha Cu and 0.601 kg/ha Zn.

Fig. 8.5. Thornless red colour plant & fruit of water chestnut plant

Nutritional properties of water chestnut *(Trapa bispinosa)*

Nutritional characteristics of germplasm water chestnut collected from different areas have been made (Table 8.2). The considerable variation in nutritional quality of water chestnut was observed. The germplasm of water chestnut collected from MP,

U.P and Bihar were evaluated for nutritional quality. The maximum acidity (0.083%), reducing sugars (2.96%), non-reducing sugars (1.69%), total sugars (4.61%), sugar/acid ratio (55.54) and TSS (9.50Brix), protein (5.1%), fat (0.2%), fiber (0.4%), carbohydrate (23%) and mineral (1.0%) was recorded in Red Spineless germplasm collected from M.P. The Green Spineless exhibited the maximum yield of 12.00 t/ha followed by Red Spineless (9.50 t/ha). Water chestnut beetle (Galerucella birmanica Jacoby.) was found to be the more dangerous pest under wet land

Table 8.2 Nutrient content of tissues of water chestnut

Elements	Leaves	Roots	Ratio of roots/leaves	Fruit
C	32%	23%	0.718	-
N	0.42%	0.26%	0.620	0.80%
P	0.80%	0.68%	0.850	0.41%
K	0.85%	0.70%	0.823	0.11%
S	0.03%	0.05%	1.666	0.04%
Fe	1989 mg/kg	2080 mg/kg	1.045	118 mg/kg
Mn	350 mg/kg	550 mg/kg	1.571	22 mg/kg
Cu	15 mg/kg	17 mg/kg	1.133	10 mg/kg
Zn	280 mg/kg	200 mg/kg	0.714	120 mg/kg

ecosystem as compared to aphid. Green colored germplasm collected from M.P. also noticed to be comparatively more resistant to beetle and aphid.

Introduction of sweet flag and vegetable Alocasia with makhana crop under wetland ecosystem of north Bihar

Eight Sweet Flag (*Acorus calamus*) germplasm collected from Jharkhand, Bihar and Karnataka were evaluated at Research Centre for Makhana, Darbhanga. It was found that Tumkur-1 collected from Karnataka was indicated as Superior in terms yield (Rhizome) (8.1 t/ha) and recorded about almost double income as compared to local cultivars Araria-1.

Seven *Alocasia* (*Alocasia montana*) germplasm were collected from ICAR-RCER, RC, Ranchi. Collection 7 (ICAR-RCER-RC-7) was found superior in comparison to others in terms of yield (22.9 t/ha.) potential. The germplasm Alocasia-18 and Ranchi-3 were also found superior in terms of low co-oxalate content 67.8 mg/100 g and 13.5 mg/100 g, respectively. Protein content of these germplasm were 4.05 and 3.58%, respectively.

Fig. 8.6. Sweet Flag

Fig. 8.7. Tumkur-1 germplasm of Sweet Flag

Fig. 8.8. Superior germplasm of Alocasia: ICAR-RCER-RC-7

Development of value-added product of makhana

Makhana powder was developed at the research Centre for Makhana, Darbhanga and nutritional quality of makhana powder was als analysed. The 100 g makhana powder contains 0.3% fat, 9.1% protein, 0.2% crude fiber, 81% carbohydrates, 360 K. cals calorific value, 60.2 mg phosphorus, 50 mg potassium, 1.5 mg iron, 15.5 mg calcium, 12.0 mg magnesium, 70 mg sodium, 0. 1 mg copper, 1.5 mg manganese and 1.0 mg zinc.

Raw makhana puff | Course powder | Fine powder

Fig. 8.9. Value added products of Makhana

9. Theme wise Institute Research Projects during 2012-13 to 2016-17

Theme: 1 Farming system research including Climate resilient agriculture

1. Integrated Farming System and Cropping system for Eastern Region

- Developing sustainable farming system models for prioritized micro watersheds in rainfed areas of Jharkhand
- Development of location specific Integrated Farming System models for rainfed eco-system of Eastern Plateau Hill region
- Development of guava + pineapple based multistoried cropping system under irrigated conditions of Eastern Plateau region.
- Development of location specific Integrated Farming System models for small and marginal farmers of Bihar
- Development of makhana based Integrated Farming System models for low land eco-system
- Development of multi-tier cropping system for rainfed uplands of Eastern Plateau and Hills
- Dynamics of nutrients under makhana and makhana based cropping system grown in inceptisols of Bihar
- Eco-energetic analysis of different cropping system in Eastern India.
- Evaluation and optimization of IFS
- Farmers Participatory Evaluation of Basic slag in Acidic soils of Jharkhand under different cropping systems
- Integrated farming system for improvement of nutrition and livelihood of farm women
- Introduction of sweet flag and tuber vegetable crop under wetland ecosystem with makhana crop for north Bihar
- Multiplication and production profiling of improved pig and poultry germplasm under Backyard farming system
- Optimization of production efficiency in livestock- fish integrated farming system

