Annual Report
2019

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

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Correct Citation

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Guidance
B.P. Bhatt
Director

Editors
Janki Sharan Mishra
Bikash Das
Pankaj Kumar
Prem Kumar Sundaram
Surajit Mondal

Secretarial Assistance
Sarfaraj Ahmad

Photography
Sanjay Rajput

Published by
Director
ICAR Research Complex for Eastern Region
ICAR Parisar, P. O. : Bihar Veterinary College
Patna-800 014, Bihar
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Preface

It is a great pleasure for me to present the 19th Annual Report of ICAR Research Complex for Eastern Region, Patna for the year 2019, highlighting the significant research achievements and activities of the Institute. The Institute undertakes multi-disciplinary and multi-commodity research to enhance the productivity of agricultural production systems, efficient management of available natural resources, and dissemination of developed technologies in diverse agro-ecological zones of Eastern region.

The Institute has developed several economically and environmentally viable technologies during the period under report for enhancing food and nutritional security and farmers' income in the region. During 2019, the research and extension activities continued to gain momentum. Emphasis has been given on development of stress tolerant varieties, management of rice-fallows, popularization of resource conservation technologies, integrated farming system, crop diversification and carbon sequestration, water productivity enhancement, ergonomic studies of farm tools, weed management, restoration of degraded lands, solar energy application in agriculture, characterization of lesser known animal, poultry and duck breeds, animal health management, development of area-specific mineral mixtures, fish-based integrated farming systems, etc. An aerobic rice variety Swarna Shakti Dhan (IET 25640) has been released and notified by the CVRC for cultivation in the states of Haryana, Odisha, Bihar and Jharkhand, Chhattisgarh, Gujarat and Maharashtra.

In order to strengthen the plant genetic resource management, promising genotypes of different fruits and improved lines of makhana, water chestnut, and pulses like lentil, chickpea and grass pea have been identified. Besides, quality seeds of rice, pulses, vegetables, and planting materials of fruits and flowers were produced and provided to the end users. Two new livestock population, including *Seemanchali* sheep and *Koshi* buffalo was noticed and characterized in the north Bihar. Studies on fish productivity, water quality, plankton density, etc. in fish-based integrations have been undertaken. Cattle-fish integration recorded the highest fish productivity. A fish diversity museum has been developed at RCM, Darbhanga with the objective to collect, preserve, catalogue, and display the species mainly found in the freshwater environments of North Bihar. A mobile based app '*Climate Smart Mango Cultivation'* has also been developed.

The Institute has also been providing technological support to the farmers, extension workers and state officials through its extensive extension net work. Climate resilient technologies have been demonstrated in 25 villages to improve the adaptive capacity of farmers to cope with the climate risks. A total of 86 training programmes, 09 Front Line Demonstrations, and 18 On Farm Trials have been conducted for the farmers and the state government officials. Thirty seven villages of six districts of Bihar and Jharkhand were covered under *Mera Gaon Mera Gaurav* to make the farmers aware of improved technologies. During the period under report, the institute has published 92 nos. of research papers in the journal of national and international repute, 05 books, 37 book chapter, 03 bulletins, 06 training manuals, 01 policy brief and 28 popular articles.

I place on record my sincere gratitude to Dr. T. Mohapatra, Secretary DARE and Director General, ICAR for his unstinted guidance and support in executing the mandate of the Institute. The encouragement, valuable guidance and support rendered by Dr. K. Alagusundaram, DDG (NRM) and Dr. S. Bhaskar (ADG, AAF&CC) are duly acknowledged. All Heads of the Divisions/Research Centres deserve appreciation for submitting their research findings in time. I also express my appreciation to the Editorial team and other staff members of the Institute for compiling and bringing out this report in time.

(B.P. Bhatt)
Director
ICAR-RCER

Content

1. Executive Summary

The salient achievements of the Institute during 2019 are summarized below:

- An aerobic rice variety Swarna Shakti Dhan (IET 25640) has been released and notified by the CVRC for the cultivation in the states of Haryana, Odisha, Bihar and Jharkhand, Chhattisgarh, Gujarat and Maharashtra for cultivation under direct-seeded condition in water limiting irrigated areas and rainfed shallow lowland to medium upland ecosystems.
- Forty eight rice genotypes were evaluated for tolerance to reproductive stage drought. Rice genotypes IR 93827-29-2-1-3, IR14L362, IR14L157, IR 95785-31-2-1-2, IR 107891-B-B-111-2-1, IR 93827-29-1-1-4, IR 90257-B-577-1-1-B, IR14L613, IR 106312-50-1-1-1 , IR 95817-5-1-1-2, IR 107891-B-B-359-3-1, IR 106516-1-2-2-2, and IR 107891-B-B-1284-2-1 have been found promising with productivity range of 4.52-5.34 t/ha.
- Rice genotypes IR 93827-29-1-1-4, IR 97034-21-2-1-3, IR 93827-29-2-1-3, IR 84899-B-184-16-1-1-1, IR 84899-B-185-8-1-1-1, IR 84898-B-168-24-1-1-1, IR14L572, IR84898-B-165-9-1-1, IR14L360, IR93827-29-1-1-2 and IR 93827-29-1-1-3 have been identified promising for aerobic condition with productivity range of 5.15-5.56 t/ha.
- Rice genotypes IR09L342, TP30191, IR10F365, TP30193-1 and IR11F195 performed better than the Swarna sub-1, Sambha Mahsuri sub-1, IR 64 sub-1 and Ciherang sub-1 under 1.25 m submergence for a period of 18 days.
- Weed competition caused 89% reduction in grain yield of direct-seeded rice. Application of pendimethalin followed by bispyribac–Na and 2 HW produced the maximum yield (3.18 t/ha). In transplanted rice, hybrids were more tolerant to increase in weed pressure than the varieties. Short duration rice hybrid Arize 6129 with low weed pressure produced the maximum grain yield (6.98 t/ha) of rice.
- In wheat, drought at reproductive stage was more harmful than that of vegetative stage. Drought combined with heat stress caused severe yield loss. Wheat varieties HD 2987, NW 1014, G 273 and HD 2967 were found promising under late-sown stress conditions.
- Chickpea test entry 'DBGC 1' (3.78 t/ha), with 100-seed wt. of 26.72 g and maturity period of 134 days showed an yield advantage by more than 13% over the best check 'Pusa 3043' (3.32 t/ha) under normal irrigated condition. Advance breeding lines namely DBGC 1', 'DBGC 2', 'DBGC 3' and 'DBGC 4' were found"moderately resistant" against the available races of *Fusarium ciceri.*
- One acre IFS model (field crops + hort.+ goat+ poultry) provided an annual net returns of Rs. 88,528/- (B:C ratio 1.85), which was about three times higher than rice-wheat cropping system.
- Rice-broccoli-spinach-greengram produced significantly higher rice equivalent yield (35.34 t/ha), net returns (Rs. 3,34,330/ha) and benefit : cost ratio (2.78).
- The highest system productivity was recorded with maize cob–pigeonpea (22.37 t/ha) followed by sorghum fodder–mustard (ZT)–urdbean (ZT) (15.36 t/ha) and soybean–maize (ZT) (18.53 t/ha) system.
- Irrespective of irrigation methods, zero-till wheat and maize resulted in 14.3 and 17.0% higher ($p<0.05$) yield, respectively than the CT. Soil moisture based irrigation resulted in a 7.7-12.0% higher ($p<0.05$) grain yield of wheat, but marginal increase (2.8-6.7%) in maize.
- In rice-lentil-mung bean system, tillage did not influence the seed yield and water productivity of mung bean. The highest mung bean seed yield (2.63/ha) was recorded with irrigation at IW: CPE at 0.6, however, the maximum water productivity (4.22 kg/ m^3) was noticed with IW: CPE at 0.4.

- In rice-fallows of Jharkhand, Chhatisgarh and Bihar, the productivity of winter season oilseeds and pulses was significantly higher under DSR with residue system as compared to that of transplanted rice system.
- Quality seed of 2.3 t rice (Swarna Shreya), 9.6 t lentil (HUL 57, IPL 8, IPL 220), 2.6 t field pea (DFP 1), 15.5 t chickpea (GNG 1581, Pusa 3043, Shubhra), 7.7 t greengram (Samrat, Virat, IPM 2-3, IPM 2-14), 0.72 t pigeonpea (IPA 203) was produced during 2019. In addition, 3.8 t vegetable seed, 3.5 t mushroom spawn and 2, 60,000 nos. of quality planting materials of fruits and flowers were also produced.
- A mobile based app '*Climate Smart Mango Cultivation'* has been developed under the NICRA project on "Mango Pest" with features like 'Weather based pest forewarning' and 'State of art mango cultivation technologies'
- Based on 13 years of performance evaluation, the sapota variety Murabba has been found most promising and recommended for the commercial cultivation under Jharkhand conditions
- Estimation of carbon sequestration potential of different lac host plants indicated that total soil organic carbon stock at 0-0.90m depth in 9 year old plants of ber, kusum and palas varied from 52.47 to 65.32 Mg/ha
- In brinjal, the promising bacterial wilt resistant line HAB-915 and F_1 hybrids HABR-6 x IC-545901 and Swarna Avilamb x IC-545901 were submitted under IET AICRP(VC) 2019 for multilocation testing
- Technological demonstration under the Farmer FIRST Project resulted in additional income of Rs 7.85 lakh by the participating farmers by selling the produce in the market with increase in the average annual gross income from Rs 1.04 lakh to Rs 1.43 lakh and decrease in the contribution of income from non-farm activities from 46.3% to 34.0%.
- Based on soil-plant- animal continuum, it was observed that 80% animals in Jharkhand had deficiency of phosphorus and calcium. Zn deficiency was also observed in about 30-50% animals.
- In Black Bengal goats, vaccination and deworming reduced the mortality rate from 19.96% to 2.89% during the current year.
- Two new livestock population, including Seemanchali sheep and Koshi buffalo was noticed and characterized. Seemanchali sheep was distributed in parts of Araria, Purnea and Katihar districts, and Koshi buffalo in the Kosi basin of Bihar.
- Chemokines CCL8 and CXCL10 may be used as a biomarker for early pregnancy detection in buffaloes.
- Molecular diagnosis of bovine theileriosis has been developed based on western blot analysis and ELISA using recombinant spm2 partial protein of *T. annulata* by cloning, expression and purification.
- The West Bengal duck having AB genotype had superior egg weight and egg quality. AB genotype had higher albumin weight but lower yolk weight than the duck having AA genotype. Therefore, *prolactin gene* can be used as marker for improving egg weight and egg quality traits.
- The highest gross primary productivity (0.18g C/m^3/h) was recorded in fish-pig integration followed by cattle- fish integration (0.17g C/m^3/h) with almost similar net primary productivity (0.07 g C/m^3/h).
- Supplementary pelleted feed with 38% protein level feeding (@ 10% body weight) showed better growth of minor Carp, *Labeo gonius* compared to other feeding regimes.
- A fish diversity museum has been developed at RCM, Darbhanga with the objective to collect, preserve, catalogue, and display the species mainly found in the freshwater environments of North Bihar.
- During the period under report, the Institute published 92 nos of research papers in journals of national and international repute, 37 book chapters, 28 popular articles, 01 technical/ extension bulletin, 06 training manuals, 03 leaflets and 01 policy brief.
- During the year 2019, thirty seven villages of six districts of Bihar and Jharkhand were covered under *Mera Gaon Mera Gaurav*, and 1025 farmers were directly benefitted through various activities like training, demonstration, supply of quality planting materials, etc.
- Further, total of 86 training programmes, 09 Front Line Demonstration and 18 On Farm Trials have been conducted for the farmers and the State Government officials.

2. Introduction

The Eastern region comprising of seven states viz., Assam, Bihar, Chhattisgarh, Eastern Uttar Pradesh, Jharkhand, Odisha and West Bengal, covers about 21.85% geographical area of the country and supports 34% human and 32% livestock population of India. Though the region is rich in natural resources, its potential could not be harnessed in terms of improving agricultural productivity, poverty alleviation and livelihood improvement. Agriculture, the mainstay of economy in the region, is by and large, complex, diverse and risk prone. Agricultural productivity and per capita income of the farmers is very low. In order to ensure food security of the nation, Eastern region has been targeted for ushering a Second Green Revolution, which can be accomplished through holistic management of land, water, crops, biomass, horticultural, livestock, fishery and human resources.

ICAR Research Complex for Eastern Region (ICAR-RCER), Patna came into existence on the 22nd February 2001 to address diverse issues relating to land and water resources management, crop husbandry, horticulture, agro-forestry, aquatic crops, fishery, livestock and poultry, agro-processing 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 25^{o}35'30" N latitude, 85^{o}05'03" E longitude, at an altitude 52m above mean sea level.

The Complex has four divisions besides two research centres and two KVKs. The organizational setup of the Complex is given in Fig. 2.1.

Finance

Summary of budget allocation and expenditure during the financial year 2019-20 of the complex is presented in Table 2.1.

Mandates

- 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 mandates

- To facilitate and promote coordination and dissemination of appropriate agricultural technologies through network/consortia approach involving ICAR institutes, State Agricultural Universities, and other agencies for generating location-specific agricultural production technologies through sustainable use of natural resources.
- To provide scientific leadership and to act as a center for vocational as well as advanced training to promote agricultural production technologies.
- To act as repository of available information and its dissemination on all aspects of agricultural production systems.
- To collaborate with relevant national and international agencies in liaison with state and central government departments for technology dissemination.
- To 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.

Table 2.1. Financial allocation and expenditure during the year 2019-20 (Rs. in Lakhs)

Head of accounts	BE allocation	Actual expenditure*
Establishment Charges	2228.04	2138.74
TA	35.00	18.43
HRD	10.00	3.88
Capital	123.47	32.89
Other charges	943.58	762.80
Total	3340.09	2956.74

*up to 31st December, 2019

Table 2.2. Staff position as on 31st December 2019.

Staff	Position	
	Sanctioned	Filled
Scientific*	91	71
Technical	61	53
Administrative	37	22
Skilled Supporting Staff	63	53
Total	252	199

*Including Director

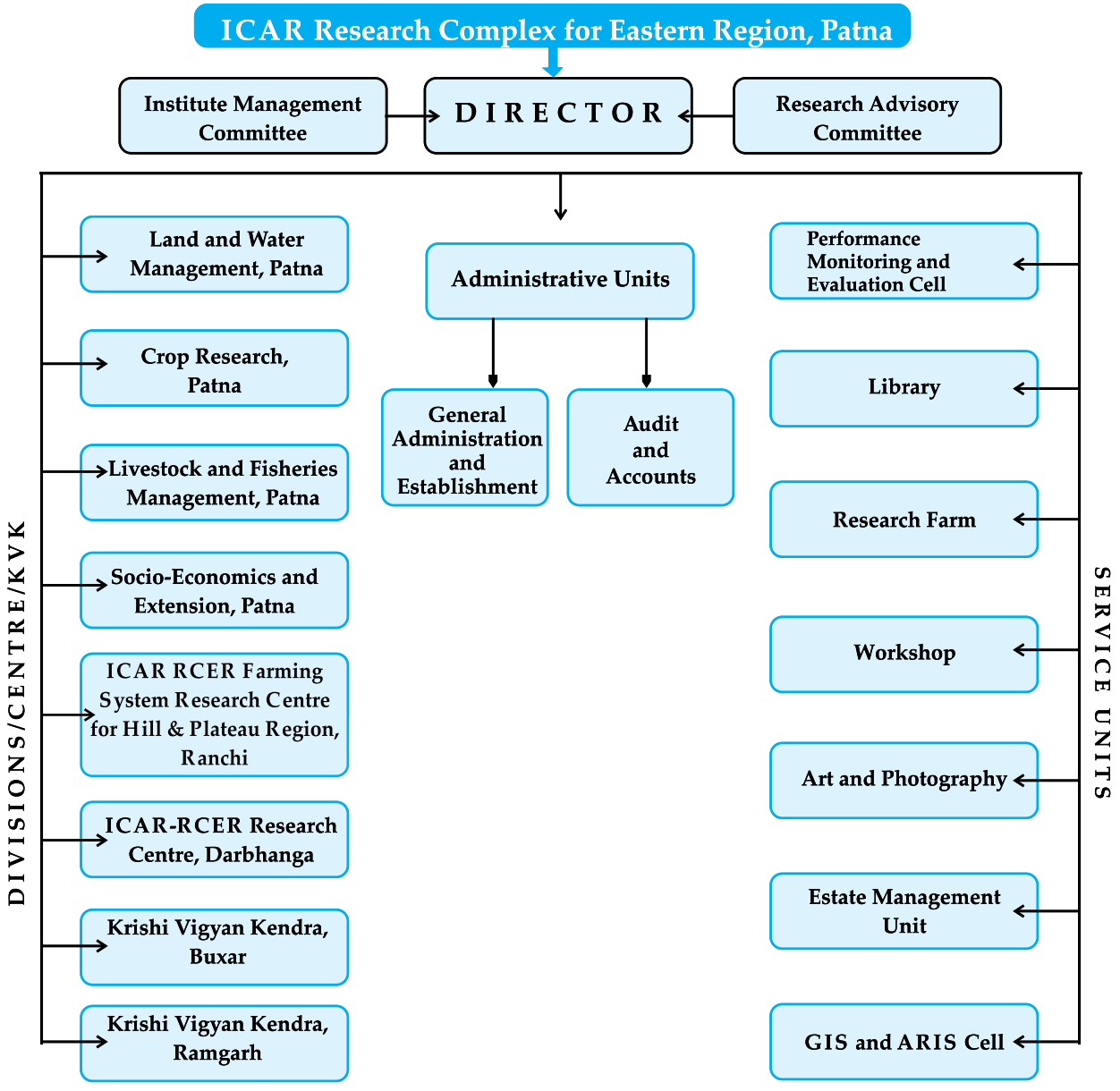


Fig. 2.1. Organogram of ICAR Research Complex for Eastern Region, Patna

3. Weather

Weather parameters *viz.* air temperature, relative humidity, bright sunshine hours, rainfall, evaporation, wind speed and direction were recorded twice in a day at ICAR-RCER, Patna (**Table 3.1)**. Mean monthly maximum temperature ranged from 22.3°C during January to 39.6°C during May showing that it was the warmest month for year 2019. Similarly, the mean monthly minimum temperature varied from 9.1°C during January to 28.6°C during June, depicting January as the coldest month. Mean monthly relative humidity was the lowest in May (46.4%) and the highest in September (80.4%). It was also observed that relative humidity peaks during monsoon months (June to September) and shutout during summer months (March to May) leaving March as the driest month for this region. A meager amount of rainfall was received during winter and summer season but water loss through evaporation remained active during these months, as mean monthly bright sunshine hours that was more during March (7.7 hrs.) along with free flowing air accelerated the rate of evaporation. During monsoon months presence of clouds resulted into less number of BSSH, and mean wind speed was also good enough though it reached its maximum during June (9.9 km/hr) due to land heating and increasing temperature. These mean monthly variations for 2019 have also been depicted in **Fig 3.1**.

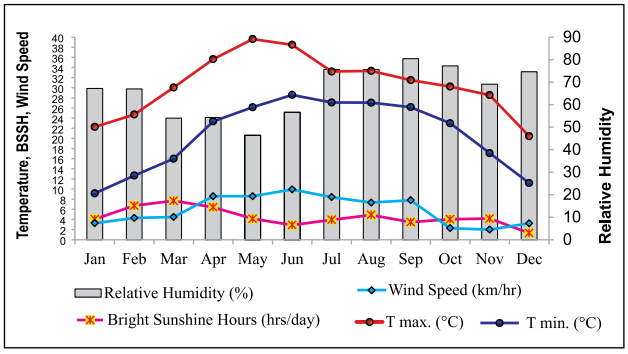


Fig. 3.1. Mean monthly variation of weather parameters during 2019 at ICAR-RCER, Patna

Year 2019 was normal rainfall year based on total amount of rainfall received throughout the year. Total amount of rainfall which was progres-

Table 3.1. Mean monthly weather data of 2019 at ICAR-RCER, Patna

Month	Mean temperature (°C)				Mean relative humidity (%)	Mean bright sunshine (hrs/ day)	Total rainfall (mm)		Total rainy days	Total pan evaporation (mm)	Mean wind speed (km/ hr)
	Max	Normal	Min	Normal			Observed	Normal			
Jan	22.3	23	9.1	9.3	67.2	4.1	2.7	20.4	0	71.4	3.3
Feb	24.7	26.1	12.7	11.6	67.0	6.7	13.8	11.1	3	70.3	4.3
Mar	30.1	32.4	16.0	16.4	54.0	7.7	0.0	11.4	0	102.4	4.5
Apr	35.7	37.4	23.4	22.1	54.3	6.4	11.6	9.0	1	140.1	8.6
May	39.6	38.4	26.2	25.1	46.4	4.1	4.4	35.6	1	188.9	8.6
Jun	38.5	36.7	28.6	26.7	56.6	2.9	61.7	141.1	4	164.6	9.9
Jul	33.2	32.9	27.1	26.1	75.6	3.9	322.6	319.2	14	100.8	8.4
Aug	33.3	32.5	27.1	26.1	75.6	4.9	117.3	279	10	126.7	7.3
Sep	31.5	32.2	26.2	25.3	80.4	3.5	551.4	212.6	12	87.0	7.8
Oct	30.2	31.7	23.0	21.6	77.2	4.0	2.2	72.3	0	103.7	2.3
Nov	28.6	28.9	17.1	14.8	69.1	4.2	0.0	8.2	0	80.6	2.0
Dec	20.4	24.6	11.2	10.1	74.6	1.3	33.0	7.4	2	48.2	3.2
Annual	**30.7**	**31.4**	**20.6**	**19.6**	**66.5**	**4.5**	**1120.7**	**1127.3**	**47**	**1284.7**	**5.8**

sively accumulated at the end was 1120.7 mm, which was 99.4% of long period rainfall average (LPA) (1127.3 mm) for the station. There were 47 rainy days in 2019. A comparative analysis of total monthly rainfall received, normal rainfall as a LPA and water loss from surface as evaporation has been depicted in Fig 3.2. Total pan evaporation in 2019 was 1284.7 mm, which was recorded minimum in December (48.2 mm) and maximum in May (188.9 mm).

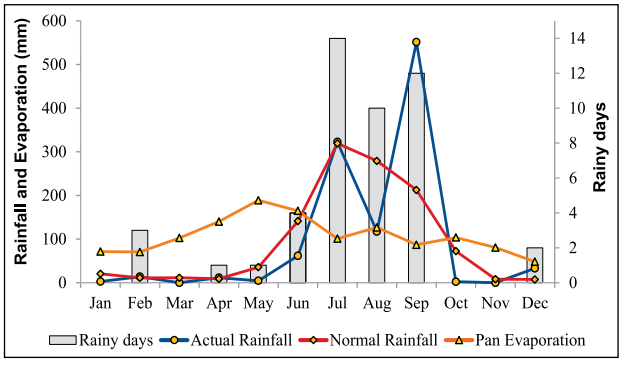


Fig. 3.2. Comparative analysis of total monthly rainfall, normal rainfall, rainy days and evaporation at ICAR-RCER, Patna

Fig 3.3 shows the comparison of mean monthly maximum and minimum temperatures over the normal values of temperature. A dip of -4.2 °C during December and a shoot of +1.8°C were reported during June for mean monthly maximum temperature over normal values. Similarly, for mean monthly minimum temperature a dip of -0.4°C during March and a shoot of +2.3°C during November was observed. In totality, minimum temperature remained slightly above and maximum temperature remained slightly below normal temperatures.

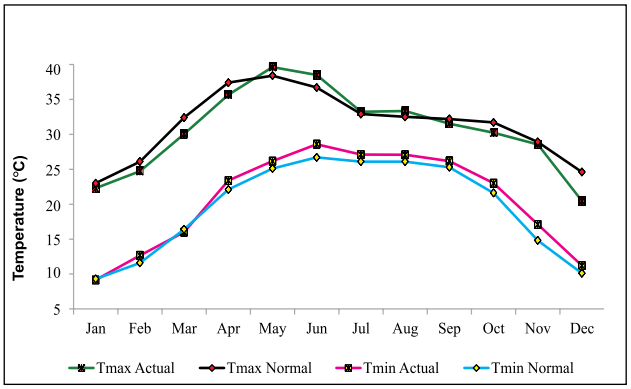


Fig. 3.3. Comparison of mean monthly maximum and minimum temperatures over the normal values at ICAR-RCER, Patna

Extremes in weather variables for 2019 have been reported in **Table 3.2**, where 15th June was recorded as the hottest day of the year (44.4°C) while 28th December was reported as the coldest day (5.8°C). September month recorded maximum amount of rainfall in a day (160.6 mm) on 28th, the highest wind speed in a day (19.3 km/hr) reached on 3rd July and the highest maximum humidity (96.5%) on 28th September but the least humidity was reported on 28th April (34.0%). Maximum bright sunshine hours of 10 hrs 30 min were recorded on 31st July.