- Studies on irrigation and nutrient requirement of diversified cropping system in irrigated eco-system of Central Bihar.
- Tribal farming system in Eastern India

2. Resource Conservation Technology

- Accelerating RCTs adoption to improve food security and rural livelihoods while reducing adverse environ-mental impacts in Indo-Gangetic plains-IFAD
- Cereal Systems Initiative for South Asia (CSISA) phase II
- Crop and resource management practices for sustainable future cereal-based systems
- Evaluation of Conservation Agricultural (CA) practices under Rice-fallow system of Eastern Region
- Evaluation of different production system for Carbon sequestration potential
- Evaluation of vegetable cropping sequences under drip irrigation with mulching in EPHR
- Evaluation of vegetable varieties under different irrigation methods
- Resource conservation and methods of planting in acid soil by vegetable based cropping system
- Sustainable Resilient Farming System in intensification (SRFSI) in the Eastern Gangetic Plane

3.Climate Resilient Agriculture

- Diversification of rice-wheat system through climate resilient cropping in Eastern India.
- Impact assessment of climate change on water resources and their productivity
- Impact of elevated CO_2 and temperature on growth and yield of rice-wheat cropping system under predicted climate change scenario.
- Land suitability classification for different crops using remote sensing and GIS
- Management of high intensity rain events in flood prone region of middle IGP for kharif crops and low temperature in Boro rice in Eastern IGP (NICRA)
- Modeling the performance of a new major cropping system in Eastern India in the light of projected climate change. (NAIP)
- Understanding the changes in host-pest interactions and dynamics in mango under climate change scenario (NICRA)
- Weather based forecasting for agricultural growth in Eastern India
- Weather crop-pest-disease interaction studies of major crops of Eastern Region

Theme: 2 Genetic Resource Management and Improvement of Field, Horticultural and Aquatic crops

4. Varietal Development

- Breeding for submergence tolerance in rice
- Characterization and evaluation of elite genotypes and high yielding varieties of rice for aerobic condition
- Characterization of bacterial wilt resistance in brinjal using conventional and molecular approaches.
- Characterization of wheat (*Triticum aestivum L.)* genotypes for terminal heat stress tolerance
- Collection, characterization and evaluation of potentials wild edibles including tuber crops
- Collection, evaluation and development of bacterial wilt resistant germplasm of brinjal
- Developing national Repository and creating facilities for DUS testing in Mango, Guava and Litchi (*Litchi chinensis*).
- Development of guidelines for the conduct of test for Distinctiveness, Uniformity and Stability (DUS) on faba bean
- Development of high yielding rice genotypes with submerge tolerance for rainfed lowlands
- Evaluation and development of drought tolerant rice for Eastern Region (STRASA Phase-II)
- Evaluation and development of drought tolerant rice for Eastern Region (STRASA Phase-III)
- Evaluation and identification of rice genotypes for tolerance to drought stress at different growth stages.
- Evaluation of advance breeding lines and maintenance of breeding in Solanaceous and Cucurbitaceous vegetable crops
- Evaluation of different genotypes of water chestnut
- Genetic enhancement of Tomato for nematode and bacterial wilt resistance through Molecular markers
- Genetic improvement for yield and biotic stress resistance in pigeonpea under Eastern Plateau and Hill Region
- Genetic variability analysis and development of mapping population for drought tolerance in rice.