Table 3.2. Extremes of weather observed during 2019 at ICAR-RCER, Patna

Parameter	Date	Value
Warmest day	15th June 2019	44.4°C (Tmax)
Coldest day	28th December 2019	5.0°C (Tmin)
Most humid day	28th September 2019	96.5% (RH)
Least humid day	28th April 2019	34.0% (RH)
Most rainy day	28th September 2019	160.6 mm (Rainfall)
Most shiny day	31st July 2019	10 hrs 30 min (BSSH)
Most Windy day	3rd July 2019	19.3 km/hr (Wind speed)

At Ranchi, the total rainfall received during the year 2019 was 1363 mm which was very close to normal rainfall recorded at the centre. The rainfall recorded for May, June and July was 71, 49 and 28% deficit while August, September and October was 21, 8 and 183% above the normal rainfall of the respective month (Fig. 3.4). There were 66 rainy days, of which 49 rainy days occurred during the monsoon season with August recording the maximum (18) number of rainy days. The average

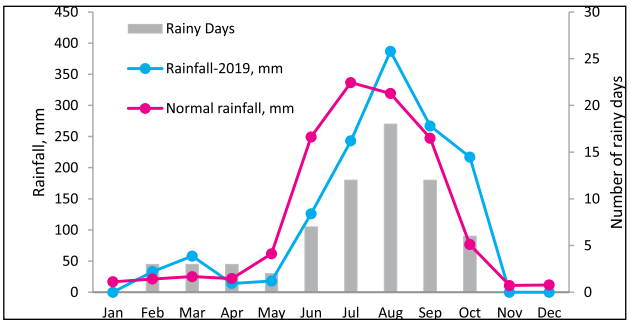


Fig. 3.4. Comparison of monthly normal rainfall with monthly rainfall at Ranchi

monthly relative humidity ranged from 85.8% in May to 91.5% in August. December was the coldest month with mean monthly minimum temperature of 10.3°C while May was the hottest month with mean maximum temperature of 37.5 °C (**Table 3.3**).

The variations in average monthly minimum and maximum year temperature is depicted in Fig. 3.5.

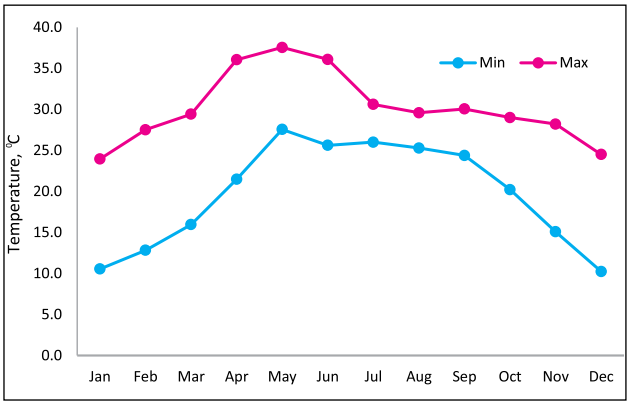


Fig. 3.5. Variations in average monthly minimum and maximum air temperature at Ranchi

Table 3.3. Mean monthly weather parameters at FSRCHPR, Ranchi for 2019

Month	Total rainfall (mm)		Rainy days	Temperature (°C)		Relative humidity (%)
	Normal rainfall	Observed rainfall		Min	Max	
Jan	16.7	0	0	10.6	24.0	89.5
Feb	21.2	33	3	12.8	27.5	87.6
Mar	25.0	58	3	16.0	29.4	86.6
Apr	21.8	14	3	21.5	36.0	87.4
May	61.7	18	2	27.6	37.5	85.8
Jun	249.4	126	7	25.6	36.1	89.9
Jul	336.6	243	12	26.0	30.6	87.5
Aug	319.1	387	18	25.3	29.6	91.5
Sep	247.3	267	12	24.4	30.0	91.4
Oct	76.6	217	6	20.2	29.0	90.3
Nov	10.8	0	0	15.1	28.2	90.6
Dec	11.6	0	0	10.3	24.5	90.3
Annual	1397.8	1363	66	19.6	30.2	89.0

4. Climate Change

Understanding the Changes in Host-Pest Interactions and Dynamics in Mango under Climate Change Scenarios

Characterization of gut micro-biota during the developmental stages of peach fruit fly, *Bactrocera zonata*

Micro-organisms associated with insects gut, hemocoel and body cells play an important role in their development and nutrition. The microbial community harboured by the peach fruit fly, *Bactrocera zonata,* a polyphagous pest of horticultural crops, was characterized across the different developmental stages using 16S rRNA gene metabarcoding on the Illumina HiSeq platform and also *in silico* prediction of their functional metabolic activities. V3-V4 region (hyper-variable region) of 16S rRNA gene sequencing based taxonomy analysis revealed that bacterial community of *B. zonata* contained total 16 bacterial phyla, comprising 24 classes, 55 orders, 90 families and 134 genera. The Venn diagram was used for showing the shared OTUs among different developmental stages of *B. zonata* at 97% similarity, in which 151 OTUs (core microbial community) were common for each stage (**Fig. 4.1A**). *Proteobacteria, Firmicutes, Actinobacteria* and *Bacterioidetes* were the most abundant phyla (**Fig. 4.1B**) with *Gammaproteobacteria, Alphaproteobacteria, Actinobacteria, Bacteroidia* and *Bacilli* as most abundant classes. The four most abundant phyla comprised of around 98% of total sequence reads which ranges from 93.7% for 1st instar larvae (BL1) to 99.9% for 3rd instar larvae (BL3). Individually, phyla *Proteobacteria* comprised with an average 93.72% (91.72% in BL1 to 95.67% in BF) followed by *Firmicutes* with an average 2.68% (0.22% in BP to 6.52% in BL3), *Actinobacteria*, 1.36% (0.02% in BL3 to 3.52% in BP), and *Bacteroidetes*, 0.43% (0% in BL3 to 1.41% in BP) of the total reads (**Fig. 4.2**). The possible exploitation of information could be a foundation for the microbiota based management programmes of fruit flies.

Development of Forewarning Based Mobile Application

Mobile based applications are effective in transferring information to farmers in a timely and cost effective manner. At present, range of apps on mango are available in online stores, majority of which deals only with cultivation practices and pest management. It has been established that life cycles of insects have stronger links with climatic parameters and that the apps with pest forecast-

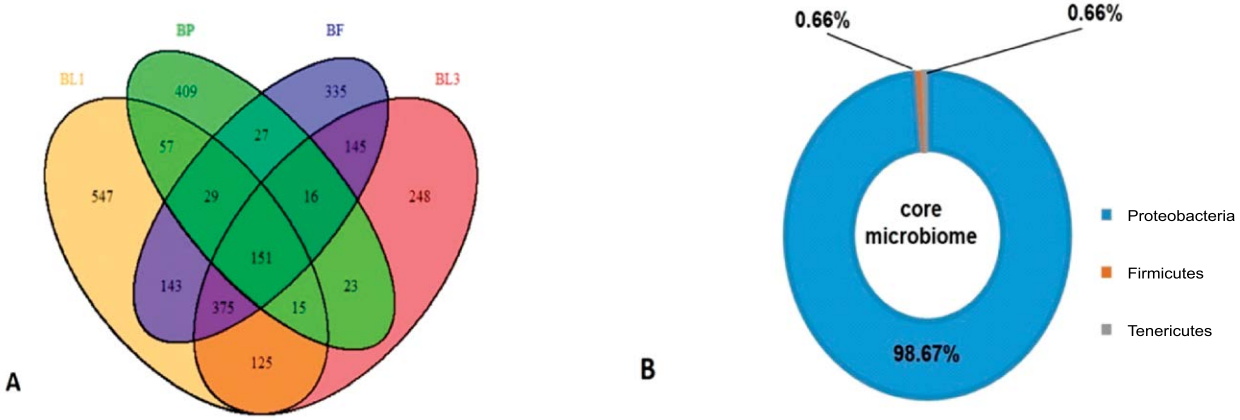


Fig. 4.1. OTUs analysis between different developmental stages of *B. zonata* at 97% similarity (A) Venn diagram showing unique and shared OTUs, of which 151 OTUs shared between all developmental stages. (B) Percentage distribution of common shared OTUs (151 OTU) between all developmental stages at phylum level. BL1, BL3, BP and BF refer to 1st Instar larvae, 3rd Instar larvae, Pupa and Adult stage of *Bactrocera zonata*.

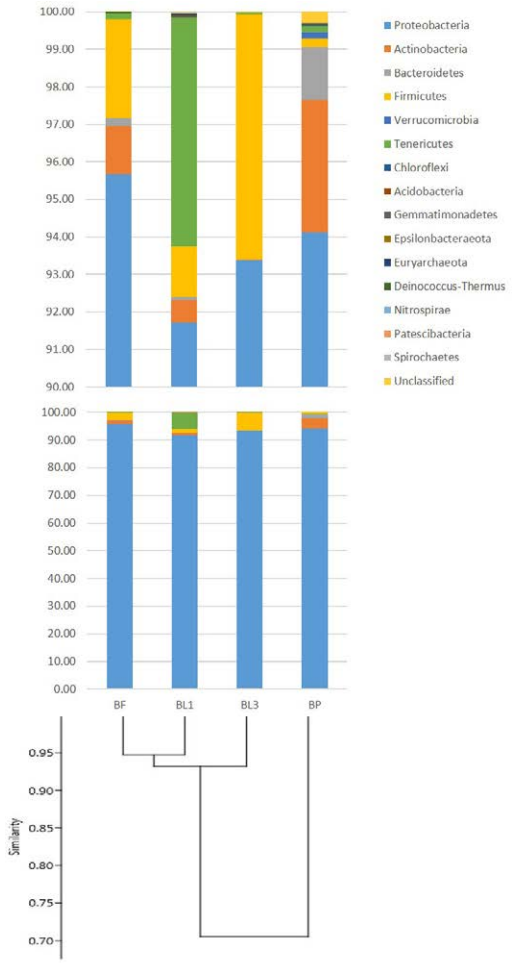
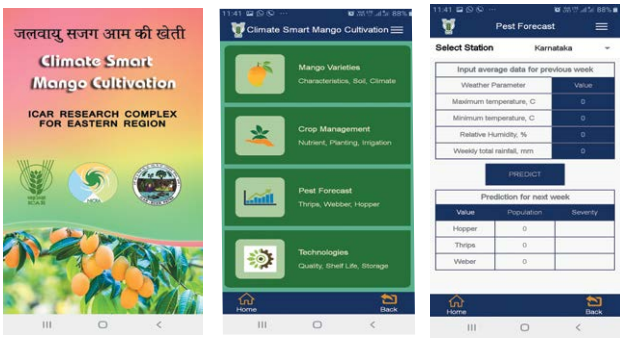


Fig. 4.2. UPGMA clustering of B. *zonata* samples at different developmental stages according to community composition and structure with relative abundance of bacterial community at the phylum level.

ing ability will be useful in effective management of insect-pests. But, the apps with weather based pest forecasting module are lacking. Keeping this in view, a mobile based app '*Climate Smart Mango Cultivation (CSMC)'* has been developed. This is an omnibus mobile app which provides information on state-of-art cultivation practices of mango along with 'pest forecasting' module which uses validated Artificial Neural Network models to predict the future pest population. The mobile app has four main modules *viz.* Mango varieties, Crop cultivation, Pest forecast and Technologies. Pest forecasting using neural network based forewarning models is unique feature of the app. Users can input the weather parameters of preceding week in the 'Pest Forecast' module and then hit the predict button to get the likely population of pests along with their level of severity (high, medium, low) for the succeeding week. The app also provides pesticide spraying recommendations on the basis of the severity of the pests (**Fig. 4.3**).



Splash screen Options page Pest forecast

Fig. 4.3. Main features of android based mobile app 'Climate Smart Mango Cultivation'

Identification of Traits, Genes, Physiological Mechanism to Develop Climate Smart Varieties for Unfavorable Environment

A field level screening was done for drought tolerance during *Kharif* 2019 at ICAR Research complex for Eastern region, Patna with aim to identify the rice genotypes having better stem reserve mobilization efficiency during drought period. Fourteen rice genotypes (12 donor lines plus 2 check varieties) *viz.*, IR64, IR74371-70-1-1 (checks), Gul murali, Camponi sml, Wanni dahanala, EZI 124, Jabor sail, Tchampa, Dular, Santhi sufaid, Aus 257, DZ78, ARC10955 and Soloi were received from IRRI and evaluated under two sets of conditions i.e. stress (drought) and non-stress (irrigated). Under drought stress experimental field, the crop was grown under normal irrigation for four weeks after transplanting and then irrigation was withdraw and no further irrigation was applied to stress field. Agro-morphological (days taken to 50% flowering, anthesis, physiological maturity) and physiological data (RWC, chlorophyll, Pn rate) related to drought tolerance and stem reserve mobilization (%) were recorded. In order to access the mobilization potential of rice genotypes kernel weight reduction (%) was calculated and stem reserve potential of rice genotypes was estimated. Study showed that genotypes Dular (22.9%), ARC10955 (20.9%) and Camponi sml (21.2%) have lower kernel weight reduction percentage thus having better stem reserve mobilization efficiency, while kernel weight reduction were higher in EZI124 (39.3%) and in Gul Murali (36.9%) thus having poor stem reserve mobilization capacity.

5. Cereals

RICE

Evaluation and Identification of Genotypes for Tolerance to Reproductive Stage Drought

In most of the rainfed regions of eastern India, the probability of occurrence of reproductive-stage drought is high due to the early withdrawal of monsoon rains. In order to develop drought tolerant rice genotypes, forty eight rice genotypes comprised of advanced breeding lines and check varieties were evaluated under reproductive stage drought stress and non-stress (irrigated/control) conditions during *Kharif* 2019. Fifty five days old plants were subjected to drought by withholding irrigation and withdrawing water from the stress field. Thereafter crop was left rainfed and there was no standing water up to maturity. Non-stress irrigated experimental field was kept continuously flooded after transplanting until 20 days before harvest. Irrespective of genotypes, drought stress at reproductive stage caused significant reduction in grain yield (26.65%), plant height (14.5%), number of effective tillers/m^2 (12.2%), panicle length (8.89%), spikelet fertility (27.77%), plant biomass (25.04%) and photosynthetic rate (18.1%); however, the responses varied among genotype. Among rice genotypes, IR 93827-29-2-1-3 (5.34 t/ha), IR14L362 (5.01 t/ha), IR14L157 (4.96 t/ha), IR 95785-31-2-1-2 (4.92 t/ha), IR 107891-B-B-111-2-1(4.82 t/ha), IR 93827-29-1-1-4 (4.80 t/ha), IR 90257-B-577-1-1–B (4.75 t/ha), IR14L613(4.67 t/ha), IR 106312-50-1-1-1 (4.67 t/ha), IR 95817-5-1-1-2 (4.65 t/ha), IR 107891-B-B-1432-2-1 (4.64 t/ha), IR 107891-B-B-359-3-1 (4.61 t/ha), IR 107891-B-B-1284-2-1 (4.57 t/ha), and IR 106516-1-2-2-2 (4.55 t/ha) showed significantly better drought tolerance at reproductive stage as compared to check varieties Sahbhagi Dhan (3.64 t/ha) and IR64 (3.14 t/ha). On an average 26.65% yield reduction was observed under drought stress (4.37 t/ha) as compared to non-stress (5.96 t/ha) condition.

Evaluation and Identification of Genotypes for Aerobic Condition

Water scarcity is the greatest threat to rice cultivation. Because of increasing water scarcity, there is a need to develop alternative system that requires less water for rice production. Aerobic rice promises substantial water savings. Under present study, thirty two rice genotypes comprises of advanced breeding lines and released check varieties were evaluated during *Kharif* 2019 under aerobic condition. Among rice genotypes, IR 93827-29-1-1-4 (5.56 t/ha), IR 97034-21-2-1-3 (5.44 t/ha), IR 93827-29-2-1-3 (5.42 t/ha), IR 84899-B-184-16-1-1-1 (5.31 t/ha), IR 84899-B-185-8-1-1-1(5.30 t/ha), IR 84898-B-168-24-1-1-1(5.23 t/ha), IR14L572 (5.23 t/ha), IR84898-B-165-9-1-1 (5.22 t/ha), IR14L360 (5.21 t/ha), IR93827-29-1-1-2 (5.18 t/ha), and IR 93827-29-1-1-3 (5.15 t/ha) were found promising for aerobic condition as compared to check varieties CR Dhan 201 (4.58 t/ha), CR Dhan 202 (4.63 t/ha) Sahbhagi Dhan (4.32 t/ha) and Rajendra Bhagwati (4.39 t/ha). Grain yield of different genotypes varied from 3.57 to 5.56 t/ha under aerobic condition.

Evaluation and Identification of Genotypes for Multi-Stages Drought Tolerance

Drought can occur at any stage of the rice growth and reproduction causing significant yield loss in rainfed areas. In the changing climate scenario, multi-stage drought tolerant rice genotypes are required to improve rice productivity in drought-prone areas. Twenty four rice genotypes were evaluated under multi-stages drought stress and non-stress (irrigated) conditions during *Kharif* 2019. In stress experimental field, irrigation was applied only once immediately after sowing so that the seeds can properly germinate. The non-stress experimental trial was maintained by applying irrigations as and when required. Grain yield of different genotypes varied from 0.512 to 2.89 t/ha and 3.65 to 5.42 t/ha under multi-stages drought stress and non-stress conditions, respectively.

Among rice genotypes; IR93827-29-1-1-2 (2.89 t/ha), IR83929-B-B-291-2-1-1-2 (2.87 t/ha), IR 93827-29-1-1-3 (2.76 t/ha), IR84899-B-182-3-1-1-2 (2.70 t/ha), Swarna Shreya (2.70 t/ha), IR84899-B-183-CRA-19-1 (2.67 t/ha), IR 88964-24-2-1-4 (2.66 t/ha), IR 84899-B-183-20-1-1-1(2.66 t/ha) and IR93827-29-2-1-3 (2.49 t/ha) were identified promising for multi-stages drought tolerance as compare to Sahbhagi Dhan (1.50 t/ha). On average 57.53% yield reduction was observed under multi-stage drought stress (1.95 t/ha) as compared to non-stress (irrigated) (4.60 t/ha) condition.

Release and Notification of New Variety

An aerobic rice variety 'Swarna Shakti Dhan (IET 25640)' has been released and notified by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops, Govt. of India for the cultivation in the states of Haryana, Odisha, Bihar, Jharkhand, Chhattisgarh, Gujarat and Maharashtra. This variety is an early duration (115-120 days), semi-dwarf, high yielding (4.5-5.0 t/ha), multiple stresses (drought, disease and insect pest) tolerant rice genotype with desirable cooking quality traits and high micronutrient (zinc) content. This variety is suitable for cultivation under direct seeded condition in water limiting irrigated areas and rainfed shallow lowland to medium upland ecosystems. It showed desirable quality parameters like high hulling (76.3%), milling (66.36%), high head rice recovery (63.2%), intermediate amylose content (22.52%), alkali spreading value (ASV=4.0) and a soft GC with very occasionally chalky and short bold grain type (**Fig. 5.1**).

Fig. 5.1. Swarna Shakti Dhan

Identification of Genotypes for Tolerance to Seedling and Vegetative Stage Drought

Twenty four rice genotypes comprises of advanced breeding lines and check varieties were evaluated under seedling stage drought and vegetative stage drought conditions during *Kharif* 2019. Drought was imposed at respective stage by withholding the irrigation. Grain yield of different genotypes were varied from 0.879 to 3.43 t/ha and 2.12 to 4.51 t/ha under seedling stage and vegetative stage drought conditions, respectively. Rice genotypes; IR93827-29-1-1-3 (3.43 t/ha), IR84899-B-182-3-1-1-2 (3.26 t/ha), IR83929-B-B-291-2-1-1-2 (3.17 t/ha), Swarna Shreya (3.15 t/ha), IR93827-29-1-1-2 (2.89 t/ha), and IR 84899-B-183-20-1-1-1 (3.07 t/ha) were identified promising for seedling stage drought tolerance as compare to Sahbhagi Dhan (1.83 t/ha). Under vegetative stage drought condition, rice genotypes *viz.*, IR83929-B-B-291-3-1-1 (4.51 t/ha), IR 88964-24-2-1-4 (4.29 t/ha), Swarna Shreya (4.26 t/ha), IR83929-B-B-291-2-1-1-2 (4.13 t/ha), IR 88964-11-2-2-3 (4.10 t/ha) and IR93827-29-1-1-3 (4.07 t/ha), were found promising as compare to Sahbhagi Dhan (3.20 t/ha) and IR 64 (2.69 t/ha).

Participatory Varietal Selection

Nine rice genotypes comprises of advanced breeding lines and released variety were evaluated in participatory mode under transplanted and direct seeded condition at on-station as well as on-farm (**Fig. 5.2**). Among rice genotypes IR 97030-7-2-2-2 (5.51 t/ha), IR 93329:61-B-21-12-21-(5.32 t/ha), IR 98925-11-1-2-1(5.27 t/ha) and IR 90257-B-273-1-B B (5.02 t/ha) performed better as compared to check varieties DRR 44 (4.61 t/ha), Sahbhagi Dhan (4.56 t/ha) and IR 64 (4.33 t/ha). Seventy farmers were participated in screening of rice genotypes. Farmers selected the genotypes on the basis of panicle length, grain quality, resistance to diseases and insect pest, and lodging.

Field Day at KVK Buxar

Field day was organized at Krishi Vigyan Kendra, Lalganj, Buxar on 8th November, 2019 to evaluate the performance of rice genotypes grown

Fig. 5.2. Participation of farmers in varietal selection

under STRASA project. Seventy farmers and scientific staff of ICAR-RCER, Patna and KVK Buxar participated in the programme (**Fig. 5.3**). Farmers were very happy and expressed satisfaction over the performance of new drought tolerant rice genotypes. Farmers identified the promising genotypes on the basis grain quality as well as resistant to diseases and insect pest.

Breeder Seed Production

As per the indent of Department of Agriculture, Cooperation and Famers' Welfare, Government of India, ICAR RCER, Patna has produced breeder seed (23.0 quintals) of rice variety Swarna Shreya during *Kharif* 2019 (**Fig. 5.4**). The regional manager of National Seed Corporation (NSC), Patna, representative of Bihar state seed certification agency (BSSCA), Patna and scientific staff of ICAR RCER, Patna were participated in monitoring of breeder seed production. Besides, nucleus seed (1.5 quintal) and truthfully labelled (TL) seed (30.0 quintals) of Swarna Shreya were also produced during *Kharif* 2019. Moreover, nucleus seed (1.2 quintal) and truthfully lebelled (TL) seed (8.5 quintals) of Swarna Shakti Dhan were also produced during *Kharif* 2019.

Maintenance and Generation Advancement of Rice Breeding Materials

One hundred sixteen advanced breeding lines and twenty five released varieties of different duration were grown, purified and maintained during

Fig. 5.3. Participation of farmers and scientific staff in field day programme

Fig. 5.4. Breeder seed production of rice variety Swarna Shreya

Kharif 2019 at ICAR RCER, Patna (**Fig. 5.5**). Besides, Thirty eight F_2, forty two F_5, twelve F_6 and sixteen F_7 generation rice breeding materials along with parents were also raised. Uniform plants or lines of early and medium early duration have been selected based on the plant type, panicle length, effective tiller numbers, grain features, lodging resistance and tolerance to diseases and insect pests. The seeds of rice breeding materials have been retained for further evaluation and generation advancement.

Fig. 5.5. Maintenance and generation advancement of rice genotypes

Evaluation of Rice Genotypes for Tolerance to Multiple Stresses (Submergence and Drought)

Twenty one rice genotypes were evaluated under submergence, drought and combine stress (submergence + drought) conditions during *Kharif* 2019 (**Fig. 5.6**). The control trial was maintained by applying irrigation as and when required. Under the submergence experiment, after eleven days of transplanting the crop was completely submerged under 1.0 to 1.25 m water depth for eighteen days and thereafter water was drained out from the field. Due to natural heavy rainfall, the crop was again submerged (28 days after first desubmergence) for one week. Under drought stress experiment, crop faced stress at the reproductive stage. Sixty days old seedlings were subject to drought by withholding irrigation and withdrawing water from the field. Thereafter crop was left rainfed. Under combine stress crop faced 16 days submergence at vegetative stage and later drought at the reproductive stage. Results of the present study revealed that irrespective of the genotypes, there was a significant reduction in grain yield of rice under drought (26.3%), submergence (90.6%) and combine stress (87.9%) conditions as compared to control. Among rice genotypes, IR96321-558-563-B-2-1-1, IR 96321-315-294-B-1-1-1, IR96321-558-209-B-6-1-1, IR83383-B-B-129-4 (RCPR 10), IR 96321-1447-521-B-2-1-2, IR 96322-34-223-B-1-1-1 and IR 96321-315-323-B-3-1-3 have been found promising for multiple stresses tolerance. Grain yield of different rice genotypes varied from 3.58-4.57 t/ha, 0.06-1.30 t/ha, 0.00-1.41 t/ha and 4.70-5.83 t/ha, under drought, submergence, combine stress and control conditions, respectively.

Fig. 5.6. Evaluation of rice genotypes under multiple stresses (submergence and drought) conditions

Evaluation of Rice Genotypes for Submergence Tolerance

Fourteen rice genotypes were evaluated for submergence tolerance along with Swarna sub1, Samba Mahsuri sub1, IR64 sub1 and Ciherang sub1 as tolerant and Swarna as susceptible checks. Thirty days old seedlings were transplanted in the main field on 30th July 2019. After twelve days of

Fig. 5.7. Submergence tolerant rice IR09L 342

transplanting, the crop was completely submerged by filling water in the field with 1.0 m to 1.25 m water depth for 18 days, and thereafter water was completely drained out of the field. The crop re-submerged for one week during 29th September to 5th October due to heavy rain. The genotypes IR09L 342 (2.20 t/ha), TP 30191 (1.71 t/ha), IR10F365 (1.66 t/ha), TP30193-1 (1.65 t/ha) and IR11F195 (1.59 t/ha) performed better as comparered to Swarna sub1 (0.61 t/ha), Samba Mahsuri sub1 (0.17 t/ha) IR64 sub1 (0.30 t/ha) and Ciherang sub1 (0.45 t/ha) (Fig. 5.7). In long-duration genotypes like Swarna, Swarna sub1 and Samba Mahsuri sub1, there was problem of poor panicle emergence and spikelet sterility due to prevalent low temperature at reproductive phase. The duration of genotypes get enhanced under flooding stress depending on the duration of submergence and hence the long-duration genotypes get affected by low temperature due to further enhancement of their maturity duration under submergence.

Drought Tolerant Rice

Chandina is a short duration rice genotype collected from the farmers' field in Madhubani district of Bihar. It gives 3.5 t/ ha grain yield under direct sown condition in 75-80 days. It was screened for drought tolerance at the Rain out shelter facility at Central Upland Research station, Hazaribag during *Kharif* 2019 (Fig 5.8). Chandina showed drought score (SES) of 3 which is similar to the drought tolerant rice variety Vandana (Table 5.1).

Table 5.1. Drought tolerance score (SES) and other traits under drought stress

Genotypes	Days to flowering	Panicles/ m^2	Biomass (g/m)	Grain yield* (g/plot)	Drought score (SES)
Sathi	54	22	120	10	9
Chandina	74	66	240	30	3
Vandana (R-check)	67	92	220	250	3
KalingaIII (S-Check	61	64	200	20	7

*Plot size- 2.30 m^2; Drought stress period 15 days (7 to 21 September 2019)

Response of Drought Tolerant Rice Cultivars to Iron and Zinc

A field experiment was conducted during *Kharif* 2019 in ICAR-RCER, Patna to study the biofortification of iron and zinc on growth and yield of drought tolerant rice cultivars. The experiment consisted of 4 rice cultivars (Swarna Shreya; RCPR 22; Sahbhagi Dhan and DRR Dhan 42) and foliar application of $ZnSO_4$ and $FeSO_4$ (No spray -Control, foliar spray of 1% $FeSO_4$; foliar spray of 1% $ZnSO_4$ and foliar spray of 1% $FeSO_4$+1% $ZnSO_4$). Combined foliar application of $FeSO_4$ and $ZnSO_4$ each @ 1% significantly influenced the grain yield (5.69 t/ha), panicle length (26.6 m), test weight (25.42 g), number of filled grains per panicle (93.89) over no foliar spray (4.72 t/ha, 24.62 m, 23.76 g and 59.9 g, respectively) (**Table 5.2**).

Fig. 5.8. Rice genotype Chandina and Sathi under drought

Table 5.2. Yield and yield parameters of rice as influenced by variety and foliar application of zinc and iron

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Panicle length (cm)	Test weight (g)	No. of tillers/m^2	Plant height (cm)	Total no. of grains/ panicle	No. of filled grains/ panicle
Variety								
Swarna Shreya	5.45	6.41	24.24	24.27	244.00	126.03	111.45	72.97
RCPR 22	5.36	6.78	25.11	26.38	281.63	134.19	134.15	92.00
Sahbhagi Dhan	4.85	5.75	26.15	22.62	262.13	121.28	113.53	79.69
DRR Dhan 42	5.30	7.06	27.08	25.18	281.25	124.28	122.91	78.37
LSD (P=0.05)	NS	0.905	1.03	1.46	20.17	2.267	9.36	8.97
Foliar applications								
Control	4.72	5.89	24.62	23.76	249.88	129.00	120.63	59.90
1% $FeSO_4$	5.22	6.26	25.77	24.78	263.50	128.81	122.78	84.68
1% $ZnSO_4$	5.32	6.70	25.61	24.49	272.50	122.81	112.33	84.56
1% $FeSO_4$ + 1% $ZnSO_4$	5.69	7.15	26.60	25.42	283.13	125.16	126.30	93.89
LSD (P=0.05)	0.638	NS	0.869	0.688	19.087	4.211	6.629	11.66

Effect of Crop Establishment Methods and Weed Management Practices on Upland Direct Seeded Rice

Performance of upland direct–seeded rice was evaluated under three crop establishment methods *viz.*, ZT-DSR, CT-dry DSR and CT-DSR-dust mulching, and three weed pressures, i.e. low weed pressure [application of pendimethalin (pre-em. at 2 DAS) followed by *(fb)* bispyribac–Na (post-em. at 20 DAS) *fb* 2 HW (30 and 50 DAS)], medium weed pressure [application of pendimethalin (pre–em. at 2 DAS) *fb* bispyribac sodium (post-em. at 20 DAS)] and high weed pressure [application of pendimethalin (pre-em. at 2 DAS)] during *Kharif* 2019 at Patna (**Fig. 5.9**). Amongst the crop establishment methods, grain yields followed the trend of CT-DSR>CT-Dry DSR>ZT-DSR. Significantly higher grain yield (2.34 t/ha) was recorded under CT-DSR. Weed competition caused 89% reduction in grain yield of DSR. Application of pendimethalin followed by bispyribac-Na and 2 HW (low weed pressure) produced the maximum yield (3.18 t/ha) (**Table 5.3**). CT-DSR with low weed pressure recorded the highest grain yield (3.56 t/ha).

Fig. 5.9. Experimental view of direct seeded rice

In another experiment, weed competitive ability of six rice cultivars: 3 hybrids [Arize 6129 (short–duration); Arize 6444 (medium–duration), Arize Dhani (long–duration)] and 3 varieties [Swarna Shreya (short–duration); Rajendra Sweta (medium–duration); MTU 7029 (long duration)] was evaluated under three weed pressures i.e. low weed pressure [application of pretilachlor (pre–em. at 2 DAT) followed by *(fb)* bispyribac–Na (post–em. at 20 DAT) *fb* 1 HW (35 DAT), medium weed

Table 5.3. Grain yields of direct-seeded rice as influenced by crop establishment methods and weed pressure

Weed pressure	ZT–DSR	CT–Dry DSR	CT–DSR	Mean
Low	2.63	3.36	3.56	3.18
Medium	2.45	2.41	3.10	2.65
High	0.38	0.33	0.36	0.35
Mean	1.82	2.03	2.34	2063
		SEm±	LSD (*P*=0.05)	
Crop establishment methods (E)		0.04	0.14	
Weed pressure (W)		0.03	0.08	
E×W		0.05	0.15	

ZT–DSR: Zero till-direct seeded rice, CT: conventional till–direct seeded rice

pressure (application of pretilachlor (pre–em. at 2 DAT) *fb* bispyribac sodium (post–em. at 20 DAT) and high weed pressure (weedy check)]. About 21 days old seedlings was transplanted on 13th July 2018 using of 2/3 seedlings/hill with spacing of 20×15 cm. Results revealed that irrespective of the varieties, increase in weed pressure significantly reduced the grain yield of rice. Among different varieties Arize 6129 produced the highest grain yield (6.10 t/ha) and MTU 7029, the least (4.68 t/ha) (**Table 5.4**). Hybrids were more tolerant to weed pressure as compared to varieties. Short duration rice hybrid Arize 6129 with low weed pressure produced the maximum grain yield (6.98 t/ha) of rice (**Fig. 5.10**).

Table 5.4. Grain yield of rice as influenced by cultivars and weed management practices under low-land transplanted condition

Cultivars	Weed management practices			
	Low weed pressure	Medium weed pressure	High weed pressure	Mean
Arize 6129	6.98	5.99	5.33	6.10
Arize 6444	6.29	5.65	5.24	5.73
Arize Dhani	6.78	5.35	4.54	5.56
Swarna Shreya	5.73	5.33	4.68	5.25
Rajendra Sweta	5.45	5.03	4.43	4.97
MTU 7029	5.43	4.90	3.70	4.68
Mean	6.11	5.38	4.65	5.38
			SEm±	LSD (*P*=0.05)
Variety (V)			0.09	0.28
Weed pressure (W)			0.12	0.34
V×W			0.28	0.84

Fig. 5.10. Cropping view of rice cultivars during the experimentation

WHEAT

Effect of Drought and Heat Stress on Wheat: Changes in Plant Physiological Traits and Yield Attributes

A field screening of 16 wheat genotypes was performed under timely sown (20th November) and late-sown (December end) conditions in order to study the effect of water deficit and heat stress on physiological traits and yield attributes. The maximum temperature at (TS) anthesis for timely sown (between 10 - 20 February, 2019): and late sown (between 10 - 20 March 2019) was 20-25^{0}C, and < 30^{0}C, respectively indicating late sown crop face moderate heat stress during anthesis. Study showed that the duration of crop was significantly reduced under late sown condition (TS= 135 days, LS = 100 days), which in turn lead to lower biomass accumulation (Table 5.5). The grain yield and biological yield were significantly declined by 34% and 32.1% from timely irrigated to late sown irrigated heat stress condition, while 41.3% and 48.5% reduction from timely sown irrigated to late sown combined stress (terminal drought and heat) stress conditions. Physiological traits like relative water content (RWC), Chlorophyll content (Chl), Photosynthetic rate (Pn) were also declined from timely sown to late sown condition (Fig. 5.11). The maximum reduction in RWC (21.4%), Pn (26.3%) and Chl (28.5%) were observed under combined stress (terminal drought and heat). Biochemical traits like TBARS content (indicating lipid peroxidation) and proline level (indicating water deficit stress) were higher under both stress conditions, indicating the negative effect of stresses on wheat genotypes. Further, powdery mildew disease was observed on leaves of Raj4238 and DBW17, only on late sown crop. Overall, drought at reproductive stage was more harmful as compared to vegetative stage drought. Further, when drought combined with heat the effect was severe. At genotypic level, varieties like HD2987, NW1014, G273 and HD2967 were performing better under late sown stress conditions.

Phyto-Sociological Studies on Weeds of Wheat in Patna District

During survey and phyto-sociological studies, a large number (44 nos.) of weed species were collected from the wheat fields and categorized

Table 5.5. Effect of water deficit and heat stress on yield and yield attributes of wheat genotypes

	Timely sown				Late sown				%reduction TSC to LSC	%reduction TSC to LSRD
	TSC	TSVD	TSRD	Mean	LSC	LSVD	LSRD	Mean		
Yield and yield attributes										
Grain yield (t/ha)	5.48	4.93	4.82	5.08	3.61	3.27	2.80	3.23	34.0	**41.3**
Biological yield (t/ha)	15.87	13.05	14.11	14.34	10.78	9.13	9.21	9.70	32.1	**48.5**
1000-grain wt. (g)	42.3	37.7	35.8	38.6	32.7	30.4	27.4	30.2	22.4	**35.2**
Ear length (cm)	10.24	9.15	9.54	9.64	8.91	8.43	8.54	8.63	14.1	**16.2**
Tillers/m^2	696	657	688	680	463	384	436	428	33.5	**37.1**
Factors										
LSD (P=0.05): TS (T X V) BY: 1.55 GY: 0.50 TGW: 1.32 Tiller: 39.8					LSD (P=0.05): LS (T X V) BY: 1.06 GY: 0.38 TGW: 1.34 Tiller: 35.3					

TSVC - timely sown vegetative stage control condition; TSVD - timely sown vegetative stage drought condition; TSRC - timely sown reproductive stage control condition; TSRD - timely sown reproductive stage drought condition; LSVC - late sown vegetative stage control condition

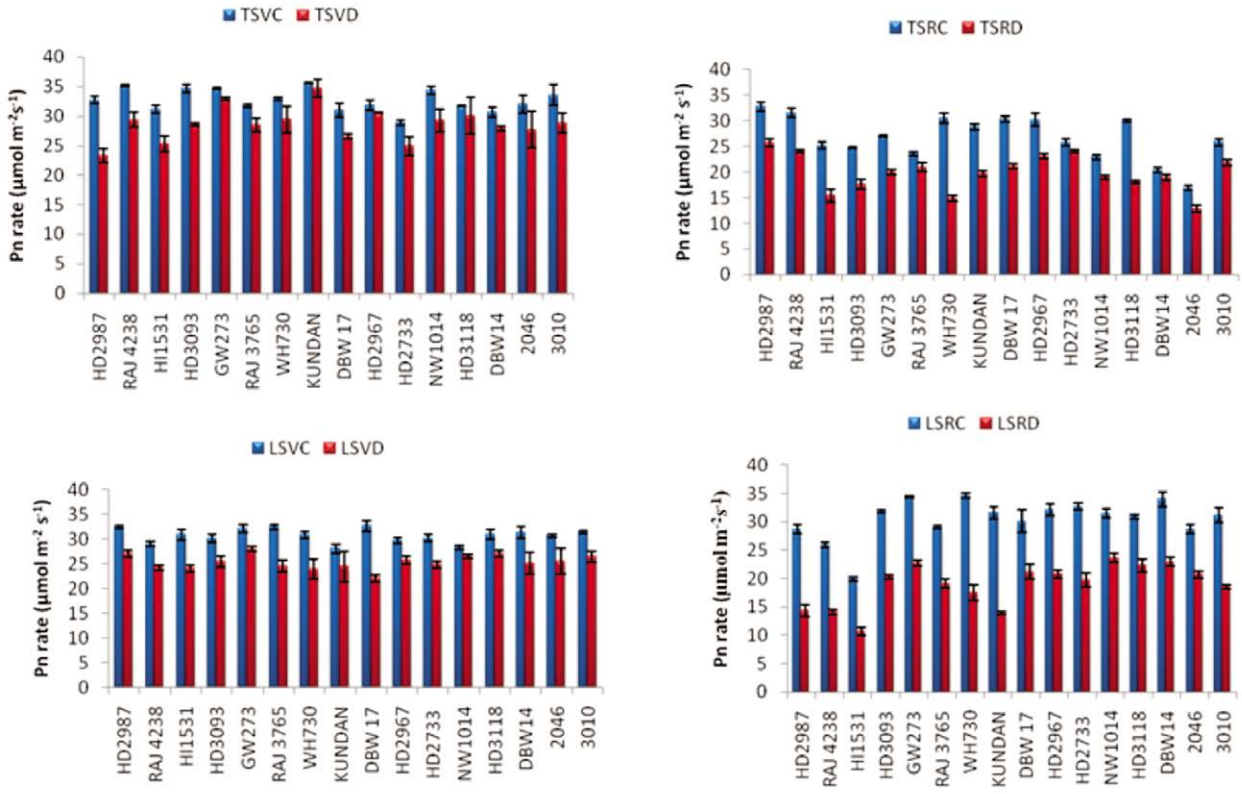


Fig. 5.11. Photosynthetic rate of wheat genotypes grown under different treatment conditions

with their family, type and life span. A total of nineteen families were recognized. Asteraceae family contains the largest number of weed species while Poaceae and Leguminosae family ranked second in terms of number of weed species within the family.

Data presented in **Table 5.6**, represents total occurrence of an individual (TOI), total number of individual weeds (TNI), frequency of individual weed species (F), density of individual weed species (D) and abundance of individual weed species (A). The most frequent species were *Phalaris minor* (42%), *Cynodon dactylon* (36%), *Anagallis arvensis* (32%), *Chenopodium album* (32%) and *Lathyrus aphaca* (30%), whereas total number of individual

Table 5.6. Phyto-sociological attributes of weeds of wheat crop in Patna district

Name of weed	TQ	TOI	TNI	F	D	A	RF	RD	RA
Phalaris minor L.	50	21	55	42	1.10	2.62	6.21	7.07	3.70
Chenopodium album L.	50	12	42	32	0.84	3.50	3.55	5.40	4.95
Anagallis arvensis L.	50	11	28	32	0.56	2.55	3.25	3.60	3.60
Oxalis corniculata L.	50	8	25	16	0.50	3.13	2.37	3.21	4.42
Vicia sativa L	50	10	21	20	0.42	2.10	2.96	2.70	2.97
Medicago denticulata L.	50	5	14	10	0.28	2.80	1.48	1.80	3.96
Trifolium fragiferum L.	50	7	20	14	0.40	2.86	2.07	2.57	4.04
Melilotus albus Medik.	50	5	12	22	0.24	2.40	1.48	1.54	3.39
Trifolium fragiferum L.	50	12	26	24	0.52	2.17	3.55	3.34	3.06
Xanthium strumarium L.	50	6	11	12	0.22	1.83	1.78	1.41	2.59
Rumex retroflexus L.	50	10	22	20	0.44	2.20	2.96	2.83	3.11
Parthenium hysterophorus L.	50	13	38	26	0.76	2.92	3.85	4.88	4.13
Physalis mimima L.	50	12	28	24	0.56	2.33	3.55	3.60	3.30
Cynodon dactylon L.	50	18	38	36	0.76	2.11	5.33	4.88	2.98
Spergulus arvensis L.	50	11	30	22	0.60	2.73	3.25	3.86	3.85
Amaranthus viridis L.	50	16	20	24	0.40	1.25	4.73	2.57	1.77
Avena fatua L.	50	13	32	26	0.64	2.46	3.85	4.11	3.48
Sonchus asper L.	50	7	22	14	0.44	3.14	2.07	2.83	4.44
Fumaria parviflora L.	50	12	35	24	0.70	2.92	3.55	4.50	4.12
Euphorbia hirta L.	50	15	25	28	0.50	1.67	4.44	3.21	2.36
Lathyrus aphaca L.	50	14	34	30	0.68	2.43	4.14	4.37	3.43
Lathyrus sativa L.	50	9	22	18	0.44	2.44	2.66	2.83	3.45
Lepidium sativum L.	50	11	25	22	0.50	2.27	3.25	3.21	3.21
Convovulus arvensis L.	50	11	18	22	0.36	1.64	3.25	2.31	2.31
Melilotus indica L.	50	15	20	30	0.40	1.33	4.44	2.57	1.88
Vicia hirsuta L.	50	6	14	12	0.28	2.33	1.78	1.80	3.30
Rumex dentatus L.	50	10	24	20	0.48	2.40	2.96	3.08	3.39
Polypogonmon speliensis L.	50	9	20	18	0.40	2.22	2.66	2.57	3.14
Cirsium arvense L.	50	16	26	22	0.52	1.63	4.73	3.34	2.30
Barbarea vulgaris L.	50	13	31	16	0.62	2.38	3.85	3.98	3.37

Note - TQ: total no. of quadrates, TOI: total occurrence of individuals, TNI: total no. of individual *spp*., F: frequency, D: density, A: abundance, RF: relative frequency, RD: relative density, RA: relative abundance

species was found highest with *P. minor* (55/m^2) *C. album* (40/m^2), *Parthenium hysterophorus* (38/m^2), *C. dactylon* (38/m^2), and *Lathyrus aphaca* (34/m^2). Density of weeds ranges from 0.4 to 1.1 in the wheat fields of Patna district. *P. minor* (1.1), *C. album* (0.84), *P. hysterophorus* (0.76), *C. dactylon* (0.76) and *L. aphaca* (0.68) resulted in maximum weed density of individual weeds in the surveyed area. Therefore, *P. minor*, *C. album*, *C. dactylon*, *P. hysterophorus* and *L. aphaca* can be considered as the dominant weed flora among the weed community prevailing over the wheat fields of Patna district. The value of relative frequency and relative density was found to be the highest for *P. minor* (6.21, 7.06) which was followed by *C. album* (5.33, 5.39), respectively. These two weed species clearly reflect their dominance among the other weed community in the wheat fields. The Importance Value Index (IVI) of *P. minor*, *C. album*, *C. dactylon* L., *P. hysterophorus* L. was most dominant among the observed weed community. The lowest IVI values represented by *Xanthium strumarium, Melilotus albus*, *Chenopodium murale*, *Medicago denticulata* reflects that these weed species rarely grow in the area and need not to be focused for its control. The IVI values ranged from 5.78 to 16.98 in the study area.

6. Pulses

Pigeonpea

Genetic Improvement for Yield and Biotic Stress Resistance Under Eastern Plateau and Hill Region

Evaluation of long duration germplasm

Eight genotypes *viz.*, IPA-203, Type-7, Pusa-9, NDA-2, RCRPP-2, RCRPP-3, IC 611683, IC 611232 identified during the previous year were evaluated along with checks NDA-1, Bahar and Asha for days to 50% flowering, grain yield and 100 seed weight. Simultaneously in another plot, resistance reaction to Fusarium wilt under natural conditions (PDI) and Pod borer under natural conditions (Percent infested) were collected and correlated with the yield data for selection of best genotypes. Based on the overall performance, four genotypes *viz.*, IC 611683, IC 611232, IPA-203 and Type-7 were selected for further evaluation. RCEA-14-6, RCEA-14-1, RCEA-14-5, DBGA-7-10, RCRPP-1, IC 611212, IC 611215, IC 611261, IC 611682 and IC 614683 were being maintained for further utilization in the breeding programme. Off-type of IPA-203 and a collection from Rajasthan were evaluated for yield and days to 50% flowering . Seed from two crosses IC 611682 x IC 611232 and IC 611682 x DBGA-7-10 was collected for further evaluation.

Evaluation of short duration germplasm

Twenty short duration genotypes collected from ICRISAT, Hyderabad were evaluated for growth and yield parameters. ICPL-92047, ICPL-81-3 (**Fig. 6.1**), ICPL-88034, ICPL-11318 (**Fig. 6.2**), ICPL-11303, ICPL-20327 (**Fig. 6.3**) and ICPL-20325 were found promising among the short duration group with respect to yield and yield characters.

Chickpea

Performance of Promising Chickpea Genotypes in Irrigated and Rainfed Situations

Two station trials each comprising the same set of 12 treatments including 2 check varieties (released for north east plains) were conducted both under normal irrigated and rainfed conditions (during the 3rd week of November 2018). The test entry 'DBGC 1' (3.78 t/ha), with 100-seed wt. of 26.72 g and maturity period of 134 days showed an yield advantage over the best check 'Pusa 3043' (3.32 t/ha) by more than 13% under normal irrigated condition (**Table 6.1**). Another station trial comprising 6 entries including two checks was conducted under late sown condition (second fortnight of December 2018) at three locations, *viz.*, KVK, Vaishali, KVK, Buxar and BAU, Sabour. Yield of both test entries and check

Fig. 6.1. ICPL-81-3

Fig. 6.2. ICPL-11318

Fig. 6.3. ICPL-20327

varieties were reduced significantly compared to those under normal sown condition at Patna. The mean performance of test genotypes and checks are given in **Table 6.2**.

Table 6.1. Mean performance of promising chickpea genotypes under normal sown conditions at ICAR RCER, Patna

Genotypes	Irrigated condition			Rainfed condition		
	Yield (t/ha)	100-seed wt (g)	Maturity period (days)	Yield (t/ha)	100-seed wt (g)	Maturity period (days)
DBGC 1	3.78	26.72	134	2.66	24.89	130
DBGC 2	3.01	29.05	132	2.38	28.60	131
DBGC 3	3.06	24.19	134	2.27	25.26	131
DBGC 4	2.98	26.53	135	2.26	28.06	131
Pusa 372	2.84	14.22	133	2.16	15.68	130
Pusa 1103	3.09	23.82	134	2.11	24.20	131
Pusa 3042	3.32	21.87	132	2.44	22.21	129
LSD (P=0.05)	0.41	2.32	1.35	0.21	2.10	0.55

Table 6.2. Seed yield (kg/ha) of promising chickpea genotypes in multi-location trials

Genotypes	KVK, Vaishali	KVK, Buxar	BAU, Sabour
DBGC 1	2.00	2.89	2.81
DBGC 2	2.18	2.59	2.54
DBGC 3	2.05	2.80	1.87
DBGC 4	1.73	2.35	2.19
Pusa 372	1.46	2.59	1.68
Pusa 547	1.63	2.60	2.35
LSD (P=0.05)	0.22	0.25	0.48

Evaluation of advance breeding lines in wilt sick nursery

Four advance breeding lines namely DBGC 1', 'DBGC 2', 'DBGC 3' and 'DBGC 4' were tested for the disease reaction in the wilt sick nursery at TCA, Dholi. All the lines were rated "moderately resistant" against the available races of *Fusarium ciceri* at TCA, Dholi (**Table 6.3**).

Table 6.3. Wilt reaction of chickpea genotypes at TCA, Dholi

Genotypes	% Wilted plants (R-I)	% Wilted plants (R-II)	Average wilt incidence	Wilt reaction
DBGC 1	16.67	22.22	19.44	MR
DBGC 2	25.00	18.42	21.71	MR
DBGC 3	14.71	12.82	13.76	MR
DBGC 4	19.44	21.62	20.53	MR
JG 62 (S-check)	81.82	80.00	80.91	S
Pusa 256 (R-check)	14.29	12.00	13.14	MR

MR: Moderately resistant; S: Susceptible

Heat stress studies in chickpea: Two trials each with the same set of 12 genotypes were sown on January 01, 2019 to assess their performance for heat stress tolerance. One trial was provided two irrigations, one at branching stage, and the other at pod-filling stage. In the second trial, no irrigation was provided with the object to observe the cumulative effects of both heat stress and drought. Drastic reduction in yield and its component traits was observed under heat stress condition. 'DBGC 4' (1.27 t/ha), 'DBGC 3' (1.22 t/ha), 'DBGC 1' (1.09 t/ha) and 'Pusa 3043' (1.09 t/ha) performed significantly better than all other genotypes and varieties in irrigated heat stress situation. The cumulative effects of heat and drought stresses brought about significant yield reduction in the second trial (Table 6.4); however, the above-mentioned genotypes provided satisfactory yield also in such a situation.

Root studies: An experiment comprising 12 chickpea genotypes was conducted in PVC pipes

Table 6.4. Mean performance of promising chickpea genotypes under heat stress and cumulative heat and drought stresses

Genotypes	Yield (t/ha)			Pods/plant (nos.)			100 seed wt (g)		
	HS*	CHDS	% Reduction	HS*	CHDS	% Reduction	HS*	CHDS	% Reduction
DBGC 1	1.09	0.87	20.44	43.00	32.6	24.18	24.64	24.13	2.05
DBGC 3	1.21	0.86	29.49	37.13	29.26	21.18	25.19	23.72	5.84
DBGC 4	1.27	1.08	15.14	33.20	28.00	15.66	24.44	24.94	0.00
Pusa 3043	1.09	0.86	21.49	41.00	30.80	24.87	20.61	18.97	7.94
Pusa 1103	0.94	0.76	19.10	29.80	25.26	15.21	23.7	21.57	8.95
LSD (P=0.05)	0.11	0.11	--	5.6	4.9	--	1.20	1.18	--

*HS: Heat stress, CHDS: Cumulative heat and drought stress

(length: 1.2 m; diameter: 15 cm) to study root length, root wt. and shoot wt. at 50 days after sowing. Root length (RL) showed significant positive association with shoot length (SL), total fresh wt (TFW), total dry wt (TDW) and shoot dry wt (SDW). SL also showed significant positive linkages with shoot fresh wt (SFW), TFW, TDW and SDW. Root fresh wt (RFW) was observed to have significant correlation with root dry wt (RDW) and TFW.