- Genetics of bacterial wilt resistance in brinjal using conventional and molecular approaches
- Improved Rice based rainfed Agricultural System (IRRAS) in Bihar State, India
- Improvement of seed quality of solanaceous and cucurbitaceous vegetables
- Management of abiotic stress in rice through biotechnological approaches.
- Management of submergence tolerance through biotechnological approaches in rice grown in lowland ecosystem.
- Management of plant genetic resources and improvement of leafy and underutilized vegetable crops
- Phenological monitoring of selected horticultural fruit tree species
- Phenotyping abiotic stress tolerant traits in Solanaceous crops
- Plant genetic resource and improvement of fruit and ornamental crops
- Standardization of inter-stock for induction of dwarfing in vigorous mango cultivars growing under Eastern Plateau and Hill Conditions
- Varietal development of faba bean (*Vicia faba L.*) for nutritional security in Eastern Region

Theme: 3 Improved Production and Protection Technologies for Agri-Horti Crops

5. Production Technologies

- Design and performance evaluation of low cost green house suitable for vegetable roduction in Bihar and Jharkhand
- Development of methods for processing and extending shelf-life of selected vegetable legumes
- Development of value-added product of makhana.
- Evaluation of decomposition rate of different organic mulch and nutrient availability in Rice-tomato cropping system
- Evaluation of different production system for Carbon sequestration potential
- Evaluation of different weeding technologies for direct seeded rice -maize cropping system.
- Evaluation of soil fertility status of acid soils of different mango orchards of Eastern Plateau and Hill Region
- Evaluation of spike production of Dendrobium hybrid under protected conditions in Jharkhand

- Evaluation of vegetable varieties under different irrigation methods
- Nutritional characterization and value addition of potential underutilized leafy vegetables of Jharkhand
- Optimization of method of transplanting and fertilizer application in trans-planted maize
- Process development for production of dried products from selected fruits and vegetables.
- Response of integrated nutrient management on the production potential of makhana crop growing under field condition in northern Bihar.
- Standardization of basin enrichment in high density orchards of bael, sapota and guava under Eastern Plateau and Hill Region
- Study on decomposition rate of different organic substrate and their nutrient release pattern
- Sustainable crop intensification through the development of suitable plant type in cool season pulses under rice-fallow and makhana-fallow cropping stystem in Eastern India
- Integrated Weed Management
  (i) Integrated weed management in makhana
  (ii) Integrated weed management in direct seeded rice
  (iii) Integrated weed management for hill and plateau region
- Development of value-added product of makhana.
- Ergonomic study of farmers' friendly farm implements in Eastern Region.
- Nutritional characterization and value addition of potential underutilized leafy vegetables of Jharkhand
- Response of integrated nutrient management on the production potential of makhana crop growing under field condition in northern Bihar.
- Standardization of basin enrichment in high density orchards of bael, sapota and guava under Eastern Plateau and Hill Region
- Studies on decomposition rate of different organic substrate and their nutrient release pattern
- Sustainable crop intensification through the development of suitable plant type in cool season pulses under rice-fallow and makhana-fallow cropping system in Eastern India

6. Protection Technologies

- Biology, Seasonal incidence and management of stink bug (*Tessaratoma sp.*) on litchi in Eastern Plateau and Hill Region

- Development and evaluation of disease suppressive potting mixtures in vegetable crops.
- Development of Bio-insecticides module for management of gram pod borer (*Helicoverpa armigera*) (Hubner) in chickpea crop
- Eco-biology and management of rodent fauna of rice- wheat cropping system
- Effect of abiotic factors on population dynamics of major insect pest in paddy-pulses-onion cropping system in Bihar state
- Exploration of biocontrol agents for the management of soil borne phytopathogens in Eastern Plateau and Hill Region.
- Fruit flies (*Tephritidae*: *diptera*) diversity and their host plant determination from Eastern Region of India.
- Management of wilt complex of lentil through bio-agents coupled with host resistance
- Monitoring of selected horticultural fruit crops
- Phenological monitoring of selected horticultural fruit tree species
- Survey and surveillance of pest complex and their natural enemies on selected horticultural crops

Themem 4. Integrated Land & Water Management

7.0 Land & Water Management

- Application of optimization techniques in planning and management of land, water and other resources
- Application of micro-irrigation in system of rice- wheat intensification for enhancing water productivity
- Crop diversification with faba bean to improve land and water productivity
- Development of bio-drainage in participatory mode under waterlogged area
- Diversification of fish farming system to maximize the water productivity
- Evaluation of Conservation Agricultural (CA) practices under Rice-fallow system of Eastern Region
- Evaluation of developed Decision Support Tool in participatory mode
- Evaluation of hydrological response of micro water sheds in Eastern Plateau and Hill Region
- Farmers Participatory Evaluation of Basic slag in Acidic soils of Jharkhand under different cropping systems
- Flood and drought mapping in Eastern Region