Entry put to AICRP/State varietal trial: Two advance breeding lines of chickpea, one (DBGC 1) for normal sown irrigated condition and the other (DBGC 4) for rainfed situation were contributed to AICRP initial varietal trial (IVT) of chickpea for evaluation during the year 2019-20. The other advance breeding line 'DBGC 2' was put to state varietal trial for yield evaluation during the year 2019-20.

Breeding materials and germplasm maintained during 2018-19: The advance breeding lines (DBGC 1, DBGC 2, DBGC 3, DBGC 4, RCECK 15-1, RCECK 15-2, RCECK 15-3 and RCECK 15-4), ICRISAT germplasm line (ICC 4958) and released Desi (Pusa 256, Pusa 372, Pusa 547, Pusa 1103, Pusa 3043, KWR 108, JG 14 and GNG 1581) and Kabuli (IPCK 2002-29 and Pusa 1003) chickpea varieties were grown and maintained. In addition, 10 single plant selections in each of the three F8 bulks (received from IARI, New Delhi) was performed, and seeds were individually harvested and kept for their utilization in the forthcoming *Rabi* season.

Lentil

Performance of lentil genotypes in station trials

Two station trials, one comprising 8 treatments including 4 checks (Pusa Vaibhav, DPL 15, KLS 218 and HUL 57) and the second with 12 released varieties, were conducted under normal sown (3rd week of November 2017) conditions. Only one test entry 'DBGL 105' (1.47 t/ha) excelled the best check 'HUL 57' (1.23 t/ha) in the first trial. Two genotypes 'DBGL 135' and 'DBGL 138' although yielded at par with check varieties showed maturity advantage by around two weeks (**Table 6.5**) at ICAR RCER, Patna. In the second trial, two varieties 'Arun' (2.03 t/ha) and 'DPL 62' (1.57 t/ha) excelled all other lentil varieties released thereafter.

Table 6.5. Mean performance of lentil genotypes in station trials

Genotypes	Yield (t/ha)			100 seed wt (g)	Maturity duration (days)
	Patna	Vaishali	Buxar	Patna	Patna
DBGL 62	1.46	1.64	2.10	3.0	118
DBGL 105	1.47	1.81	2.04	3.6	117
DBGL 135	1.11	1.60	1.68	2.8	103
DBGL 138	1.15	---	---	2.9	104
Pusa Vaibhav	1.12	--	--	3.0	117
DPL 15	1.02	---	---	3.8	118
KLS 218	1.07	1.40	1.92	3.0	118
HUL 57	1.23	1.39	1.92	3.2	118
IPL 220	---	1.39	1.96	---	---
LSD (P=0.05)	0.24	0.15	0.19	0.24	0.74

Association studies among root traits in lentil

An experiment comprising 12 lentil genotypes was conducted in PVC pipes (length: 1.2 m; diameter: 15 cm) to study root length, root wt and shoot wt at 50 days after sowing. Root length (RL) showed significant negative association with shoot length (SL). Root fresh wt (RFW) showed significant positive correlation with shoot fresh wt (SFW), root dry wt (RDL), total fresh wt (TFW) and total dry wt (TDL). RDW showed highly significant positive correlation with RFW, SDW and TDW.

Entry put to AICRP/State varietal trial

One advance breeding line 'DBGL 62' of lentil was contributed to AICRP (MULLaRP) initial varietal trial (IVT) for evaluation during the year 2019-20. Another advance breeding line 'DBGC 105' was put to state varietal trial for evaluation during the year 2019-20.

Breeding materials and germplasm maintained during 2018-19: Eighteen advance breeding lines and 17 released varieties were grown, purified and maintained. A total of 45 SPS (12 from ILWL 118 × DPL 58 and 33 from varieties) was performed and kept for further multiplication. Extra early spreading and extra early tall and compact types maturing in less than 90 days were also multiplied. Besides, 3 individual plant progenies from a local land race 'Gopalpur Local' were also grown and maintained.

Nutritional profile studies in cool season pulses

In order to assess nutritional quality of cool season pulses, seed samples were sent to ICAR RCER Regional Centre, Ranchi for detailed analysis of protein and micronutrient content during 2019. It is evident that the chickpea variety 'Pusa 3043' (released in 2018) has significantly lower protein content than older varieties such as 'Pusa 256' and 'Pusa 372', indicating the necessity to pay due attention on quality attributes while assessing a prospective genotype for release and notification. A few advance breeding lines of chickpea (DBGC1, DBGC 2 and DBGC 3) and lentil (DBGL 135) bred at ICAR RCER, Patna have a balanced proportion of both protein and Zn content (**Table 6.6a&b**).

Table 6.6a. Nutritional profile of selected genotypes/ varieties of chickpea

Genotype	N (%)	Protein (%)	Zn (ppm)
DBGC 1	3.21 ± 0.11	20.06	36.8±1.30
DBGC 2	3.46 ± 0.21	21.63	42.2±1.25
DBGC 3	3.47±0.16	21.69	37.8±1.90
DBGC 4	2.55 ±0.12	15.94	34.8±1.45
Pusa 256	3.08 ± 0.13	19.13	42.2±1.80
Pusa 372	3.17± 0.18	19.81	38.3±1.60
Pusa 547	3.29 ± 0.25	20.56	36.8±1.85
Pusa 1103	3.32 ± 0.15	20.75	41.7±2.15
Pusa 3043	2.49 ±0.13	15.56	44.7±1.75
ICC 4958	2.95 ± 0.15	18.43	17.6±1.35
JG 14	3.24 ± 0.21	20.25	45.2±1.90

Table 6.6b. Nutritional profile of selected genotypes/ varieties of lentil

Genotype	N (%)	Protein (%)	Zn (ppm)
PL 8	3.73 ± 0.15	23.31	49.6
DPL 15	3.94 ± 0.16	24.62	50.6
HUL 57	4.00 ± 0.27	25.00	56.0
DBGL 135	4.29 ± 0.20	26.81	53.5
DBGL 62	3.60 ± 0.13	22.50	55.5
DBGL 138	3.81 ± 0.10	23.81	53.1
Pusa Vaibhav	3.70 ± 0.15	23.12	49.1
KLS 218	3.44 ± 0.13	21.50	57.0
IPL 220	4.07 ± 0.10	25.43	59.0
IG 4258	3.84 ± 0.16	24.00	58.0
DBGL 105	4.09 ± 0.22	25.56	50.1

Pulse Seed Hub

Under the aegis of NFSM funded mega project on "Creation of seed hubs for increasing indigenous production of pulses in India", quality seed production of lentil, field pea, chickpea, mungbean, urdbean and pigeonpea were undertaken at ICAR RCER, Patna and KVK, Buxar. Details of quality seeds produced are mentioned in the **Table 6.7**. During the year 2019, the construction of seed processing *cum* seed storage godowns and re-installation of seed processing plant at the newly constructed sites was completed both at ICAR RCER, Patna and KVK, Buxar.

Table 6.7. Quality seeds of pulses produced during the year 2019

Pulse Seed Hub	Crop	Variety	Class of seed	Quantity (t)
ICAR RCER, Patna	Lentil	HUL 57	C/S, T/L	6.0
		PL 8	T/L	3.0
		IPL 220	Nucleus, T/L	0.6
	Field pea	DFP 1	C/S, T/L	2.6
	Chickpea	Pusa 3043	Nucleus	0.4
		Shubhra	Nucleus, T/L	0.1
	Pigeon-pea	IPA 203	Nucleus	0.02
			TL	0.7
	Mung-bean	Samrat	T/L	2.0
		Virat	C/S	4.0
		IPM 02-3	T/L	0.7
		IPM 02-14	T/L	1.0
	Urdbean	Uttara	T/L	0.05
		IPU 02-11	Nucleus	0.01
KVK, Buxar	Chickpea	GNG 1581	C/S	15

CS: Certified seed; T/L: Truthfully labelled seed

7 Fruits

Plant Genetic Resource Management

Widening genetic base of litchi

This trial is being undertaken since 2000 to widen the narrow genetic base of litchi in India by raising segregating population of popular litchi genotypes. During 2019, nineteen litchi seedlings evaluated for the fruit quality and sensory scores. The fruit weight ranged between 13.54 g (seedling 2/6) to 22.49 g (seedling 5/4). The maximum pulp content was recorded in seedling 16/4 (72.40%) whereas, maximum TSS was recorded in seedling 14/3 (21°B). Keeping in view the fruit quality and sensory scores (average fruit weight >200 g, pulp content >65%, TSS>19°B and sensory scores >7), the seedling litchi germplasm 10/5, 14/1and 14/3 were found to be the most promising for further evaluation (**Table 7.1 and Fig. 7.1**).

Fig. 7.1. Promising segregants of litchi

Evaluation of sapota varieties under Jharkhand conditions

A total of eleven sapota varieties conserved in the field gene bank were evaluated for fruit quality. Among the promising varieties (Murabba, Cricket Ball, Bhuripatti and Jhumakiya), the maximum fruit weight (102.78 g) and pulp % (89.76%); lowest peel% (8.34%), seed% (1.99%) and seed number per fruit (1.99) was recorded in case of Murabba. The maximum TSS was recorded in case of Bhuripatti (28.38^0B). Murabbba variety also recorded higher yield for the age group 10-15 year (15.15 kg/plant), 15-20 year (30.80 kg/plant) and >20 years (52.50 kg/plant). Hence, based on long term data on sapota fruit quality and yield, the variety Murabba is found most promising and recommended for the commercial cultivation under Jharkhand conditions (**Table 7.2**).

Fig. 7.2. 'Murabba' promising sapota varieties

Table 7.1. Fruit quality of promising segregants of litchi

Seed-lings	Fruit weight (g)	Pulp (%)	TSS (°B)	Acidity (%)	Total sugar (%)	Sensory scores based on 1-10 scale			
						Colour and appearance	Taste	Aroma	Texture and mouth feel/ Juiciness
4/3	18.41	68.57	18.20	0.06	12.50	7.57	6.71	7.00	7.14
5/4	22.49	61.24	18.40	0.05	14.71	8.14	7.57	8.00	7.57
5/5	19.92	56.39	17.30	0.07	6.10	7.43	6.14	6.14	5.71
7/7	22.03	66.99	17.30	0.09	9.26	7.71	6.00	6.29	7.29
10/5	19.95	65.22	19.90	0.07	14.29	8.00	7.71	7.43	7.57
11/2	21.71	64.26	20.90	0.04	11.90	6.86	6.71	6.29	6.86
12/1	21.61	63.57	18.40	0.03	11.36	8.14	7.57	7.00	7.71
14/1	20.81	67.87	20.40	0.03	13.51	7.71	7.86	7.71	7.86
14/3	19.83	69.83	21.00	0.07	15.15	7.86	7.29	7.57	7.43
16/4	21.22	72.40	17.60	0.05	10.87	8.00	6.86	7.00	7.43

Table 7.2. Fruit quality parameters and yield of different sapota varieties based on 13 years fruiting data (2005 to 2018)

Characters		Murabba	Cricket Ball	Bhuripatti	Kalipatti	Jhumakiya
Fruit weight (g)		102.78	94.79	63.64	91.34	67.05
Pulp (%)		89.76	88.96	84.53	86.88	86.33
Peel (%)		8.34	8.70	11.20	10.32	9.37
Seed (%)		1.99	2.38	4.26	2.51	4.71
Seed number per fruit		1.98	2.05	2.98	2.93	3.50
TSS (°B)		26.54	24.39	28.38	25.72	22.91
Acidity (%)		0.10	0.07	0.10	0.09	0.17
Yield (kg/plant/year)	10-15 year	15.15	11.47	5.40	9.60	7.50
	15-20 year	30.80	27.65	27.40	17.05	26.25
	>20 years	52.50	45.50	31.00	31.60	39.00
Fruit fly infestation		Moderate	Moderate	Moderate	Moderate	Low

Evaluation of Jackfruit Germplasm for Vegetable Purpose

During the year 2019, jackfruit germplasm were evaluated for their suitability as vegetables. The fruits were evaluated at tender stage (fruit weight varies from 0.5 to 1.0 kg) based on per cent edible portion, TSS, acidity and firmness of edible portion after boiling. The per cent edible portion varied from 44.29 % (ICARRCER JS 3/8) to 68.75 % (ICARRCER JS 7/4). The minimum firmness was recorded with ICARRCER JS 1/4 (1.73 lbs) whereas maximum firmness was recorded in the ICARRCER JS 7/4 (6.5lbs). Hence, based on per cent edible portion and firmness ICARRCER JS 1/4, 2/9, 8/9 and 10/3 were found promising for vegetable purpose (**Fig. 7.3**).

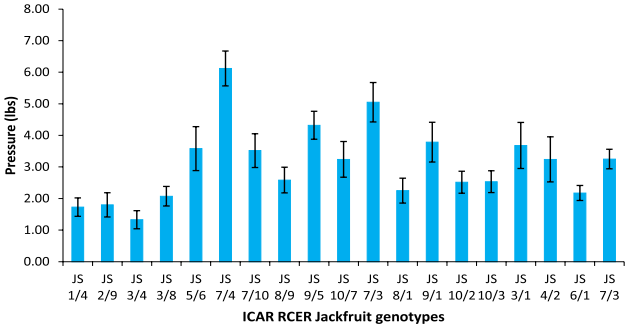


Fig. 7.3. Firmness (lbs) of edible part after boiling of different jackfruit genotypes.

Standardization of Basin Enrichment under High-density Orchards of Bael

During the 6th year of experimentation, the maximum dry biomass yield was recorded with subabul (26.6±7.71 t/ha) whereas no biomass yield could be harvested from tephrosia. However, the cumulative dry biomass yield (6 years) was maximum in case of tephrosia (141.87 t/ha). The bael plants had started fruiting from 5th year onwards and during the 6th year the fruit yield ranged between 0.1 to 1.24 t/ha although the treatmental effects were non-significant. All the treatments resulted in significant reduction in soil bulk density than the control at 0-15 and 15-30 cm soil depth and the minimum bulk density was recorded with soil incorporation of subabul (**Fig. 7.4**). Basin enrichment with subabul resulted in significant increase in the available soil nitrogen over that of control. In the litter decomposition studies, the rate of release of nitrogen was found significantly faster in case of both subabul and tephrosia than that from rice bean and vegetable soybean. Slower rate of release of nitrogen from rice bean biomass coupled with higher soil bulk density might have contributed towards low leaching loss of nitrogen and higher uptake by the bael plants whereas faster rate of release from subabul biomass coupled with lower soil bulk density might have contributed towards higher leaching loss of nitrogen and lower uptake by bael plants.

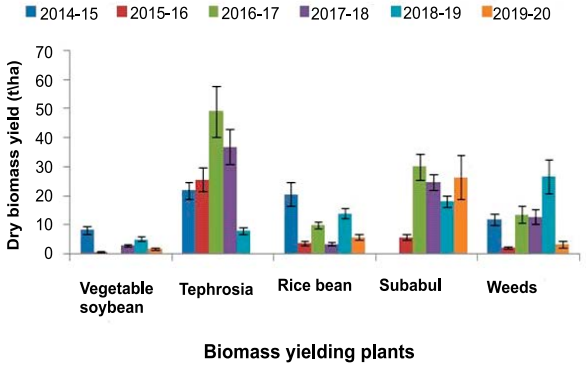


Fig. 7.4. Pattern of annual biomass yield of different plants grown under bael orchards

8. Vegetables

Collection, Evaluation and Development of Bacterial Wilt Resistant Germplasm of Brinjal

Evaluation of bacterial wilt resistant (BWR) germplasm

Eleven promising genotypes/ ABLs/ varieties *viz.*, HAB-915 (**Fig. 8.1**), HAB-917, IC-545901 (**Fig. 8.2**), HAB-792, IC-545901-1, HABR-6, Swarna Avilamb, IC-261786, HAB-905, HAB-906 and HAB-901 were evaluated for fruit yield and wilt resistance (**Table 8.1**). HAB-915 (RCBR-22) was submitted under round varietal trial of IET AICRP (VC), 2019. Individual plant selection of F_7 generation of Swarna Shyamali x Swarna Pratibha (**Fig. 8.3**) was carried out for wilt resistance and non spiny fruits.

Evaluation of BWR F_1s

Best performing twelve F_1 hybrids i.e., HAB-792 x IC-545901, HABR-6 x IC-545901, Swarna Avilamb x IC-545901, Swarna Avilamb x HAB-901, HABR-6 x HAB-901, HAB-905 x IC-545901, HAB-906 x IC-545901, IC-261786 x IC-545901, HAB-917 x HAB-906, HAB-917 x HAB-901, HAB-917 x IC-545901 and HAB-917 x IC 261786 selected from previous experiments were evaluated for yield, fruit characters and bacterial wilt resistance in field conditions. Five hybrids have been selected for further evaluation (**Table 8.2**). HABR-6 x IC-545901 (RCBRH-18/ Round hybrid) and Swarna Avilamb x IC-545901 (RCBLH-20/ Long hybrid) (**Fig. 8.4**) were submitted under IET AICRP (VC) 2019 for multi-location testing.

Table 8.1. Promising lines for wilt resistance

Genotype	Yield (t/ha)	Fruit weight (g)	Fruit length (g)	Days to 50% flowering	Fruit
IC 545901	20.63	119.33	14.73	51.00	Long purple, green calyx
IC 545901-1	32.76	110.67	9.85	51.33	Long dark purple
IC 261786	22.91	119.67	15.00	47.00	Long preen, green calyx
HAB-915	19.74	164.00	9.17	48.33	Round green stripes, green calyx
Swarna Shyamali x Swarna Pratibha-15-24 F_7	27.66	148.00	9.3	47.67	Round green stripes, green non spiny calyx

Improvement in Seed Quality of Solanaceous and Cucurbitaceous Vegetables

An experiment was conducted to study the

Fig. 8.1. HAB-915

Fig. 8.2. IC-545901

Fig. 8.3. Swarna Shyamali x Swarna Pratibha-15-24 F7

Fig. 8.4. Swarna Avilamb x IC-545901

Table 8.2. Promising F_1 hybrids

Genotype	Yield (t/ha)	Fruit weight (g)	Fruit length (cm)	Days to 50% flowering	Fruit
Swarna Avilamb x IC 545901	36.52	143.67	20.60	44.3	Long purple, green calyx
IC 261786 x IC 545901	26.10	127.67	15.10	49.0	Long purple, green calyx
HAB-906 x IC 545901	36.95	139.00	19.63	48.0	Long purple, green calyx
HABR-905 x IC 545901	30.46	95.67	15.83	40.0	Long dark purple
HABR-6 x IC 545901	38.46	135.67	12.83	46.0	Oblong purple

effect of seed treatment of brinjal var. Swarna Shyamali with different plant protectants (Hexaconazole, copper-oxy-chloride, *Trichoderma asperellum* NAIMCC-F-03167 formulation, *T. viridae* formulation) in addition to an untreated control (**Fig. 8.5**). Seed priming with granular spore of *Trichoderma* asperellum resulted in the lowest incidence of damping off (2.4%) and the highest seedling dry weight (254 mg) as compared to that of control (14.3 % and 242 mg, respectively). The initial gain in seedling dry matter later resulted in faster growth of plants in field in case of seed treatment with *T. asperellum* followed by control. Hexaconazole treatment was found to reduce the incidence of damping-off (7.3%) but seedling vigour was lower (seedling dry weight 177 mg) as compared to *Trichoderma asperellum* and control.

Fig. 8.5. Healthy seedlings of brinjal var. Swarna Shyamali as a result of seed treatment with T. asperellum

Exploration and Collection of Germplasm

An exploration was conducted in collaboration with ICAR-NBPGR RS Ranchi for collection of Cucurbits (*Coccinia, luffa, momordica, cucumis* etc.), other vegetables (except *Solanum*) and millets from Katihar and Purnia districts in Bihar. In total 33 accessions were collected from 21 sites. The collected germplasm of muskmelon (1), long melon (1), cucumber (2), sponge gourd (black seeded) (1), sponge gourd (white seeded) (2), bitter gourd (1), ash gourd (2), bottle gourd (2), pumpkin (1), pointed gourd (3), coccinia (3) and satputtia of cucurbits (1), amaranths (green) (1), amaranths (red) (1), lafa saag (1), sem (2), methi (1) and basella (2) in other vegetables were deposited to NBPGR, New Delhi. A striped fruited bottle gourd was also found during exploration which is very rare trait in bottle gourd (**Fig. 8.6**).

Fig. 8.6. Striped fruited bottle gourd cultivar

Seasonal Incidence and Evaluation of Management Strategies against Insect Pests of Cabbage, Cauliflower and Chilli

The major insects on cauliflower were diamondback moth (*Plutella xylostella* (L.) and *Phyllotreta cruciferae* and on cabbage diamondback moth (*P. xylostella* (L.), *P. cruciferae* and *Brevicoryne brassicae* while chilli was infested with thrips, *Scirtothrips dorsalis.* Coccinellids and spider were the major natural enemies on chilli. The maximum temperature showed significant negative correlation with *P. cruciferae* infestation, whereas, other weather parameters showed non-significant cor-

relation . The coccinellid beetle was recorded as an important predator of thrips in chilli, which was positively correlated with thrips population.

Spray of flubendiamide 20% WG @ 0.4 g/l followed by lufenuron 5.4% EC @ 1 ml/l, spinosad 2.5% SC @ 0.3 ml/l, indoxacarb 14.5 SC @ 1.0 ml/l and cypermethrin 25 EC @2.0 ml/l were found to be effective against insect pests of cauliflower and cabbage.

Management of Wilt Complex in Leguminous and Cucurbitaceous Crops of Eastern Region

For development of management strategies against wilt complex of leguminous and cucurbitaceous crops, three new fungicides *viz*., azoxystrobin 250SC, fluopyram (17.6%) + tebuconazole (17.6%), iprovalicarb (5.5%) + propineb (25%) were evaluated for their antifungal efficacy *in vitro.* Iprovalicarb (5.5%) + propineb (25%) and azoxystrobin 250SC and fluopyram (17.6%) + tebuconazole (17.6%) were showed strong efficacy against *Pythium aphanidermatum* followed by *Fusarium oxysporum*, *Rhizoctonia solani and Sclerotium rolfsii* at very low concentration (0.05%). Moreover in field evaluation, seed treatment with combination of iprovalicarb (5.5%) + propineb (25%) showed the highest protection and minimum *Fusarium* wilt incidence (6.55%) followed by azoxystrobin 250SC (6.94%), fluopyram + tebuconazole (8.82%) at 2.5/kg seed of chickpea. While in bioagents, *T. asperellum* @ 10 g per kg seed (11.24%), *T. viride* @ 10g/ kg seed (12.38%) and *P. fluorescens* (14.79%) showed minimum wilt incidence over control (24.59%) after 90 days of the sowing in chickpea.

Collection, Identification and Conservation of Wild Edible Mushroom from Forest and Local Market

Rugda (*Scleroderma* sp.) and Tecnus (*Termitomyces* sp.) mushroom were consistently recorded in the local market of Ranchi, Ramgarh, Chibasa, Gumla, Chatra and Hazaribag of Jharkhand as well as in local forest nearby the research centre (Fig. 8.7). It is now well established that wild edible mushrooms play an important role in ensuring livelihood security of the tribal people residing in the forest. Among the edible mushroom, Rugda is collected from the forest of Saal in rainy season from July to August and sold at a premium price @ Rs. 300-400/kg in the local market while Tecnus (*Termitomyces* species) is widely collected by mushroom collector during the rainy season from August to October and sold at a premium price @ 400-600/kg.

Fig. 8.7. Different types of wild edible mushroom

9. Makhana

Effect of Secondary and Micronutrients on Seed Quality of Makhana

An experiment was conducted to find out the effect of secondary and micronutrients on seed quality of makhana in field condition. Results indicated significant improvement in seed quality (seed weight) by application of micronutrients along with NPK. Test weight (100-seed weight) of makhana seeds improved by 21% over control due to recommended NPK application. A further improvement of 8-27% over NPK application was recorded consequent to Mg and micronutrients (Zn, Cu, B) application, with the most profound influence was observed in treatments involving Cu spray (0.1% $CuSO_4$) as evident in **Fig. 9.1**.

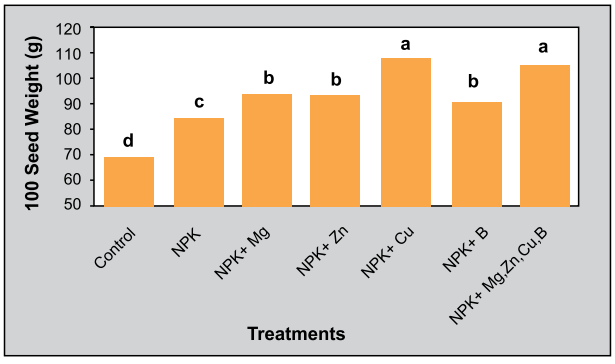


Fig. 9.1. Effect of Mg, Zn, Cu and B on test weight of makhana seeds

The seed quality improvement by Mg and micronutrients application was further recognized by grading of makhana seeds in 8 different diameter groups (**Fig. 9.2**). While 74% of the seeds obtained from control fell in >1cm diameter grade, the percentage rose near to 80% or over in the treatments involving secondary and micronutrients (**Fig. 9.3**). Particularly noticeable improvement was observed with Cu spray treatments. The observations from the first year of experiments established Mg, Zn Cu and B as the potential booster of makhana yield and quality, a line of makhana research which was hitherto unattended. Potential benefit of Cu spray on makhana seed quality deserves particular attention.

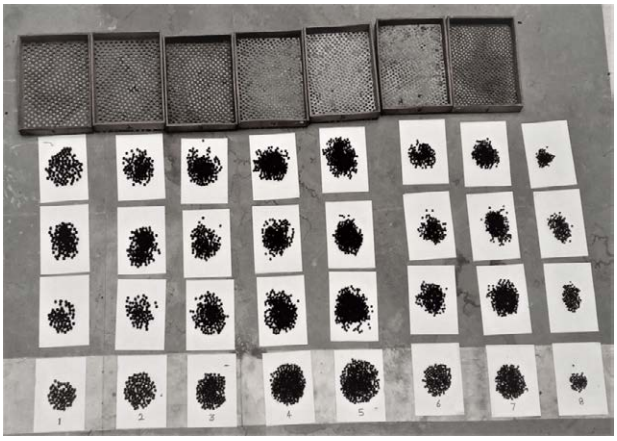


Fig. 9.2. Grading of makhana seeds in various size groups

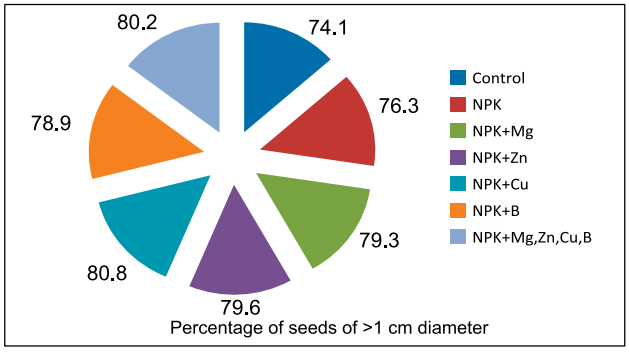


Fig. 9.3. Effect of Mg, Zn, Cu and B on makhana seed size

Chemical Properties of Water and Soil of Water Chestnut-cum- Fish Pond

Chemical properties of water (During July to October)

Chemical reaction (pH) of water ranged between 8.2 and 8.6. The alkalinity varied from 13.5 to 31.0 mg/L. Hardness of water ranged from 7.2 to 26.0 mg/L. Concentration of Ca and Mg was recorded between 1.65 to 7.31 mg/L and 0.52 to 2.25 mg/l, respectively. Free CO_2 content ranged from 3.4 to 16.7 mg/l. The pond water also showed chloride content varying from 6.21 to 13.82 mg/l. The dissolved oxygen (O_2) was found between 2.41 and 9.26 mg/l. The above mentioned chemical properties of water showed that underground irrigation water is highly suitable for the growth

of carp fishes and its introduction with water chestnut- an aquatic crop of high economic importance.

Chemical properties of soil

The soils of the water chestnut-cum fish pond have exhibited its properties as pH 7.25, EC 0.30 dS/m, organic carbon 0.52%, N 265 kg/ha, P 33 kg/ha and K 440 kg/ha, Fe 51 mg/kg, Mn 25 mg/kg, Cu 2.35 mg/kg and Zn 0.48 mg/kg. The above soil properties revealed that water chestnut-fish integration maintained the soil reaction in neutral range due to continuous flooding of soil and deposition of organic matter into the soil. Considering even the highest value of critical limits of Fe (6.5 mg/kg), Mn (1.4 mg/kg), Cu (0.22 mg/kg) and Zn (0.4 mg/kg), these pond soils appeared to be sufficiently rich in these micronutrients except available zinc, and suitable for cultivation of water chestnut and fishes.

Physico-chemical Properties and Yield of Different Water Chestnut Genotypes Collected from Central and Eastern India

Significant variations in water chestnut genotypes were observed in TSS (7.0-9.3^{0}B), reducing sugar (1.71-2.85%), and total sugar (3.00-4.16%) (**Table 9.1**). The sugar/acid ratio among the various genotypes ranged from 30.0 (Green spine) to 52.0 (Red spineless). The maximum reducing sugars (2.85%), total sugars (4.16%) and sugar/acid ratio (52.0) were recorded in Red spineless genotype. However, the maximum TSS (9.3^{0}Brix) was found in Red spineless genotype which was procured from Jabalpur area of M.P. followed by Green Spineless genotype (8.7^{0}B) from the same state. The statistically similar sugar/acid ratios were observed in Red spineless (52.0) and Green spineless (50.25) genotypes. The genotype Green spineless exhibited the maximum yield of 12.8 t/ha followed by Red spineless (9.4 t/ha) and Orange spineless (8.77 t/ha). Red spineless genotype was attractive in appearance and had the highest TSS of 9.3^{0}B. More cloudier and rainy days caused more production of water chestnut this year but TSS and sugar formation were less due to not so efficient conversion of sugar from starch.

Evaluation of Sweet Flag Germplasm

Nine sweet flag germplasm were evaluated at RCM, Darbhanga, during 2019. Tumkur-1 genotypes gave the highest yield of 7.9 t/ha cleaned rhizome followed by Tumkur-2 (7.4 t/ha) (**Table 9.2**). The maximum plant height (78.2 cm) and rhizome length/plant (62.0 cm) were observed in Tumkur-1 genotype. The genotype Bach-1 procured from BAU, Ranchi, recorded yield of about 7.01 t/ha fresh rhizome. The sweet flag genotype collected from GKVK, Bangalore, did not perform well under RCM, Darbhanga climate.

Table 9.2. Performance of Sweet Flag Germplasm

Sweet Flag Acc No.	Height (cm)	Rhizome girth (cm)	Rhizome length (cm)	Yield (g/plant)	Yield (t/ha)
Bach-1	42.7	5.4	43.3	155	7.01
Bach-2	62.1	7.6	50.2	142	6.18
Supaul -1	44.9	6.3	38.5	109	4.95
Supual-2	62.6	6.1	47.6	124	5.36
Araria	45.5	6.3	46.1	107	5.12
Tumkur-1	78.2	8.1	62.0	175	7.98
Tumkur-2	80.1	7.7	51.1	164	7.42
Mandya	72.3	7.9	41.3	129	5.75
GKVK collection	60.6	6.8	30.0	105	3.90
LSD (P=0.05)	4.9	NS	3.7	4	0.55

Table 9.1. Physico-chemical characteristics of water chestnut genotypes

Water chestnut genotypes	TSS (^{0}B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non-reducing sugar (%)	Sugar acid ratio	Yield (t/ha)
Balia Red (U.P.)	7.0	0.09	1.92	3.00	1.08	33.33	2.90
Bihar Red Large	7.0	0.08	2.00	3.17	1.21	39.63	5.33
Bihar Red Small	7.6	0.09	2.40	3.76	1.37	41.78	2.72
Green Spine (Bihar)	7.1	0.10	1.71	3.00	1.29	30.00	3.78
Green Spineless (M.P.)	8.7	0.08	2.52	4.02	1.52	50.25	12.8
Lucknow Green (U.P.)	7.2	0.10	1.90	3.16	1.36	31.60	1.80
Orange Spineless (M.P.)	8.2	0.09	2.32	3.88	1.53	43.11	8.77
Red Spineless (M.P.)	9.3	0.08	2.85	4.16	1.31	52.00	9.40
LSD (P=0.05)	0.35	NS	0.17	0.22	NS	2.78	1.53

10. Medicinal and Aromatic Plants

Collection and Conservation of Germplasm

Thirteen medicinal and aromatic plant species *viz. Curculigo orchioides, Piper longum, Stevia rebaudiana, Pogostemon cablin, Rauvolfia serpentine, Aloe barbadensis, Cymbopogon flexuosus, Cymbopogon martini, C. citrates, Chrysopogon zizanioides, Lawsonia inermis, Mentha × piperita* and *Plumbago zeylanica* were collected from Patna, Bihar. All plants belong to clade angiosperm with six from monocots and seven from dicot plants. The crops belong to nine families and eight orders. The family with a higher number of species is Poaceae. All the collected plants maintained in a herbal garden situated at ICAR-RCER, Patna.

Screening of Medicinal Plants for the Higher Content of Bioactive Compounds

To study bioactive compounds, initially thirteen plant species were studied for their phenolics and antioxidant potentiality. Phenolic content ranged from 225.62 to 1215.2 GAE/100g, whereas flavonoid content ranged from 62.1 to 865.8 mg CE/100g. Antioxidant activity (FRAP) ranged from 3.6 to 64.9 µMol TE/g. A significant higher antioxidant activity was observed for CUPRAC methods. Plant with higher antioxidants activities were helencha, black tulsi, jangli tulsi, ban tulsi and artemisia. Among these plants, helencha was used for profiling of the phenolic compounds using ultra-performance liquid chromatography with quadrupole time of flight mass spectrometry. A total of 25 compounds, including 6 flavonols, 4 phenolic acids, 3 lignans, 3 flavone, 1 flavanol, flavanone, dihydro flavonol, tetramethoxy flavone, isoflavonoids and methylated flavonols, and 3 other phenolic compounds were putatively identified. Flavonols were the most abundant type of phenolics exhibiting 26.76% of the total phenolics in *helencha* leaves. Tetramethyl scutellarein was single predominant compounds in *helencha*, exhibiting 26.46% of the total phenolic. In the antimicrobial assay, significant antimicrobial activity of the methanolic extract of *helencha* was found against *Shigella flexneri, Salmonella paratyphi* A and *Pseudomonas aeruginosa* against standard antibiotics like ampicillin and ciprofloxacin. Further, the *in silico* interaction studies of 21 compounds with LasR protein of *P. aeruginosa* showed Demethyloleuropein to be the best candidate compound.

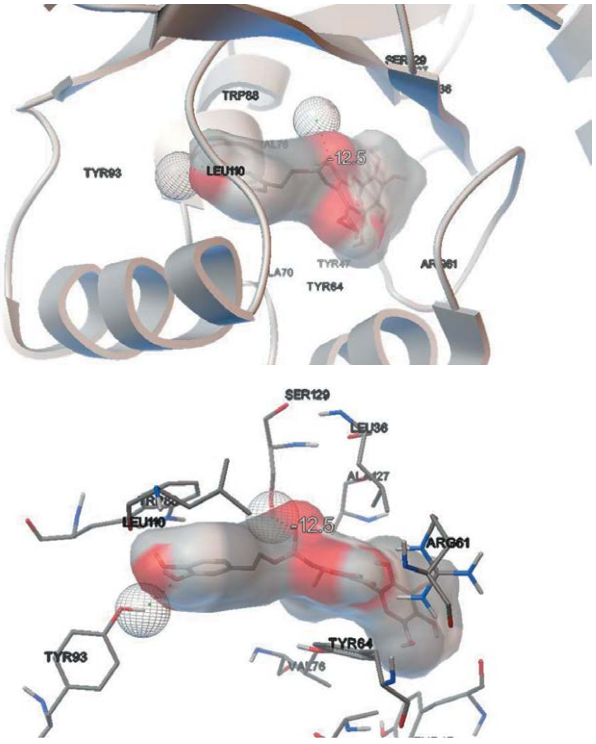


Fig. 10.1. Interaction of LasR protein with best interacting phenolic compounds of helencha: Interaction with Demethyloleuropein

Fig. 10.2. *Andrographis paniculata* (Kalmegh)

11. Farming System Research

Development of Climate Resilient Farming System Models for Livelihood Improvement

To improve productivity, profitability, and sustainability of smallholder agriculture by providing critical inputs with technological backstopping, a project entitled 'Development of climate-resilient farming system models for livelihood improvement' has been implemented for the last three years in four adopted villages of East Champaran district of Bihar. The following activities were carried out during *Rabi* 2018-19 and *Kharif* 2019.

Improving fish production and livelihood support

Fingerlings of six cultivable fish species *viz.*, *Catla catla* (Catla), *Labeo rohita* (Rohu), *Cirrhinus mrigala* (Mrigal), *Hypophthalmichthys molitrix* (Silver carp), *Ctenopharyngodon idella* (Grass carp) and *Cyprinus carpio* (Common carp) were stocked together at the rate of 4,000 fingerlings/acre. In the current polyculture system, the stocking was done based on the adaptation to the ecological niches of different fish species as surface feeders 40% (Catla & Silver carp), column feeder 30% (Rohu & Grass carp) and bottom feeders 30% (Mrigal & Common carp) were stocked in each pond (Fig. 11.1). The total area covered under the project as fish ponds are about 1.72 acre, which includes six fish ponds in four different villages of East Champaran district of Bihar. The stocking of fingerlings was carried out during the last week of July 2018. The average body weight of fingerlings was 28.0 ± 4.5 g at the time of stocking. After a culture period of one year, the average body weight of all the species when taken together varied from 540.3-700.5 g. The survival rate of fishes was estimated to be 80-95%. The fish productivity varied from 1749.7-2693.8 kg/acre.

The economic analysis revealed that fish seed and feed together contributed about 75% of the total expenditure incurred. The total spending includes the cost of seed, feed, diesel, electricity, fertilizers, manure, labour and depreciation cost of fixed (capital) expenditure (pond construction, motor/diesel pump set and borewell). The analysis revealed that fish farming is more beneficial in monetary terms than other agricultural crop production in this region, and can be adopted to enhance the farmers' income.

Fig. 11.1. Fish farming model developed at Chandrahiya village

Introduction of improved varieties in major crops and its production technologies

Quality seed of high yielding varieties of potato (*Kufri Sinduri*, *Kufri Khyati* and *Kufri Pukhraj*), wheat (HD-2967 and HD-2733), lentil (PL 8), greengram (IPM 2-14), chickpea (GNG 1581), paddy (CR Dhan 909 and *Swarna Shreya*) and maize (*Maharaja*) were provided to farmers in the adopted villages to cultivate them in *Rabi* 2018-19, *Zaid* and *Kharif* 2019 for improving crop productivity and income level of the farmers. The increase in yield due to quality seed varied from 142.47% in chickpea to 16.6% in maize (**Table 11.1**). This indicates that seed replacement by improved varieties along with improved management practices is essential to obtain better productivity for enhancement in farmers' income and improved livelihood in the region.

Integration of agroforestry for multiple production systems

The performance of fruit trees was measured two years after planting in all the four villages. Random sampling was carried out to measure increment in tree height (m) and diameter at breast height (DBH, cm) (**Fig. 11.2 & 11.3**). Results indi-

Table 11.1. Increase in yield of major crops due to quality seed and improved management practices at farmer's field during 2018-19

Crop	Yield (t/ha)		Absolute increase in yield (t/ha)	Per cent increase in yield
	Beneficiary farmers plots	Non-beneficiary farmers plots		
Wheat	3.94	3.17	0.77	24.27
Lentil	1.33	0.98	0.36	36.40
Green gram	0.95	0.80	0.15	18.92
Chickpea	1.43	0.59	0.84	142.47
Potato	28.11	13.43	14.68	109.31
Paddy	4.97	4.10	0.87	21.13
Maize	5.21	4.46	0.74	16.60

cated that the performance of all mango varieties was at par in terms of height and diameter, but the best performance was observed in Khairimal Jamunia, which could be attributed to suitable topographic situations and optimum moisture levels all through the growing period. Guava (var. L 49 and *Allahabad Safeda*) plant height and diameters were more than the mango. Teak plants established in two villages have attained an average height of 4.47 m and diameter (DBH) of 4.86 cm in Chintamanpur and in Chandrahiya the average height is 6.11 m and diameter 4.23 cm (**Fig. 11.4 & 11.5**). The performance of field crops grown in association with fruit trees was estimated by collecting data on crop yields at harvest.

Fig. 11.2. Well established mango (cv. Zardalu) planted on mounds in a paddy field

Fig. 11.3. Well established teak seedling planted on field boundaries

Energy Budgeting under One-Acre IFS Model

Under the one-acre IFS model, field crops, fruits and vegetable crops, goat, poultry were selected as the main enterprise while mushroom as a secondary enterprise. Allocation of land to selected enterprises was optimized through linear programming by keeping in view the farm family requirements, the requirement to the system and profitability. The details of land under different enterprises and days taken has been shown in **Table 11.2.** Upon economic analysis of selected components under the model, the selected integra-

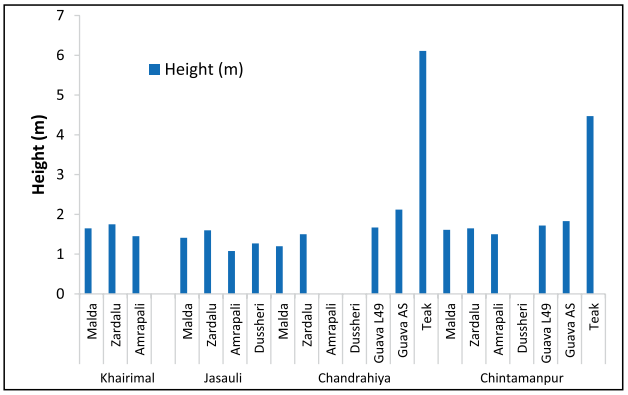


Fig. 11.4. Performance of fruit and timber species planted in the four locations two years after planting

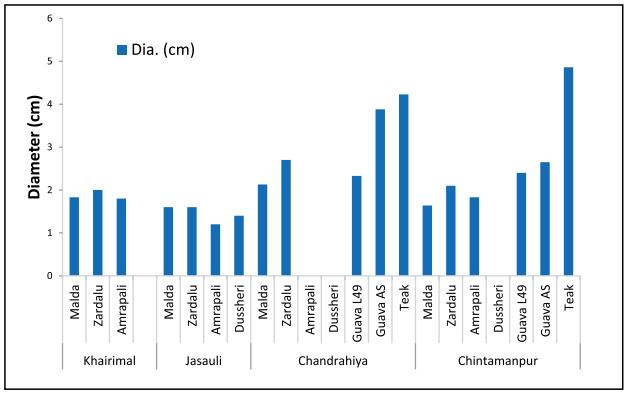


Fig. 11.5. Diameter of fruit and timber species in the four locations after two years of planting

Table 11.2. Details of one-acre IFS model

Sub-system	Area (m^2)	component	Season	Days
Field crops	2000	Rice	June-Nov	135-140
		Wheat	Nov-Mar	140-145
		Maize	Nov-Apr	160-170
		Lentil	Nov-Mar	130-135
		Moong	Nov-Mar	110-115
Fodder crop	500	Sorghum	June-Sep	90-100
		Cowpea	June-Sep	80-100
		Berseem	Oct-Mar	60-150
		Oat	Oct-Mar	60-135
Veg-etables	500	Okra	May-Aug	95-100
		Tomato	Oct-Mar	130-140
		Onion	Feb. May	120-130
		Cauliflower	Oct-Feb	90-110
		Cabbage	Oct-Feb	100-110
Fruit crops	500	Lemon	-	-
		Guava	-	-
		Banana	-	-
Mush-room	Oyster		Oct- Apr	90 days/ cycle
Poultry	100 numbers		40 days/cycle	
Goatry	20+1 numbers		One year	

tion had provided about 3-4 times more returns over the traditional cropping system (rice-wheat) i.e., Rs. 88, 528/year/acre. The increasing demand for food to meet food, nutritional and health security has resulted in intensive use of energy inputs in agricultural productions which are threatening public health as well as the environment. Therefore energy budgeting in agricultural production systems is essential to get sustainability, profitability in the farming practices and to identify the best performing agricultural practice that can be adopted in the specific regions.

The highest total energy input (24.84 GJ/20 goats/year) was required for the goat rearing followed by field crops, vegetables, green fodders, fruits, poultry and mushroom cultivation (**Table 11.3**). The energy use efficiency ratio was found to be the highest in fodder crops (8.66) followed by field crops, vegetables, fruits, mushroom, poultry and goatry. Here, it is important to mention that goatry and poultry farming are of least energy-efficient agricultural production systems, which have produced negative energy mileage. The energy use efficiency ratio for the main output (EERm) has shown that green fodders and field crops yielded better energy productivity (**Fig. 11.6**). Among different agricultural production subsystems, labour energy input recorded maximum in field crops followed by vegetables, green fodder, goatry, poultry (broiler), fruit and mushroom cultivation, respectively. Moreover, diesel and electrical energy inputs recorded maximum in field crops and followed by green fodder and vegetable crop production systems. The direct and indirect energy sources were calculated and found to be invested utmost in field crops and goat rearing as 2.98 GJ and 24.53 GJ, respectively. Similarly, renewable and non-renewable energy sources were utilized in goat rearing and field crops as 24.39 GJ and

Table 11.3. Energy indices for one-acre IFS model

Energy indices	Field Crop	Vegetable	Fruits	Fodder	Mushroom	Poultry	Goatry
TE input (GJ)	9.98	3.72	2.12	2.73	0.21	1.48	24.84
TE output (GJ)	60.44	9.35	4.18	23.63	0.34	0.38	4.22
TE output main (GJ)	28.08	2.12	1.38	23.63	0.31	0.31	3.65
EER	6.06	2.51	1.97	8.66	1.62	0.26	0.17
EERm (main output)	2.81	0.57	0.65	8.66	1.48	0.21	0.15
NEG	50.46	5.63	2.06	20.90	0.13	-1.10	-20.62
EP	5.06	1.51	0.97	7.66	0.62	-0.74	-0.83
DE	2.98	1.18	0.37	1.28	0.19	0.46	0.31
ID	6.99	2.54	1.75	1.45	0.02	1.02	24.53
RE	1.75	1.04	0.56	0.33	0.19	1.22	24.39
NR	8.23	2.68	1.56	2.40	0.02	0.26	0.45
HEP	56.69	17.15	16.66	49.47	1.50	1.79	13.63

TE: total energy, EER: energy efficiency ratio, NEG: net energy gain, EP: energy profitability, DE: direct energy, ID: indirect energy, RE: renewable energy, NR: non-renewable energy, HEP: human energy profitability

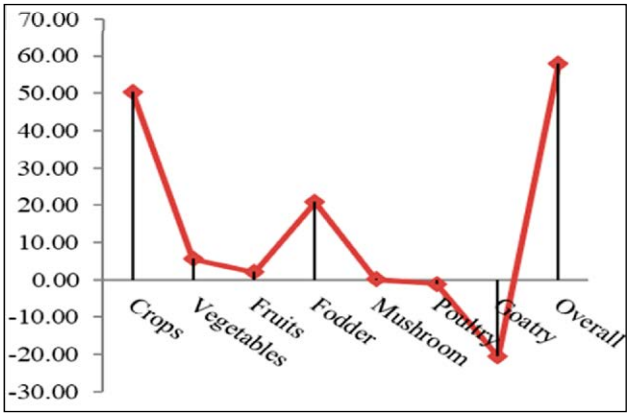


Fig. 11.6. Net energy gain

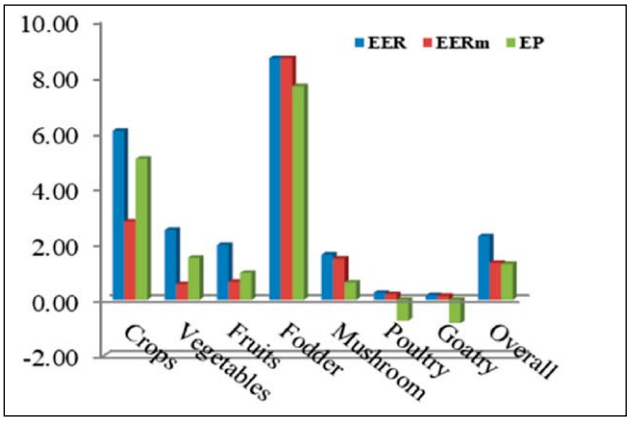


Fig. 11.7. Energy efficiency ratio for total and min output and energy profitability

6.99 GJ, respectively. The net energy gain recorded maximum from field crops subsequently followed by green fodder crops, vegetables, fruit crops and mushroom productions, whereas goatry and poultry have resulted negative trends in terms of net energy gain (**Fig.11.6**). The energy profitability of different agricultural productions under an acre integrated farming system was analysed and found that green fodders cultivation is most profitable in terms of energy and produced EP ratio as 7.66 followed by field crops and vegetables. Human energy profitability (HEP) was found maximum (56.69 GJ) with the field crops while minimum in poultry production (1.50 GJ) followed by mushroom cultivation (1.79 GJ) indicating that these enterprises have consumed more human input energy over other components. The overall, total energy input in the one-acre IFS model was calculated to be 45.08 GJ and total energy output, energy efficiency ratio, net energy gain and energy profitability as 102.54 GJ, 2.27 GJ GJ^{-1}, 57.46 GJ and 1.27 GJ (**Table 11.3**). This indicates that livestock or birds farming in alone are not profitable, yet these components can perform better in integration with other agricultural production systems Moreover, the study revealed that there is scope to enhance the feed efficiency for the goats and birds by formulating more efficient diets which have better conversion ratios.

Development of Location-Specific Integrated Farming System Models for the Rainfed Ecosystem of Eastern Plateau and Hill Region

A 0.75 Acre IFS model (Crop + Horti + Dairy) has been developed and livestock (2 cows + 3 calves), fruits (Guava and Badhal) have been integrated with cereals, pulses and oilseeds. During the *Kharif* 2019, the total guava yield was 256.2 kg, which is sufficient for fulfilling the daily dietary requirement of 5.85 persons. The total milk production was 1646.6 lit. from two cows, which is adequate for the 22.56 persons. So, the milk and fruit production were in surplus in the IFS. The rice, ragi and maize (cereals) obtained from IFS were 162.35 kg, 27 kg and 120 kg, respectively, which is sufficient for fulfilling the daily dietary requirement (cereals) of 1.55 person only. Vegetable production from tuber crops (124.95 kg) is sufficient for fulfilling the daily dietary requirement of 1.13 persons. The total FYM production was recorded as 11.76 t/year and cow urine production as recorded as 3782.73 litres/year from two cows and three calves. The total green fodder production was 4.5 t/year.