- Genetic improvement for yield and biotic stress resistance in pigeonpea under Eastern Plateau and Hill Region
- Improving rice-lentil-moong bean system productivity through water management.
- Optimization of water productivity of aerobic rice based cropping system
- Optimizing land and water productivity in Rice-Lentil-Okra
- Participatory management of rice-fallow in Eastern Plateau and Hill Region
- Refinement of LEWA for its better performance
- Rehabilitation of coal mine affected area of Jharkhand through agroforestry interventions
- Rehabilitation of coal mine affected areas through agroforestry interventions
- Rice - fallow management
- Solar energy utilization in agriculture
- Design and assessment of solar powered aerator for fish pond
- Assessment of solar energy operated micro-irrigation system in mango and guava orchards
- Design and assessment of solar humidifier for animal shed
- Design and assessment of solar watering system for animal shed.
- Solar energy utilization in drip irrigation system, aerator for fish pond, humidifier and washing system for dairy management.
- Solar energy utilization in drip irrigation system, aerator for fish pond, humidifier and washing system for dairy management.
- Standardization of planting geometry and growth stage based fertigation patterns for commercial cultivation of vegetables using drip irrigation system.
- Standardization of water and fertilizer use efficiency of Sapota based high density intercropping of different fruits under Eastern Plateau and Hill Region
- Systemic approach to research and adoption of SRI.

Theme: 5. Livestock and Fisheries Management

8.0 Livestock and Avian Management

- Adaptability and management study for poultry species in Bihar (Turkey, Quail and Vanaraja) in Bihar
- Adaptability and management study of rabbit in Bihar

- Assessing stocking density of livestock under different land use system of fodder production.
- Buffalo improvement
- Characterization and evaluation of duck germplasm in Eastern Region.
- Characterization of lesser known breeds of farm animals in Eastern India
- Characterization of Red Purnea cattle.
- Chronic exposure effect of Carbofuran and Chlorpyrifos in ducks and role of Vitamin C and Vitamin E in its amelioration
- DBT Twining Programme on Elucidating the mechanisms involved in higher feed conversion efficiency of bovine species by expression of the genes regulating mitochondrial proton leak kinetics
- Development of herb-based calf care mix for production of disease free calf.
- Epidemiological study of Respiratory viral diseases in calves.
- Evaluation and characterization of duck germplasm in Eastern Region.
- Evaluation of feeds and fodders in ruminants to develop mixed ration for production of milk and meat
- Evaluation of nutraceuticals as supportive therapy for subclinical mastitis in peri-urban cattle
- Exploring Growth Hormone and prolificacy gene for improvement of growth performance traits in Black Bengal goat
- Field bailing of crop residues for animal feeding
- Formulation of area specific mineral mixture for Bihar based on Soil-plant-animal continuum
- Health monitoring and disease surveillance of farm animals
- Identification, documentation and quantification of non conventional feed resources in traditional swine husbandry practices
- Isolation and characterization of *Fusarium* species responsible for Degnala like disease in animals
- Management of heat stress in buffalo
- Management strategies for optimum performance of improved and deshi breed of ducks
- Meso level animal health interventions and evaluating economic losses from animal diseases
- Network Project on Animal Genetic Resource: Characterization of Red Purnea cattle.

- Network project on Buffalo improvement
- Network project: Growth performance of poultry and pig as influenced by phytase supplementation in Eastern Region
- Serological epidemiology of major viral pathogen of caprine in Bihar
- Study of prolificacy genes in Black Bengal goat by molecular methods
- Fisheries Management
- Assessment of Ichthyofaunal biodiversity and stock assessment of the selected fish species from wetland ecosystems.
- Breeding, rearing and culture of Magur (*Clarius batrachus*) for Eastern Region
- Feed formulation for production of quality fish seed from locally available feed ingredients
- Formulation of mineral mixture for Indian Major carps based on soil-water and fish continuum
- National Surveillance Programme for Aquatic Animal Disease (NSPAAD)
- Optimization of production efficiency of fish-livestock integrated farming system

Theme:6 Socio-Economics, Extension and Policy Research

10.0 Socio-economic Research

- Econometric analysis of diffusion of zero tillage in wheat in Eastern Region.
- Growth and instability in production of principal crops in Bihar
- Impact assessment of adopted technologies
- Impact Assessment of agriculture technology in Eastern India
- Risk proneness of major crops of Eastern India
- Sustainable livelihood improvement through need based integrated farming system Model in disadvantaged Dist. of Bihar.
- Technology out-scaling for sustainable food production and livelihood improvement
- Tracking change in rural poverty in village and household economics in South Asia.
- Tribal farming system in Eastern India.

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