12. Crop Diversification

Diversification of Rice-Wheat System through Climate Resilient Cropping System in Eastern India

A long- term study was initiated at the ICAR–RCER Patna, keeping 10-diverse cropping system *viz.* transplanted rice (TPR) - wheat–mungbean (Farmers practices), conventional till-direct seeded rice (CTDSR) - wheat (ZT) - mungbean (ZT), soybean - maize (ZT), CTDSR - mustard (ZT) - urdbean (ZT), foxtailmillet - lentil (ZT) - fallow, pearlmillet - chickpea (ZT) - fallow, fingermillet - *toria* (ZT) - fallow, sorghum (grain) - chickpea (ZT) - fallow, maize (cob) - pigeonpea (ZT) and sorghum (fodder) - mustard (ZT) - urdbean (ZT) during rainy season of 2016 on clay loamy soil (sand: 50.4%, silt: 35.04, clay: 14.56%). Results revealed (from the presented data of 2018-19) that significantly highest system annual productivity (SREY) had recorded with maize cob - pigeonpea (22.37 t/ha) followed by sorghum fodder - mustard (ZT) - urdbean (ZT) (15.36 t/ha) and soybean–maize (ZT) (18.53 t/ha). Among millet-based system, sorghum (grain) - chickpea (ZT) - fallow (11.69 t/ha) had higher system productivity and lowest with fingermillet–*toria*–fallow (5.81 t/ha) (**Table 12.1**). From the findings of three years study, it may be concluded that rice and wheat may be diversified with adoption of suitable crops/cultivars like soybean, maize for cob/fodder, fodder jowar and major millets like jowar/bajra during rainy season and maize, pigeonpea and mustard in winter (**Fig. 12.1**).

Table 12.1. System annual productivity (SREY) as influenced by diverse cropping system

Cropping system	Rice equivalent yield (t/ha)			System rice equivalent yield (t/ha)
	Kharif	*Rabi*	Summer	
TPR- wheat - mungbean (FP)	4.85	5.78	4.35	14.98
CTDSR - wheat (ZT) - mungbean (ZT)	5.35	6.13	3.63	15.12
Soybean - maize (ZT)	3.65	9.66	0.00	13.31
CTDSR - mustard (ZT) - urdbean (ZT)	5.26	7.30	3.83	16.40
Foxtailmillet - lentil(ZT) - fallow	1.43	5.65	0.00	7.08
Pearlmillet - chickpea (ZT) - fallow	4.04	6.87	0.00	10.91
Fingermillet - toria (ZT) - fallow	2.01	3.80	0.00	5.81
Jowar (grain) - chickpea (ZT) - fallow	4.51	7.18	0.00	11.69
Maize cob - pigeonpea (ZT)	12.49	9.88	0.00	22.37
Sorghum (fodder) - mustard (ZT) -urdbean (ZT)	9.72	6.27	2.54	18.53
LSD (*P*=0.05)	0.47	0.57	0.23	1.17

FP: farmers practices, ZT: zero tillage

Fig. 12.1. Diversification of rice-wheat system with millets during *Kharif* as well as pulses and oilseeds during *Rabi*

Diversification of Rice-Wheat Cropping System with Vegetables

An experiment was conducted to identify the most suitable diversified rice-based cropping system for silty clay loam soil at ICAR-RCER, Patna. Two rice varieties (medium and long duration) were grown during *Kharif* followed by vegetables and wheat in *Rabi* and greengram as summer crop. Rice-vegetables-greengram systems were compared with rice-wheat-greangram for productivity and profitability. Medium duration rice variety Swarna Shreya attained maturity in 118 days, while long-duration variety Swarna (MTU 7029) took 27 more days than S. Shreya. Rice crop duration significantly influenced the yield of *Rabi* crops and system productivity as a whole. *Rabi* crops grown after medium duration rice produced significantly higher yield with better quality than those grown after long duration rice variety. During *Kharif* season Swarna produced 28 per cent higher yield than Swarna Shreya (5.26 t/ha) but yield of *Rabi* and summer crop were significantly lower than those grown after Swarna Shreya (**Table 12.2**). The system productivity of rice-broccoli-greengram (27.82 t/ha) was significantly superior over other cropping systems except for rice-cauliflower- greengram (26.61 t/ha). Cauliflower and broccoli grown after Swarna Shreya (medium duration rice variety) provided an opportunity to introduce one more crop in the system before the sowing of greengram. Hence, onion and spinach were sown after cauliflower and broccoli, respectively, which further enhanced the productivity of the respective cropping system. Significant differences were also observed within the system due to the duration of rice crop. Further economics of different cropping systems was also affected due to variation in rice crop duration (**Table 12.3**). Rice-broccoli-spinach-green gram produced significantly higher rice equivalent yield (35.34 t/ha), net returns (Rs. 334330) and benefit : cost ratio (2.78) among all cropping systems followed by rice-cauliflower- leafy onion-greengram (B:C : 2.36) and rice-tomato-greengram (B:C : 2.10).

Development of Multitier Cropping System for Rainfed Uplands of Eastern Plateau and Hills

Planting of aonla as a filler crop resulted in the maximum height and girth of mahogany and mango in a five years old rainfed upland multitier system. The performance of filler crops (aonla and peach) in terms of growth perametrs were significantly higher in combination with rice. Here the maximum incidental solar radiation percentage (% PAR) was received in fallow, followed by no filler, mango + mahogany + aonla combination and minimum in mango + mahogany + peach combination (**Fig. 12.2 & 12.3**). The dehydrogenase activity in the soil under different silvi-horti- agricultural systems was recorded and found highest in mango + mahogany + aonla system (11.25 micro gram TPF 24/hr/g). The maximum yield of rice (1.30 t/ha) and *ragi* (1.46 t/ha) was recorded in case of sole cropping.

Table 12.2. Effect of rice varieties and cropping system on rice equivalent yield (t/ha)

Treatments	Rice yield (t/ha)	*Rabi* yield (t/ha)	Greengram yield (t/ha)	REY of *Rabi* crops (t/ha)	REY of greengram (t/ha)	System REY (t/ha)
Rice variety						
Swarna Shreya (medium duration)	5.26	24.72	0.9	15.04	2.82	23.11
Swarna (long duration)	6.74	11.05	0.58	7.41	1.73	14.76
LSD (P=0.05)	0.48	2.62	0.12	1.27	0.29	1.80
Cropping system						
R-W-GG	5.99	3.82	0.40	4.27	1.20	11.40
R-P-GG	5.88	16.38	1.08	6.34	3.22	15.46
R-T-GG	5.84	26.24	0.48	16.93	1.49	24.27
R-CF-GG	5.90	29.26	0.62	18.87	1.84	26.78
R-Br-GG	6.19	27.58	0.81	18.31	3.49	28.04
R-pea-GG	6.19	4.04	1.17	2.61	2.40	7.67
LSD (P=0.05)	NS	4.02	0.22	2.48	0.66	4.58

R: rice, W: wheat, GG: greengram, T: tomato, CF: cauliflower, Br: brocooli,

Table 12.3. Effect of rice crop duration on economics

Cropping Systems	REY (t/ ha)	Gross income (Rs./ha)	Cost of cultivation (Rs./ha)	Net returns (Rs./ha)	B:C ratio
Medium duration rice					
Rice-wheat-greengram	12.06	180968	127336	53632	1.42
Rice-tomato-greengram	16.31	244720	158214	86506	1.55
Rice-potato-greengram	27.38	410666	195536	231314	2.10
Rice-cauliflower-spring onion -greengram	35.34	530166	224699	305467	2.36
Rice-broccoli-spinach - greengram	34.80	521952	187622	334330	2.78
Rice-pea-greengram	11.72	175821	136667	39154	1.29
Long duration rice					
Rice-wheat-greengram	10.85	162804	133900	28904	1.22
Rice-tomato-greengram	14.57	218482	164584	53898	1.33
Rice-potato-greengram	19.22	288323	187912	100411	1.53
Rice-cauliflower-spring onion - greengram	17.88	268147	181558	86589	1.48
Rice-broccoli-spinach - greengram	20.86	312902	180347	132555	1.74
Rice-pea-greengram	10.58	158744	139504	19240	1.14

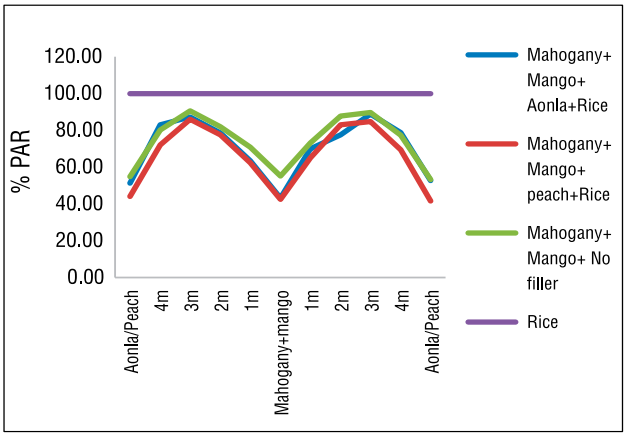


Fig. 12.2. Variation in the intensity of light with distance in rice plot under different silvi-horti-agricultural systems

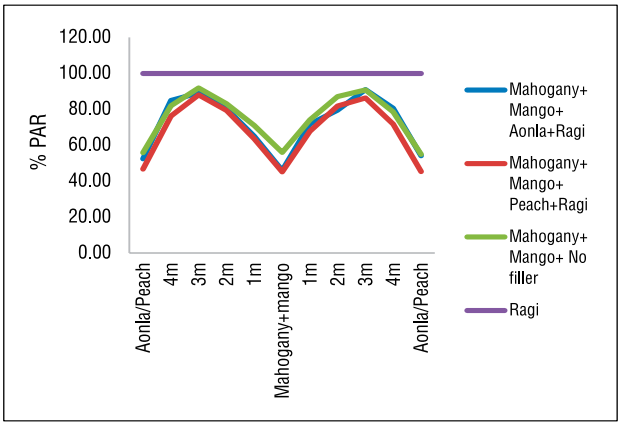


Fig. 12.3. Variation in the intensity of light with distance in ragi plot under different silvi-horti-agricultural systems

Rehabilitation of Coal Mine affected Areas through Agroforestry Interventions

A model of Agri-horti-silvi-pastural system was developed in the year 2015 at coal mine affected area of Phusri village, Near Charhi, Mandu, Ramgarh, Jharkhand. In this model, agroforestry species *viz., Aegle marmelos, Artocarpus heterophyllus, Citrus limon, Dalbergia latifolia, Mangifera indica, Melia azedarach, Pongamia pinnata, Psidium guajava, Punica granatum, Swietenia mahogany* and *Tectona grandis* have been planted. After four years of plantation, the maximum plant height (4.05 m) and trunk diameter (18.82 mm) was recorded in *Pongamia pinnata* compared to other MPTs. Among the fruit crops, maximum plant height (2.91 m) and plant spread were recorded in the *Aegle marmelos* . Among the fruit trees, the maximum average yield was recorded in pomegranate (6.25 kg/plant) followed by guava (5.24 kg/plant) and mango (4.85 kg/plant). A total of 846 kg green fodder was harvested from perennial grasses, *Melia azedarach* and *Tephrosia candida.* Apart from this, the farmer could obtain returns of approximately of Rs. 8200/- by growing intercrops like tomato, chilli and lentil during the rainy season and selling the surplus produce in the market after fulfilling the requirement of a family of 4 members.

13. Carbon Sequestration and Nutrient Dynamics

Assessment of Total Soil Organic Carbon and Oxidisable Organic Carbon in Different Tree-based Production Systems

Soil organic carbon stock in multipurpose trees in eastern Plateau and Hill region

An investigation was undertaken to evaluate the dynamics of total soil organic carbon in different soil depths of 0-0.15, 0.15-0.30, 0.30-0.45, 0.45-0.60 and 0.60-0.90 m in 9 year old plantations of Ber, Kusum and Palas in eastern Plateau and Hill region. The highest C_{tot} (total soil organic carbon) in 0-0.90 m depth was 65.32 Mg/ha in Kusum plantations, which registered 24.5 % increase over control. However, palas plantations recorded the highest C_{tot} of 22.85 Mg/ha over all other plantations in the surface soil depth of 0-0.15 m. The oxidizable organic carbon (C_{oc}) was highest in Kusum plantations (49.13 Mg/ha) and was non-significant among the different plantations (**Table 13.1**).

Table 13.1. Total and oxidisable organic C (Mg/ha soil) in soils in different layers (m) of 9 year old MPTs at Namkum.

MPTs	Total soil organic carbon (C_{tot})					
	0-0.15	0.15-0.30	0.30-0.45	0.45-0.60	0.60-0.90	Total (0-0.90)
Control	17.76^{c}	11.49^{c}	9.42^{b}	7.83^{b}	5.98^{a}	52.47^{c}
Ber	20.65^{b}	13.62^{b}	11.62^{a}	10.14^{a}	7.10^{a}	63.13^{ab}
Kusum	20.73^{b}	15.16^{a}	12.48^{a}	10.43^{a}	6.52^{a}	65.32^{a}
Palas	22.85^{a}	12.69^{b}	10.20^{b}	8.70^{b}	6.46^{a}	60.90^{b}
Mean	20.50	13.24	10.93	9.28	6.51	
SEm (±)	0.468	0.358	0.451	0.445	0.524	1.3
LSD(p≤0.05)	1.44	1.10	1.39	1.37	1.61	3.98
Oxidizable organic carbon (C_{oc})						
Control	13.37^{b}	8.62^{b}	7.08^{c}	5.87^{b}	4.47^{a}	39.42^{b}
Ber	15.54^{ab}	10.26^{ab}	8.72^{ab}	7.62^{a}	5.34^{a}	47.49^{a}
Kusum	15.58^{ab}	11.42^{a}	9.37^{a}	7.85^{a}	4.91^{a}	49.13^{a}
Palas	17.18^{a}	9.57^{b}	7.67^{bc}	6.54^{ab}	4.87^{a}	45.82^{a}
Mean	15.42	9.97	8.21	6.97	4.90	
LSD(P=0.05)	2.18	1.72	1.40	1.63	1.874	4.58

Active and passive pool of carbon and soil microbial biomass carbon in multipurpose trees in eastern Plateau and Hill region

The highest active carbon pool in the rhizosphere soil was 36.8 Mg/ha in Kusum plantations throughout the soil profile depth of 0-0.90 m and registered significantly higher over control and found non-significant among the different plantations (**Table 13.2**). In the surface soil, Palas plantations recorded highest active carbon pool of 14.5 Mg/ha in 0-0.15 m depth. Similarly, the passive carbon pool was highest of 28.53 Mg/ha in Kusum plantations throughout the soil profile depth of 0-0.90 m and was significantly higher over control and Palas plantations, while it showed non-significant variations with Ber plantations. The active and passive pool of carbon gradually decreased with increasing depth of soil profile.

All the plantations of Arjun, Palas and Kusum showed higher soil microbial biomass carbon in the upper soil surface up to 0-0.30 m depth. Among

Table 13.2 Active and passive carbon pool in soils in different layers (m) of 9 year old lac-host tree plantations at Namkum.

Lac host tree spp	Active carbon pool (Mg/ha)					
	0-0.15	0.15-0.30	0.30-0.45	0.45-0.60	0.60-0.90	Total (0-0.90)
Control	10.77^{b}	6.69^{c}	5.33^{b}	4.13^{c}	3.01^{a}	29.9^{b}
Ber	11.71^{b}	7.63^{b}	6.59^{a}	5.53^{ab}	3.52^{a}	35.0^{a}
Kusum	11.66^{b}	8.60^{a}	7.06^{a}	6.04^{a}	3.44^{a}	36.8^{a}
Palas	14.50^{a}	7.33^{bc}	5.69^{b}	4.71^{bc}	3.38^{a}	35.6^{a}
Mean	12.16	7.56	6.17	5.10	3.34	
LSD (p≤0.05)	1.15	0.721	0.872	0.967	1.16	2.68
	Passive carbon pool (Mg/ha)					
Control	6.99^{b}	4.80^{c}	4.08^{c}	3.70^{b}	2.97^{a}	22.54^{c}
Ber	8.93^{a}	5.99^{ab}	5.03^{ab}	4.62^{a}	3.58^{a}	28.15^{a}
Kusum	9.07^{a}	6.57^{a}	5.42^{a}	4.39^{ab}	3.08^{a}	28.53^{a}
Palas	8.35^{a}	5.36^{bc}	4.51^{bc}	3.99^{ab}	3.09^{a}	25.30^{b}
Mean	8.34	5.68	4.76	4.17	3.18	
LSD (p≤0.05)	0.991	0.924	0.831	0.700	0.709	1.86

the plantations, the highest SMBC in 0-0.15 m soil depth was 155.2 µg/g in palas plantations and was followed by ber plantations.

Soil organic carbon stock in agroforestry tree plantations

The rhizosphere soils of different agroforestry plantations of 9 year old Arjun (*Terminalia arjuna*), Gamhar (*Gmelia arborea*) and Teak (*Tectona grandis*) showed significantly higher total SOC over control (No plantations) throughout the soil profile (0-0.90 m). The highest C_{tot} (Total soil organic carbon) in 0-0.90 m depth was 67 Mg/ha in teak plantations, which registered 41.6% increase over control and was significantly higher than control and other plantations. The C_{tot} showed variations among the different plantations up to 0-0.60 m and thereafter no significant difference was observed. The highest oxidizable organic carbon (Coc) was 50.8 Mg/ha in Teak plantations, which was followed by Gamhar in 0-0.90 m depth.

The different pools of soil organic carbon *viz.*, very labile (C $frac_1$), labile (C $frac_2$), less labile (C $frac_3$) and non-labile (C $frac_4$) soil organic carbon in agroforestry species of 9 year old Arjun, Gamhar and Teak plantations showed variations among the plantations. The Very labile pool (C $frac_1$) was significantly highest of 18.7 Mg/ha in Teak plantations throughout the entire soil profile depth (0-0.90 m) over control, while it showed non-significant variations among the plantations. The C $frac_2$ was significantly highest in Gamhar plantations (18.06 Mg/ha) over Arjun and control, while it showed non-significant variation with Teak plantation. The less labile carbon (C $frac_3$) registered significantly highest value of 14.02 Mg/ha in Teak plantations over Gamhar and control throughout the soil profile depth of 0-0.90 m. Similarly, the non-labile carbon (C $frac_4$) showed the highest value of 16.76 Mg/ha in teak plantations and was followed by Gamhar (15.57 Mg/ha).

Active and passive pool of carbon in agroforestry plantations

The active carbon pool was significantly highest of 36.7 Mg/ha in Gamhar plantations over Arjun and control, but it showed non-significant with Teak plantations throughout the soil profile depth of 0-0.90 m. Similarly, the passive carbon pool was significantly highest in Teak plantations (30.78 Mg/ha) over control, Arjun and Gamhar throughout soil depth of 0-0.90 m. Both active and passive pool of carbon showed variations among the plantations up to soil depth of 0.60 m. The carbon pools gradually decreased with increasing soil depth.

Soil microbial biomass carbon in different agroforestry plantations

The SMBC in 9 year old agroforestry plantations was higher in the surface soil compared to sub-surface soil. The teak plantations registered highest SMBC of 289.9 µg/g and was followed by Gamhar plantations (204.9 µg/g) in the soil profile depth of 0-0.15 m. The higher value of SMBC in different agroforestry plantations was attributed to the congenial environment for microbial growth due to the leaf litter additions leading to higher SMBC. Further the variation of SMBC among the different plantations was attributed to the quantity and quality of leaf litter additions. The lower value of SMBC in control was seemed to be related to the unfavorable environment.

Evaluation of Leaching Loss of Nutrients in Acidic Soils of Jharkhand under Different Cropping Systems

The project is being undertaken to quantify the leaching loss of nutrients and water balance in different vegetable-based production systems under the eastern plateau and hill region. For this, the specially designed experimental plots of 4 x 3 m^2 dimensions were prepared by excavating the soil up to a depth of 1.2 m and then 500µ polythene sheet has lined the walls of the dug-out pit. Finally, the pit was filled up with soils in layer-wise to mimic the natural soil of desired bulk density.

Leaching loss of nutrients

Different fertilizer applications treatments comprised of T1: N0P0K0 (Control), T2: 100% recommended NPK as inorganic fertilizer; T3: 100% recommended NPK as organic manure; T4: 50% recommended NPK as inorganic fertilizer + 50% recommended NPK as organic manure were applied to winter season tomato and pea crop. Irrigations were applied to all the plots by flood irrigations as per farmer's practice as and when required. Periodically leachates were collected from all the plots and were analysed for nutrient losses.

In pea crop, the highest nitrogen loss of 9.97 kg/ha was recorded in the treatment receiving 100% recommended NPK as inorganic fertilizer (T2) with a loss of 23% N from the applied fertil-

izer. The treatment receiving 100% recommended NPK as Organic manure (T3) recorded the lowest N loss of 5.76 kg/ha, which corresponds to loss of 6.12% N from applied fertilizer. The leaching loss of P was very low, which varied from 8.5 to 11.6 g ha^{-1} and was found non-significant among the different treatments. The leaching loss of K varied significantly among the different treatments. The highest K loss of 13.31 kg/ha was recorded in the treatment receiving 100% recommended NPK as inorganic fertilizer (T2) with a corresponding loss of 28.7% K from the applied fertilizer. The lowest K loss was 7.7 kg/ha in T3 treatments with a corresponding loss of 6.2% K from the applied fertilizer (**Table 13.3**).

In tomato crop, the treatments receiving 100% recommended NPK as inorganic fertilizer registered highest N loss of 23.9 kg/ha with a corresponding 14.9% N loss from the applied fertilizer. The leaching loss of P was very low, which varied from 5.9 to 10.6 g ha^{-1} and found non-significant among the treatments. The leaching loss of K varied significantly among the treatments and the highest K loss was 15.56 kg/ha in T2 treatment with a corresponding 23% K loss from the applied fertilizer (**Table 13.4**).

Nutrient balance under different treatments

The nutrient balance of pea showed that the actual balance of available N in soil was negative compared to the initial value in all the treatments. The higher negative N balance was -39 kg/ha in the control plot (T1) and the least negative N balance was -11.6 kg/ha in the treatment receiving 100% recommended NPK as organic manure (T3). The available P balance in soil also showed negative value in T1 (-15 kg/ha), T2 (-3.7 kg/ha) and T3 (-4.1 kg/ha) treatments, while T4 showed positive value of 1.2 kg/ha. The available K balance showed the negative value and varied from -11.8 to -48.0 kg/ha, being highest in control.

In tomato, the available N balance varied from -22.7 to -91.7 kg/ha, being highest in control. The lowest negative N balance was recorded in the treatments T3 (-22.7 kg/ha) and T4 (-25.8 kg/ha). The available P balance showed negative value, which varied from -1.6 to -13.3 kg/ha. The lowest negative P balance was observed in the T4 treatment, followed by T3. The available K balance showed the negative value and the highest negative K balance was recorded in T1 treatment (-71.2 kg/ha), while lowest negative K balance was observed in T3 treatment (-45.6 kg/ha).

Table 13.3. Leaching loss of N, P and K in pea under different nutrient management practices

Treatments	Loss of N (kg/ha)	Loss of P (g/ha)	Loss of K (kg/ha)
T1: N0P0K0 (control)	4.23	8.53	6.13
T2: 100% RDF as inorganic	9.97 (22.96)	11.64 (0.006)	13.31 (28.71)
T3: 100% RDF as organic	5.76 (6.12)	8.66 (0.00)	7.68 (6.20)
T4: 50% RDF as inorganic +50% RDF as organic	7.53 (13.19)	10.44 (0.004)	10.68 (18.17)
LSD (p≤0.05)	3.46	4.19	4.61

*values in parenthesis indicate % nutrient loss from applied fertilizer
*RDF: 25:50:25 kg N: P: K/ha

Table 13.4. Leaching loss of N, P and K in tomato under different nutrient management practices

Treatments	Loss of N (kg/ha)	Loss of P (g/ha)	Loss of K (kg/ha)
T1: N0P0K0 (control)	5.15	5.92	4.02
T2: 100% RDF as inorganic	23.93 (14.91)	10.66 (0.009)	15.56 (23.08)
T3: 100% RDF as organic	10.93 (4.59)	6.15 (0.00)	6.33 (4.63)
T4: 50% RDF as inorganic + 50% RDF as organic	16.44 (8.96)	9.33 (0.007)	11.42 (14.80)
LSD (p≤0.05)	4.18	4.17	4.80

*RDF: 130:26:50 kg N: P: K/ha
*Figures in parenthesis indicate % nutrient loss from applied fertilizer

Water balance

The total water applied through flood irrigation in pea and tomato was 225 and 200 mm, respectively. The total evaporation in the crop growth period of pea and tomato was 123.5 and 98.8 mm, respectively. There is negative soil water storage of -36.2 and -97.3 mm, respectively in both crops of pea and tomato. The total deep percolation during the entire crop growth period was 30.8 and 43 mm, which corresponds to 13.7 and 21.5% of applied irrigation, respectively, in pea and tomato.

14. Water Quality and Productivity

Water Conservation under Different Irrigation and Tillage Management in Rice-Based Cropping Systems

To quantify water saving due to the adoption of tensiometer based irrigation over farmers' practice of irrigation (critical crop growth stage based) in rice-wheat-mungbean and rice-maize-mungbean cropping system, studies were initiated during 2018-19. Two types of establishment methods *viz.* puddled transplanted rice (PTR) - conventional-tilled wheat/maize (CTW/CTM) - ZT mungbean (ZTMB) and unpuddled TPR (UPTR) - zero-tilled wheat/maize (ZTW/ZTM) - ZTMB were adopted. Soil moisture potential reveals that farmers' practice of irrigation based on critical growth stages caused a significant amount of water loss through irrigation (**Fig. 14.1**). During the first irrigation of wheat, soil moisture was sufficient in I_1 for crop growth but the application of water caused a loss of water. The gap between two irrigations also highlights the water-saving. Water saving was more under zero tillage than CT.

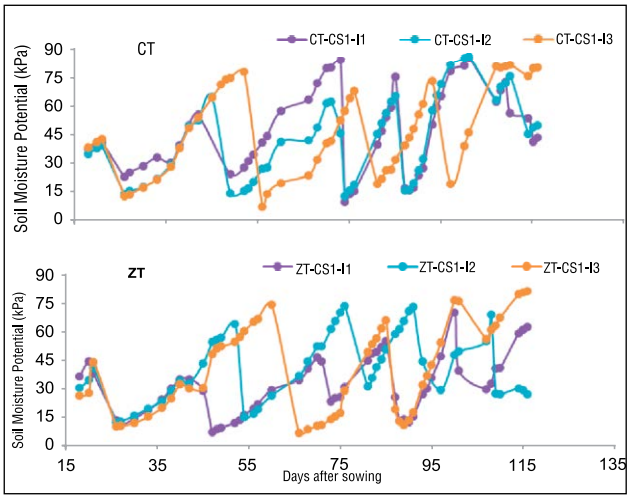


Fig. 14.1. Soil water potential as affected by different irrigation and establishment methods.

CT: Conventional tillage; ZT: Zero-tillage; CS1: Rice-wheat-mungbean, CS2: Rice-maize-mungbean; I1: Farmers' practice of irrigation; I2: Soil moisture based irrigation; I3: Deficit irrigation.

The effect of tillage was significant on crop yield for both wheat and maize (**Table 14.1**). Irrespective of irrigation methods, zero-tillage wheat and maize resulted in 14.3 and 17.0% higher ($p<0.05$) yield, respectively, than CT practices. Soil moisture based irrigation resulted in a 7.7-12.0% higher ($p<0.05$) grain yield of wheat, but a marginal increase (2.8-6.7%) in maize.

Table 14.1. Yield of wheat and maize (t/ha) as affected by different irrigation and tillage management practices.

Tillage	Irrigation methods			Mean (Tillage)	p-value
	Farmers' practice	Soil moisture-based irrigation	Deficit irrigation		
Wheat					
CT	4.7^{b}	5.5^{a}	4.7^{b}	4.9^{B}	Tillage = 0.0045**
ZT	5.3^{b}	5.8^{a}	5.7^{a}	5.6^{A}	Irrigation = 0.0014**
Mean (Irrigation)	5.0^{B}	5.6^{A}	5.2^{B}	GM = 5.3	Tillage x Irrigation = 0.0522^{ns}
Maize					
CT	9.6	10.2	10.1	10.0^{B}	Tillage = 0.0497*
ZT	11.4	12.1	11.7	11.7^{A}	Irrigation = 0.414^{ns}
Mean (Irrigation)	10.5	11.2	10.9	GM = 10.9	Tillage x Irrigation = 0.962^{ns}

Values followed by the same letter in column are significantly different at $p<0.05$ by Duncan Multiple Range Test (DMRT). CT: Conventional tillage; ZT: Zero-tillage

Irrespective of irrigation method, ZT gave significantly higher (6.2-21.7%; $p<0.05$) water use efficiency in wheat than CT. Similar results were recorded in maize. Among the irrigation methods in wheat, soil moisture based irrigation caused 27.7-41.9% higher ($p<0.05$) water use efficiency than others, whereas in maize, farmers' practice of irrigation and deficit irrigation recorded the lowest (350 kg/ha/cm) and the highest (494 kg/ha/cm) water use efficiency, respectively.

Table 14.2. Water use efficiency (kg/ha/cm) of wheat and maize as affected by different irrigation and tillage management practices

Tillage	Irrigation Methods			Mean (Tillage)	p-value
	Farmers' practice	Soil moisture based irrigation	Deficit irrigation		
Wheat					
CT	186^{c}	273^{a}	235^{b}	231^{B}	Tillage = 0.0027**
ZT	210^{b}	290^{a}	286^{a}	262^{A}	Irrigation = <0.0001**
Mean	198^{C}	281^{A}	261^{B}	GM = 247	Tillage x Irrigation = 0.0287*
Maize					
CT	321	409	403	378^{B}	Tillage = 0.0296*
ZT	379^{c}	485^{b}	585^{a}	483^{A}	Irrigation = 0.0001**
Mean	350^{B}	447^{A}	494^{A}	GM = 431	Tillage x Irrigation = 0.0196*

Evaluation of Irrigation System and Improvement Strategies for Higher Water Productivity in Sone Canal Command

Low water requiring rice cultivation technique - SRI (System of Rice Intensification) was demonstrated in the farmers' field of Pansuhi village in Sone canal command. SRI- line marker and weeder were demonstrated to the farmers. (**Fig. 14.2**).

Fig. 14.2. Paddy cultivation through SRI technique and use of marker and weeder

Estimation of Crop Water Requirement in High Density Guava Orchard

A study was taken to estimate daily crop water requirement in 8 year old high density (1.5 x 1.5 m) guava orchard at ICAR RCER Patna. Potential evapotranspiration was estimated using FAO Penman-Monteith equation. Variation of daily actual crop water requirement of guava tree is shown in **Fig. 14.3**. The highest crop water requirement, 6.25 mm/day, was observed in the month of June, whereas the lowest, 1.44 mm/day, was observed in the month of January.

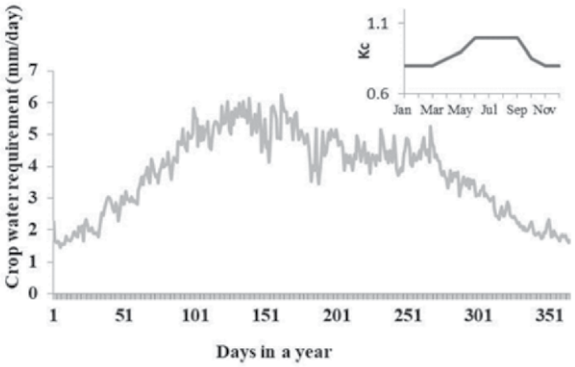


Fig. 14.3. Variation daily actual crop water requirement in guava tree

Improving Rice–Vegetable Pea-Summer Maize System Productivity through Efficient Water Management Practices

An experiment was initiated at ICAR RCER Patna during 2018 to improve the productivity of rice-vegetable pea-summer maize system through efficient water management. Three varieties of each crop were evaluated under 4 levels of water management (W_1 IW: CPE=0.4, W_2 IW: CPE=0.6), W_3 IW: CPE=0.8) and W_4 IW: CPE=1.0) in a split-plot design.

During summer 2019, three maize genotypes namely S-999 (V1), Vishal (V2) and S-585 (V3) were evaluated under 04 water regimes based on IW:CPE ratios 0.4 (W1), 0.8 (W2), 1.0 (W3) and 1.2 (W4) (**Fig. 14.4**). Results revealed that genotype Vishal produced the highest green cob yield (16.75 t/ha) (Table 14.3). In case of water management treatment, the highest green cob yield (19.06 t/ha) was recorded with W_4 (IW: CPE=1.2). Maximum irrigation water productivity (4.79 kg/m^3) was recorded by genotype Vishal and irrigation at IW: CPE=0.4.

Table 14.3. Green cob yield (t/ha) of maize as influenced by water management and genotypes

Treatments	Green cob yield (t/ha)	WP (kg/m^3)
W_1 (IW:CPE=0.4)	11.61	5.81
W_2 (IW:CPE=0.8)	15.22	4.76
W_3 (IW:CPE=1.0)	18.33	4.58
W_4 (IW:CPE=1.2)	19.06	3.97
CD (P=0.05)	1.31	0.21
V_1=S-999	15.25	4.36
V_2=Visal	16.75	4.79
V_3= S-585	16.17	4.62
CD (P=0.05)	0.76	0.17

Fig. 14.4. Evaluation of maize genotypess under different water regimes

In subsequent *Kharif* 2019, three varieties of rice, namely CR Dhan 40 (V1), Rajendra Shweta (V2) and Swarna Shreya (V3) were evaluated along with 04 levels water management (**Fig. 14.5**). Results revealed that genotype Swarna Shreya produced significantly higher rice (3.98 t/ha) as compared to other tested rice genotypes (**Table 14.4**). In case of water management practices, W_4 produced higher grain yield (4.05 t/ha) than others.

Fig. 14.5. Evaluation of rice varieties under different water management practices

Table 14.4. Performance of rice as influenced by water management and genotypes

Treatments	Grain yield (t/ha)	Bio-logical yield (t/ha)	Harvest index	IWP (kg/m^3)
W_1 = (IW: CPE=0.4)	3.58	10.23	0.35	1.79
W_2= (IW: CPE=0.6)	3.78	11.12	0.34	1.51
W_3 =(IW: CPE=0.8)	3.95	11.62	0.34	1.32
W_4= (IW: CPE=1.0)	4.05	12.26	0.33	1.16
LSD (P=0.05)	0.11	0.34	NS	0.28
V_1= CR Dhan 40	3.81	11.12	0.34	1.39
V_2= Rajendra Shweta	3.73	10.96	0.34	1.36
V_3= Swarna Shreya	3.98	11.70	0.34	1.45
LSD (P=0.05)	0.82	2.47	NS	0.22

Effect of Tillage and Water Management on Productivity of Summer Mung Bean in Rice-Lentil-Mungbean System

Two tillage systems *viz.*, Conventional tillage (CT) and conservation tillage (ZT) and four water management level (irrigation at IW: CPE ratios 0.2, 0.3, 0.4 and control) were evaluated in summer mung bean.

Results revealed that tillage systems did not influence the seed yield and water productivity of mung bean. The highest mung bean seed yield (2.63 t/ha) (**Table 14.5**) was recorded with IW: CPE=0.6 (W_3). However, the maximum water productivity (4.22 kg/m^3) was noticed withW_2 (IW: CPE=0.4**.**

Table 14.5. Effect of tillage and water management on summer mungbean

Treatments	Bio-logical yield (t/ha)	Grain yield (t/ha)	HI	WP (kg/m^3)
ZT	5.59	1.81	0.32	2.45
CT	6.06	1.75	0.29	2.36
LSD(P=0.05)	NS	NS	NS	NS
W_1 (Rainfed)	4.21	0.57	0.14	4.07
W_2 (IW:CPE=0.4)	5.57	2.28	0.41	4.22
W_3 (IW:CPE=0.6)	6.12	2.63	0.43	2.80
W_4 (IW:CPE=0.8)	6.25	2.17	0.35	1.62
LSD (P=0.05)	1.34	0.23	0.07	0.87

15. Conservation Agriculture

Evaluation of Establishment Methods for Improving the Productivity of Rice Fallows

A long-term study was initiated during the rainy season of 2016 at the ICAR-RCER Patna to find out the most suitable rice–winter crop rotation; and appropriate crop establishment methods and residue management practices in rice–fallows (**Fig. 15.1**). Treatment comprised of six levels of crop establishment methods and residue management (CERM) practices: zero–till direct seeded rice (ZTDSR), conventional-till DSR(CTDSR), puddle transplanted rice (PTR), ZTDSR with rice residue retention ($ZTDSR_{R+}$), CTDSR with rice residue retention ($CTDSR_{R+}$), PTR with rice residue retention (PTR_{R+}) and five post–rainy season crops *viz.* chickpea (Pusa 256), lentil (HUL 57), mustard (Proagro 5111), linseed (T 397) and safflower (PBNS 12) fitted in a split–plot design. Rice yields were typically higher after pulse crops as compared to oilseeds. Rice productivity was the highest in PTR followed by CTDSR and lowest in ZTDSR irrespective of the residue management (**Table 15.1**).

Fig. 15.1. Crop performance during the *Kharif* season at the rice fallows experimental plot

Long-term conservation agriculture impact on microbiome and soil health indicators for resource efficiency and resilience in maize systems

A long-term field experiment with three cropping systems, i.e., rice-wheat (RW), rice-maize (RM) and rice-lentil (RL) (lentil replaced by chickpea) and three tillage practices (conventional tillage (CT), reduced tillage (RT) and zero tillage (ZT) in factorial RBD was initiated in 2012. All these systems were evaluated for yield potential and soil total organic carbon (TOC).

Table 15.1. Rice grain yields as influenced by establishment methods and residues management practices and succeeding crops (Mean data of one year)

CERM	Grain yield (t/ha)					
	Chick-pea	Lentil	Saf-flower	Lin-seed	Mus-tard	Mean
$ZTDSR_{R+}$	4.13	4.03	4.03	3.98	3.86	4.01^{BC}
ZTDSR	3.75	3.81	3.75	3.78	3.60	3.74^{C}
$CTDSR_{R+}$	4.29	4.23	4.15	4.13	4.05	4.17^{ABC}
CTDSR	3.94	3.97	3.82	3.71	3.67	3.82^{BC}
PTR_{R+}	4.69	4.71	4.58	4.33	4.43	4.55^{A}
PTR	4.14	4.47	4.35	4.00	4.21	4.24^{AB}

*CERM: crop establishment methods and residues management, WC: winter crops

The TOC content was the highest in top 0-10cm layer (9.33 g/kg) followed by 10-20 cm (8.51 g/kg) and 20-30 cm (9.91 g/kg) soil depth (Fig15.2). Among the treatment chickpea sown by reduced tillage recorded higher TOC (9.24 g/kg) followed by chickepea sown under ZT (9.0 g/kg). Conventional wheat recorded the lowest TOC content (8.13 g/kg) followed by CT maize (8.34 g/kg). Wheat and chickpea under reduced tillage recorded highest grain yield (4.52 & 1.24 t/ha, respectively) whereas ZT maize recorded higher grain yield (4.28 t/ha) than RT and CT treatments (Table 15.2).

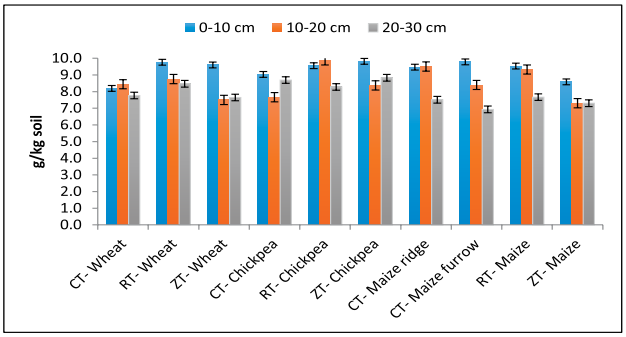


Fig. 15.2. Total organic carbon in soil as influenced by establishment methods in different soil depths

Table 15.2. Crop productivity as influenced by establishment methods

Treatment	Grain yield (t/ha)			Straw yield (t/ha)			Biological yield (t/ha)			Harvest Index (HI)		
	Wheat	Maize	Chickpea	Wheat	Maize	Chickpea	Wheat	Maize	Chickpea	Wheat	Maize	Chickpea
CT	3.97	4.03	0.97	7.44	7.13	1.35	11.41	11.15	2.32	34.72	36.13	41.79
RT	4.52	4.28	1.24	8.16	7.68	1.64	12.68	11.95	2.88	35.61	35.76	42.9
ZT	4.35	4.35	1.17	8.04	8.14	1.58	12.39	12.49	2.75	35.1	34.83	42.51
Mean	4.28	4.22	1.13	7.88	7.65	1.52	12.16	11.86	2.65	35.14	35.58	42.4
CV(%)	8.82	9.53	3.46	7.85	10.86	-	8.15	9.79	1.72	1.29	4.69	2.93

*CT: Conventional tillage; RT: Reduced tillage; ZT: Zero tillage

Effects of long-term tillage, termination of zero-till and cropping system on productivity, energetic and economics

Long-term experiments have been undertaken under the CSISA project on conservation agriculture in rice-based cropping systems at ICAR RCER Patna since 2009-10. After 7th year, ZT DSR in CA-based rice- mustard-maize cropping system faced a severe problem of rice mealy bug (*Brevennia rehi*), and hence, divided into 4 plots (ZT DSR, CT DSR, Puddle transplant and Unpuddle transplant). After two years of tillage, these plots were again converted to ZT DSR. Results after 9th year revealed that the maximum system productivity in terms of rice-equivalent yield (21.37 t/ha), system water productivity (1.01 kg rice equivalent grain/m^3) and net returns (Rs. 2,43,022/-) was recorded in puddle transplanted rice-ZT mustard-ZT maize cropping system and minimum (12.95 t/ha, 0.61 kg rice equivalent grain/m^3 and Rs. 1,74,746/-) with farmers practice of puddle random transplanting rice-conventional till wheat system (**Table 15.3**). During the 10th year (2019), maximum rice grain yield 6.78 t/ha) was recorded with ZT DSR in CA-based rice-wheat and greengram system.

Evaluation of CA practices on the productivity of winter crops in rice-fallows of eastern Plateau and Hill region

The effect of rice establishment methods (ZTDSR, ZT transplanting-ZTT and conventional transplanting-FP) was evaluated with and without rice residue mulch on winter crops *viz.*, lentil (KLS-218), mustard (Pusa-26) linseed (BAU 06-03) and safflower (PBNS-12) after the harvest of rice during 2018-19 in farmer's field at two locations *viz.*, Chene, Ranchi (Jharkhand) and Kandora, Jaspur (Chhattisgarh). The rice straw mulch was applied at 5 t/ha at the time of sowing of winter crops in the respective CA practices. Results revealed that in Jharkhand, ZT mustard after ZTT rice along with rice residue mulch produced significantly higher seed yield (317 kg/ha) followed by ZTT

Table 15.3. Effects of long-term tillage, termination of zero-till and cropping system on system productivity, net returns and energetic

Treatment	System productivity (REY t/ha)	Water productivity (kg grain/m^3)	Net returns (Rs/ha)	Energy output: input ratio (MJ)	Rice grain yield (t/ha) in 10th year
Rice-wheat (conventional row transplanting)	13.47	0.64	1,81,883	8.76	6.10
Rice-wheat (conventional random transplanting)	12.95	0.61	1,74,746	8.62	5.71
Rice (MTR)-ZT wheat-ZT greengram	18.49	0.82	2,26,515	7.04	6.71
ZT DSR-ZT wheat-ZT greengram	16.83	0.71	2,12,341	7.54	6.78
ZT DSR-ZT mustard-ZT maize	19.06	0.75	2,20,417	5.93	4.61
CT DSR-ZT mustard-ZT maize	19.69	0.85	2,24,425	5.87	5.43*
PTR-ZT mustard-ZT maize	21.37	1.01	2,43,022	6.07	6.56*
UPTR-ZT mustard-ZT maize	20.13	0.82	2,24,435	6.06	5.91*
LSD (P=0.05)	2.13	0.09	39,014	0.78	0.43

PTR-Puddle transplanted rice, UPTR-Unpuddle transplanted rice, *ZT DSR

rice without mulch (258 kg/ha). The lowest seed yield (195 kg/ha) of mustard was recorded after transplanted rice. However, in case of linseed, the seed yield after puddled transplanted rice (200 kg/ha) was on a par with that after ZTDSR (188 kg/ha) and ZTT (175 kg/ha). Similarly, in Chhattisgarh, ZTT with mulch recorded significantly higher seed yield of lentil (193 kg/ha) and linseed (321 kg/ha) as compared to farmer's practice (123 and 268 kg/ha, respectively). Mustard yield after ZTT (585 kg/ha) and DSR (490 kg/ha) were on par with FP (590 kg/ha).

During *Kharif* 2019, rice establishment techniques were evaluated at both the locations with four genotypes *viz.*, Naveen, Lalat, IR-64 and Sahabhagi. In Jharkhand, ZTT rice produced significantly higher grain yield (3.11 t/ha) followed by FP (2.30 t/ha) and ZTDSR (1.93 t/ha). Among the genotypes, IR-64 recorded the highest grain yield of 2.62 t/ha followed by Naveen (2.53 t/ha), Sahbhagi (2.26 t/ha) and Lalat (2.05 t/ha). Similarly, in Chhattisgarh, grain yield of rice in ZTDSR (5.80 t/ha) and ZTT rice (5.53 t/ha) was significantly higher than that of FP (4.24 t/ha). The grain yield of all the four rice varieties was however on a par.

Fig. 15.3. Winter crops in rice-fallows

Fig.15.6 . Linseed under DSR-mulch

Fig. 15.4. Mustard under ZTT-non mulch

Fig. 15.5. Lentil under DSR-mulch

Fig. 15.7. ZTDSR

16. Solar Energy Application

Deteriorating farm power supply and many-fold increase in fuel prices severely undermine the assured water supply required to meet supplementary irrigation during erratic rainfall and prolonged dry spells. In eastern region, solar energy can play a significant role in water abstraction, particularly the groundwater. The use of solar energy could provide an opportunity to use pressurized irrigation for high irrigation efficiency and water conservation, as this region is endowed with immense solar energy potential with monthly averaged solar radiation ranging from 3.6-6.4 kWh/m^2/day and 250 -280 number of bright sunshine days. The instantaneous solar radiation in this region is ranging from 400- 980 W/m^2 (Fig. 16.1) over a longer duration over a day and can operate solar pump for a considerable period in the neighbourhood of rated value. Further, the groundwater depth regime in most of the area this region is quite shallow, 2-10 m bgl, with annual fluctuation of ±2 to ±4 m.

To assess the performance of solar pump for its feasibility in this region, different capacity solar pumps were tested at Patna, Madhubani and East Champaran districts of Bihar (**Fig. 16.2**). However, sighting the popularity and acceptability of 3 hp solar pump, operated by 3.0 kWp solar array, this pump was selected for detailed study, under the prevailing solar radiation condition, for its V-I character, efficiency, available delivery pressure head over a day for operating pressurized irrigation system, irrigation command are per day etc. There are more than 400 solar pumps of 3 hp capacity pumps installed in Bihar, as government providing a hefty subsidy on this capacity pump. The specifications of the pump and solar modules are given in **Table 16.1**.

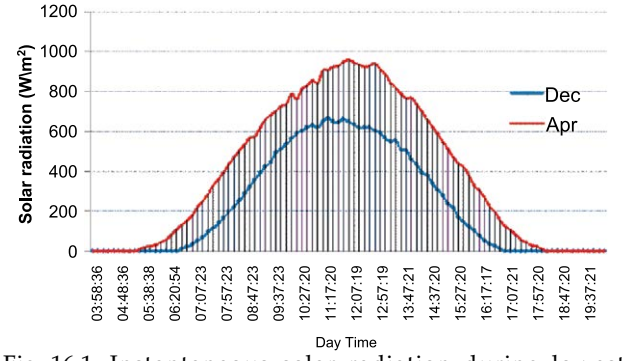


Fig. 16.1. Instantaneous solar radiation during lowest insolation (Dec) and maximum insolation (Apr)

Fig 16.2. Solar pumps, operated by 3.0 kWp solar array, selected for evaluation in eastern region

Table 16.1. Specifications of solar system component

Electrical parameters of solar module		Electrical characteristics of pump and controller	
Type of module	Polycrystalline	Pump	DC centrifugal submersible pump
Power (P_{max})	300 W ±3%	Shutoff head	35 m
Open circuit voltage (V_{oc})	44.64 V	Suggested solar conf.	300 Wp, 10 Nos in series
Short circuit current (I_{sc})	8.75 A	Motor capacity	2.2 kW
Current at maximum power (I_{pm})	8.35 A	Pump controller rating	2.2 kW
Voltage at maximum power (V_{pm})	35.93 V	DC voltage range	250-780 VDC
Nominal opt. cell temperature	46 ± 2 °C	MPPT tracking	Automatic
Temperature coefficient of power	± 0.4% / °C	Rated current (max)	10 A
Module efficiency	15.4%	Driver efficiency	97%

Theoretically, motors equipped with induction motor driven by 3 phase AC power, provided by Variable Frequency Drive, VFD. This VFD also controls the rpm of the pump. For rated power, the desired phase voltage and current should be 220 V and 6.0 A, respectively, in each phase for rated value 2.2 kW. The module combination, V- I characteristics etc. are reported in **Table 16.2**.

Table 16.2. V-I requirement of pump for rated power of solar array

Pump motor		Array characteristics	
Pump rating	2.2 kW	Combination	In Series
Power supply arrangement	3- wire arrange-ment	Open circuit voltage (V_{oc})	446 V (DC)
Phase arrange-ment	120^0	Short circuit current (I_{sc})	8.75 A (DC0
Phase voltage	220 V (AC)	Voltage at maximum power (V_{pm})	359 V (DC)
Current for rated power	6.0 A (AC)	Current at maximum power (I_{pm})	8.25 A (DC)

AC voltage characteristics of solar system

The AC voltage from VFD was measured and plotted against the time, shown in **Fig. 16.3**. As day starts, the open-circuit voltage is taken over by the load voltage. The voltage in a phase line is very close to 220 V over a considerable period. As dusk approaches AC voltage decreases because of the decrease in solar produced current.

Alternation current (AC) characteristics of solar system

The AC current from the inverter was measured and plotted with time, shown in **Fig. 16.4**. The AC voltage remains around 220 V while the current varied as per the radiation intensity. This variation in current induces change in power, available to the pump for the run. From the graph,

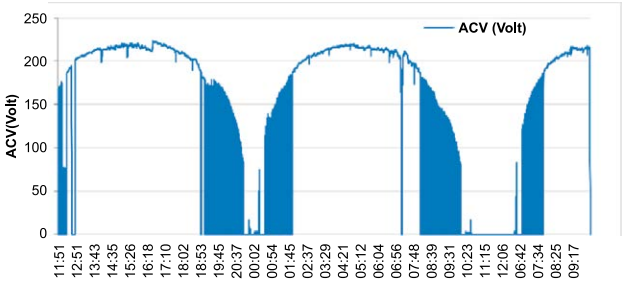


Fig. 16.3. AC voltage output from driver

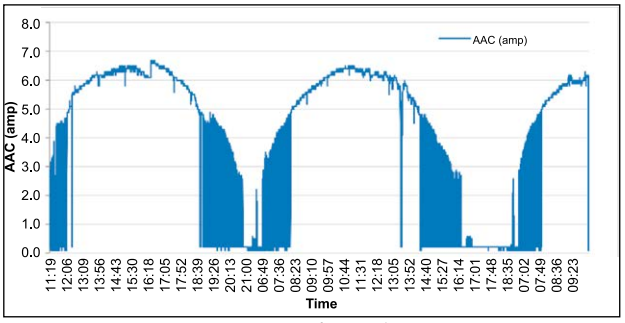


Fig. 16.4. AC current output from driver

it is observed that over a day the current varies between 4.0 to 6.7 A.

Water abstraction and irrigable area

The available delivery pressure head was found to be in the range of 1.4-1.5 kg/cm^2 with suction head less than 10m. Therefore pressurized irrigation such as drip and micro-sprinklers can be operated successfully as suction head is low. The average irrigable area per day by flood method is reported in **Table 16.3,** assuming the depth of water by flood irrigation 7.0 cm.

Efficiency of 3 hp solar pump

Based on available solar radiation, ground-water depth, bgl, the total dynamic head- which includes suction head and the delivery head both - measured from the available pressure at the immediate delivery point, solar panel area, efficiency of solar modules, hydraulic energy, solar photovoltaic power, the efficiency of 3 hp pump for eastern region solar pumps evaluated for the months of March and October (**Table 16.4**). The mean hydraulic efficiency of the pump was 50.2%. This is the maximum efficiency of the pump.

Table 16.3. Water availability for dry season agriculture

Sep-Nov	Dec-Jan	Feb	Mar-June
Water yield per day (m^3/day) from a solar pump on a cloud free day			
120- 130	75-85	90-110	140-130
Irrigable area per day (m^2/day) from a solar pump on a cloud free day			
1700-1850	1100-1250	1300-1600	2000-1800

Table 16.4. Efficiency of 3 hp solar pump operated by 3kWp solar array

Hydraulic energy Eh(kWh/d)		Solar PV power Epv (kWh/d)		Efficiency (Eh/Epv)*100		Mean effi-ciency
March	Oct.	March	Oct.	March	Oct.	
7.3	6.1	14.2	11.8	51.4%	49.1%	50.2%

17. Farm Machinery

Ergonomic Evaluation of Hand Operated Maize Sheller for Reducing Drudgery of Farm Women in Bihar

To reduce the drudgery of farm women involved in maize shelling, a hand-held octagonal maize sheller (OMS) tool (**Fig. 17.1a&b**) was introduced and its performance was compared with hand shelling. The OMS tool and hand shelling recorded an output of 23.71 and 8.87 kg/h, respectively. The cardiac cost per unit of output worked out was 69.73 and 287.09 beats/kg for OMS tool and hand shelling, respectively. Compared to hand shelling, the OMS tool reduced drudgery by 75.71%. Overall discomfort rating (ODR) was 1.58 and 2.12 while the body part discomfort score (BPDS) was 21.27 and 30.41 for OMS tool and hand shelling, respectively. Adoption of OMS tool reduced the physical stress, as small percentage of subjects (<40%) reported about the body pain. In view of increased shelling efficiency and reduced physical pain, the OMS tool was found more suitable and is recommended for maize shelling in Bihar.

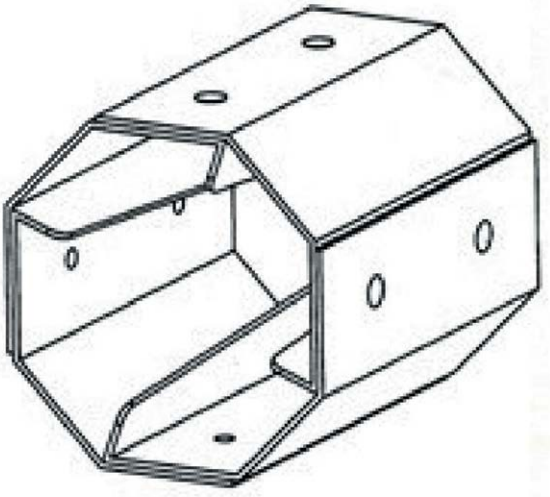


Fig. 17.1(a) Maize sheller

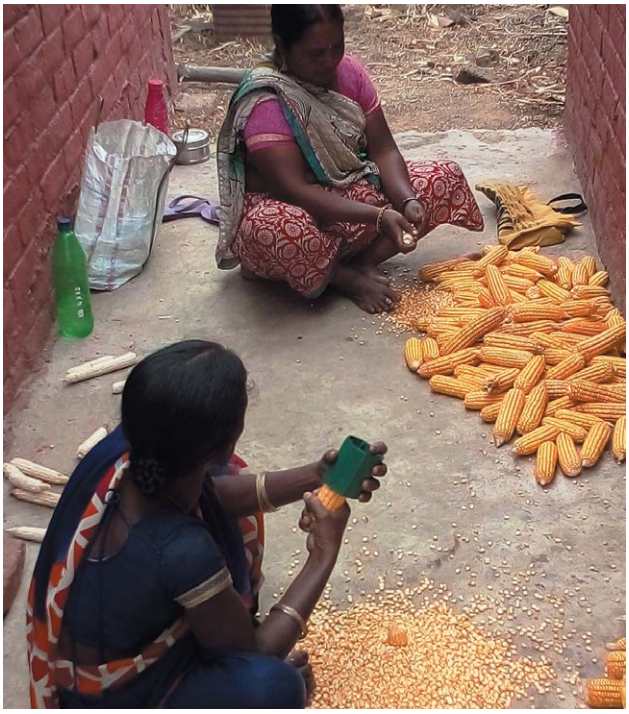


Fig. 17.1(b) Operation of maize sheller by farm women

Survey of Traditional Agricultural Tools Used by Tribal Farmers in Chhotanagpur Plateau

An exploratory study was conducted to enlist the traditional agricultural tools used by tribal farmers of five selected villages of Ramgarh district, Jharkhand. Most of the tribal farmers are using traditional tools, like spade, sickle, khurpa, axe, *dao* etc. Almost 84 percent of farmers were using bullock as conventional source of power. The majority of farmers (75%) were having a pair of bullock; however, a few (9.33%) farmers had single bullock with them (**Table 17.1**). They hired bullocks from nearby farmers during the cropping season. *Desi hal* (plough) drawn by a pair of bullocks was used by 86.67% of farm families. Almost every family who had *desi hal* was also having local iron/wood made leveller. Nearly 19 percent of farmers hired *desi hal* along with bullock with charges of between Rs. 300-400 per day.

Table 17.1. Distribution pattern of farm tools and implements among farmers (N = 150)

Particulars	No. of Households (%)
Traditional Power source	
Bullocks (more than 1) Bullock (Single)	112 (74.66) 14 (9.33)
Traditional tools	
Desi Plough (Iron Make) Desi Plough (Wood make) Wooden cum hollow angle plough	91 (60.67) 27(18.00) 12 (8.00)
Leveller or *Dohra* (Wood make) Leveller (Iron make) Leveller (Karha)	99(66.00) 20 (13.33) 9 (6.00)
Other traditional tools (*Khurpa*, Sickle, and D*ao*)	150 (100.00)

Eco-energetic Analysis of Different Cropping Systems in Eastern India

The study assessed the cropping system based on energy use for efficient utilization of inputs. The comparison of the energy performance of six cropping sequences with different input management intensities were carried out. Six cropping systems in three zones were *viz.* Indo-Gangetic Plains : rice- wheat- mung and rice- wheat; Coastal Zone: rice- greengram and rice- rice; and Hill and Plateau region: rice- potato and rice-fallow. Inputs used in calculation of energy were human labor, machinery, electricity, chemicals, diesel, water, fertilizers, and seeds etc. Energy outputs from main product and their residues were calculated by multiplying production and their corresponding energy equivalent. Rice had the maximum energy input followed by wheat and the least energy input was for potato. The maximum energy in rice is mainly due to higher number of tillage with puddling and fertilizer requirement as compared to other crops. Fertilizer consumption was responsible for the major share of total energy input (3.22-70.34%) followed by diesel (4.722- 41.45%) and irrigation (1.40-26.90%). Total energy input of 63442.49 MJ/ha was the highest for rice-wheat-mung in IGP and the lowest for rice-fallow systems (8479.28 MJ/ha) in hill and plateau region. The total input energy requirement of crops under different cropping systems ranged from 8479.28 – 63442.49 MJ/ha.

The share of farm mechanization was the highest (26.80%) in IGP region due to use of farm machinery followed by coastal zone (24.88%). Commonly used implements were tractor and power tiller. Contribution of farm mechanization was the least in Hill and Plateau region (20.50%).

18. Livestock and Fisheries

LIVESTOCK

Development of Area Specific Mineral Mixture Based on Soil-Plant-Animal Continuum in Bihar and Jharkhand

Samples of soil, feed and fodder resources and animal were collected from different districts of Jharkhand namely Hazaribagh, Ramgarh, Ranchi, Khunti, Lohardaga, Dumka, Deogarh, Saraikela, East Singhbhum and Palamau, and analyzed for major and trace minerals (**Table 18.1**). It has been observed that the pH of soils was medium to heavy acidic in the selected districts. Soils of more than 70% area of the surveyed districts had medium availability status of nitrogen, however, soils of 97.8% area were low in available phosphorus (P) content. About 52% soils were deficient in zinc (Zn), and 18% in manganese (Mn). Soils of 97% area contained excess iron (Fe), however, 67% soils were deficient in P.

Major and trace minerals content of green and dry fodder collected from the surveyed villages are presented in **Table 18.2**. It has been observed that all the dry fodder were deficient in P but excess of Fe. About 32% samples of dry fodder were deficient in Mn, however, 42% samples were deficient in Zn and 21% were deficient in copper (Cu). All samples of green fodder had sufficient calcium (Ca) but 17% samples were deficient in P. All samples had excess Fe and Cu but sufficient Mn. About 19% of green fodder were deficient in Zn.

Table 18.1. Major and trace minerals content of soils of Jharkhand

Districts	P (kg/ ha)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn **(ppm)**	**pH**
	Critical limit					
	10.0	**<0.3**	**<2.5**	**<5**	**<1**	
Hazaribagh	4.81	1.63	262.40	28.41	1.84	5.2
Ramgarh	5.06	3.11	747.22	45.87	0.74	5.1
Ranchi	5.75	2.74	193.56	39.90	0.96	5.3
Lohardaga	9.56	3.48	342.09	62.33	1.11	4.9
Khunti	4.89	4.09	825.96	64.60	0.88	5.4
Saraikela	5.32	4.22	293.16	46.83	2.08	4.9

The mineral content of blood serum collected from the cattle and buffalo **(Fig. 18.1)** in surveyed districts are presented in **Table 18.3**. It has been

Table 18.2. Major and trace minerals content of green and dry fodder (Mean ±S.E)

Feed	Ca (%)	P (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
Critical level	<0.30	0.25	<8.0	<50.0	40.0	30.0
Wheat straw	0.31 ±0.08	0.06 ± 0.001	2.4 ± 0.65	829 ± 81.00	46.92 ± 5.26	25.62 ± 1.92
Paddy straw	0.37 ± 0.06	0.07 ± 0.001	1.67 ± 0.41	756 ± 42.00	594.4 ± 34.10	41.46 ±2.05
Lentil plant (dried)	1.09 ± 0.008	0.11 ± 0.005	13.03 ± 0.64	1406 ± 74.00	104 ± 12.00	23.08 ± 1.41
Gram plant (dried)	0.94 ± 0.007	0.12 ± 0.002	25.76 ± 0.32	1211 ± 84.00	83 ± 9.89	19.76 ± 1.14
Urd plant (dried)	0.88 ± 0.004	0.14 ± 0.006	22.42 ± 0.53	620 ± 52.00	89 ± 11.84	32.65 ± 3.51
Maize plant (dried)	0.76 ± 0.002	0.42 ± 0.004	31.06 ± 1.73	481 ± 33.00	157 ± 20.76	35.86 ± 2.73
Maize fodder	0.45 ± 0.08	0.28 ± 0.060	18.56 ±0.78	1643 ± 122.00	184 ± 3.42	41.45 ± 3.14
Bajra fodder	0.56 ± 0.05	0.34 ± 0.040	27.42 ±1.11	1290 ± 59.00	109 ± 4.76	22.53 ± 1.53
Local grass	0.76 ± 0.09	0.29 ± 0.030	9.87 ± 0.78	2120 ± 131.00	182 ± 8.70	18.46 ± 2.07
Sudan grass	0.52 ± 0.11	0.28 ± 0.010	16.58 ± 0.84	1174 ± 124.00	178 ± 5.54	31.67 ± 2.53
Cowpea fodder	1.43 ± 0.15	0.56 ± 0.070	13.56 ± 0.78	1543 ± 85.00	109 ± 1.58	29.64 ± 1.48
Jowar fodder	0.58 ± 0.07	0.22 ± 0.010	11.95 ± 1.12	1378 ± 74.00	128 ±2.66	21.77 ± 0.96

Table 18.3. Serum minerals content of cattle and buffalo (Mean ±S.E)

District			Hazaribagh	Ramgarh	Ranchi	Khunti	Lohardaga	Saraikela
Ca (mg/dl)	Critical limit	8.0	7.04 ± 0.62	6.44 ± 0.38	7.32 ± 0.45	6.96 ± 0.27	5.66 ± 0.41	5.87 ± 0.73
P (mg/dl)		4.0	3.17 ± 0.12	3.64 ± 0.20	4.63 ± 0.09	3.77 ± 0.01	3.81 ± 0.16	3.08 ± 0.08
Cu (ppm)		>0.65	0.76 ± 0.01	0.67 ± 0.02	0.59 ± 0.01	0.80 ± 0.01	0.48 ± 0.02	0.75 ± 0.01
Fe (ppm)		<1.0	15.12 ± 2.74	14.35 ± 1.07	19.72 ± 2.87	17.09 ± 3.53	14.22 ± 1.61	17.91 ± 2.06
Mn (ppm)		>0.2	0.12 ± 0.02	0.11 ± 0.03	0.16 ± 0.08	0.28 ± 0.08	0.38 ± 0.06	0.18 ± 0.11
Zn (ppm)		>1.0	0.75 ± 0.06	0.67 ± 0.13	0.44 ± 0.12	0.76 ± 0.51	0.95 ± 0.09	0.84 ± 0.19

Fig. 18.1. Blood collection from cattle

observed that 80% animals had deficiency of P. Calcium and Zn deficiency was also observed in about 30-50% animals.

All India Coordinated Research Project on Goat Improvement

AICRP on Goat Improvement was initiated during 2018-19 with the basic objective of enhancement of productivity of goat genetic resources of the State in their habitat. Five districts of Bihar namely Samastipur, East Champaran, Araria, Katihar and Jamui were selected for the study based on the density of goat population. One village was selected from each of the district. From the baseline survey, it was observed that more than 90% of goats were owned by landless and marginal farmers and sharecroppers belonging to SC, ST and Muslim community. The average herd size ranged from 1.83 to 3.91 in different districts of Bihar **(Fig. 18.2)**. It has been observed that population growth of Black Bengal goats in the selected clusters was 16.73%. Mean birth weight of male and female goats were observed at 1.22 ± 0.05 and 1.02 ± 0.04 kg, respectively. The body weight at one year age were recorded at 10.58 ± 0.35 and 8.27 ± 0.31 kg, respectively for male and female. The milk yield of Black Bengal goats varied according to litter size. The average lactation milk yield was recorded at 21.05±0.27 kg up to 3 months. Mortality rate of goats during baseline survey was recorded at 16.96% in the selected clusters. Through vaccination and deworming, the mortality rate was reduced to 2.89% during the current year. During the period one capacity building programme, five animal health camps **(Fig. 18.3)** and five awareness programme were organized. A total of 1706 goats were dewormed and 1306 goats were vaccinated against PPR and enterotoxemia in the surveyed clusters.

Fig. 18.2. Holding size of goat

Fig. 18.3. Vaccination of goats at project site

Evaluation and Characterization of Duck Germplasm in Eastern Region

An experiment was conducted to compare the performance of Khaki Campbell and Maithili ducks **(Fig. 18.4**) under extensive system of management in Bihar. Brooding of ducklings for one month was managed with commercial feed. Latter, they were exposed to free range management system. Leftover feed materials and kitchen wastes were provided as feed. Vaccination against duck plague was done as per schedule. Growth, egg production, mortality and egg quality data were recorded. The study revealed that Khaki Campbell ducks gained significantly (P<0.05) higher body weight (1135.00 ± 16.79 vs 853.44 ± 28.35 g) as compared to Maithili duck from day old to 24th week of age. Egg weight was higher in native ducks (56.76 g) as compared to Khaki Campbell ducks (54.71 g). Egg production rate of local native ducks (21.46 %) was significantly (P<0.001) lower compared to Khaki Campbell duck (32.05%). The age at sexual maturity of female ducks were 178.92 for Khaki Campbell and 191.12 days for native ducks. Shell thickness was comparatively less in Maithili (0.41mm) than Khaki Campbell (0.43 mm). The mortality rate in local duck (2.17%) was significantly (P<0.05) lower compared to Khaki Campbell duck (4.76%). Economics of duck rearing between the two varieties was non-significantly different. It is recommended that both Khaki Campbell and Maithili ducks are suitable for rearing under extensive system of management.

Fig. 18.4 Maithili duck

Effect of Genetic and Non- Genetic Factors on Prolificacy of Bengal Goat

A study was conducted to observe the effect of age and parity on milk composition in highly prolific Bengal goats having the litter size of 3 to 5. Milk composition was analyzed weekly for fat, protein, solid not fat and lactose percentage for all the experimental animals. The fresh samples collected in the morning were utilized for analysis. The milk protein percentage decreased with advancing lactations. The protein values during colostrum period, 1st week, 2nd week, and 3rd week of lactation were 5.58± 0.41, 3.83± 0.11, 3.70± 0.03 and 3.69 ± 0.03%, respectively. However, the milk fat content was affected by both lactation stage and parity. The milk fat content had a decreasing trend as lactation progressed. The fat contents during the colostrum period, 1st, 2nd and 3rd week of lactation were 6.06 ± 0.41, 5.09 ±0.50, 3.26 ± 0.30 and 3.19 ± 0.33 %, respectively. Milk of 1st and 2nd parity goats have a higher fat content (7.01 to 8.41%) than the milk obtained from older goats (4.37 to 5.22%). There was also significant (P<0.05) decrease in lactose as lactation progressed. The lactose content during colostrum period was 8.26± 0.57% and during 3rd week of lactation the value was 5.63±0.12%.

Seemanchali Sheep

The Seemanchali sheep are found in Seemanchal region of Bihar and distributed in parts of Araria, Purnea and Katihar districts **(Fig. 18.5)**. The population looks unique in their morphological characteristics and found to inherit the traits from one generation to next generation. The sheep were medium in size with black coat colour. Sporadic presence of patches of white and brown markings were found in majority of sheep. Similarly, there was uniformity in the body and head colour in most of the sheep.

An average flock size of the sheep was 35.8 with the range from 22 to 58 in the breeding tract. Males possessed short horns with an average length of 8.6 cm (in 64.3 per cent cases) whereas the females are polled. Muzzle, eyelashes and hooves were black in colour. They have small size udder with two laterally oriented teats. Lambing percentage in the flock was 72.5 and the lambing interval was 11.2 months. Generally, ewe gives single lamb per birth with an occasional twinning. Seemanchali sheep are maintained by grazing from morning to

evening without providing concentrate or supplementary feed ingredients. Random breeding was undergoing in which every flock had 1-3 breedable rams in it. Scientific interventions in breeding, feeding and housing of Seemanchali sheep offer scope for improvement in the productivity *vis-à-vis* livelihood status of sheep farmers.

Fig. 18.5 Flock of Seemanchali sheep in breeding tract

Kosi Buffalo

These buffaloes are distributed in the Kosi basin covering the parts of Madhepura, Supaul, Araria, Purnea and Katihar districts of Bihar **(Fig. 18.6).** They are medium sized buffaloes with black coat colour. Forehead of these animals are marginally protruded with sickle shaped horns. Though the buffaloes are reared for milk purpose, the milk productivity of these animals are less with a range from 2 to 5 kg per day. More than 55% of Kosi buffaloes were stall fed whereas the rest were allowed for grazing at least 2-3 hours a day.

Fig. 18.6. Kosi buffalo in breeding tract

Network Project on Buffalo Improvement

The project is implemented in order to evaluate the genetic merit of Murrah bull based on the production performance of their daughters. A herd of Murrah buffaloes are maintained with the herd strength of 93 buffaloes in which 53 are breedable stocks **(Fig. 18.7)**. There are 2 teaser bulls for detection of heat in females. During the period from April to December 2019, 23 births were recorded with sex ratio of 0.77. The mortality rate was 2.15 % and causes of death were tumor in urinary bladder and lung infection. During this period, a total 25 animals have been inseminated and the conception rate was 44.80%.

The total lactation milk yield, standard lactation milk yield and the average peak yield of Murrah buffalo observed during the period were 2450.12±126.21 kg, 2015.18±110.12 kg and 12.88±0.50 kg, respectively. Lactation length, service period, dry period and intercalving interval were found to be 341.25±20.25 days, 130.56±10.01 days, 96.22±12.86 days and 437.47±24.18 days, respectively. Apart from regular feeding and mineral mixture supplementation, therapeutic and hormonal interventions were resorted to in order to bring the anoestrus buffaloes back to normal cycling.

Fig. 18.7. Murrah buffalo in paddock

Studies on Development of Early Pregnancy Diagnosis Method in Buffalo

To evaluate expression profile of chemokine genes CCL8 and CXCL10, in peripheral blood leukocytes (PBLs) during peri-implantation period in Murrah buffaloes, blood samples were collected on 12, 15, 18 and 21 days after artificial insemination (AI). The blood samples were used for RNA extraction. Total RNA was reverse transcribed into cDNA. Conventional PCR was used to check the synthesis of cDNA template in all the samples by amplification of endogenous control *GAPDH gene* **(Fig. 18.8).** Pregnancy status of animals was confirmed by ultra-sonographic examination and per rectal palpation. Estimation of transcriptional abundance of chemokines CCL8 and CXCL10 in peripheral blood leucocytes was estimated by relative quantification using Delta-Delta-Ct (ddCt) algorithm model from cDNA templates. Day 0 sample was taken as calibrator sample and *GAPDH gene* as endogenous control. The expression profile revealed that both these genes were upregulated in pregnant animals as compared to non-pregnant animals ($P < 0.05$) post 12 days of AI **(Fig. 18.9 and 18.10).** The results imply that these chemokines may have a role in maternal recognition in buffaloes and therefore may be used as a biomarker for early pregnancy detection in buffaloes.

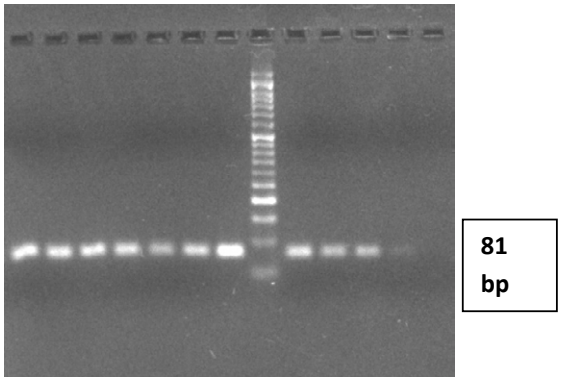


Fig. 18.8. Amplification of GAPDH gene by conventional PCR

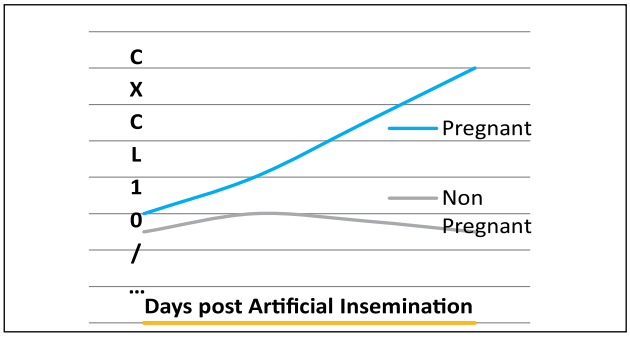


Fig. 18.9. Expression Profile of *CXCL10 gene*

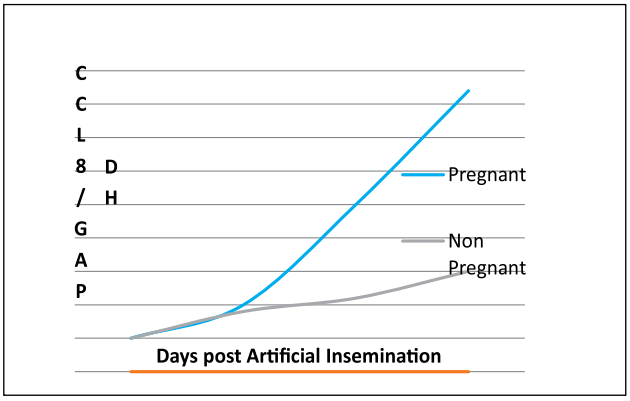


Fig. 18.10. Expression Profile of *CCL8 gene*

Meso-Level Animal Health Interventions and Evaluating Economic Losses from Animal Diseases

Animal health camps were organized in the village Babhanpura and Simra in Patna district **(Fig. 18.11**). Active disease screening was undertaken for diagnosis of mastitis, haemo-protozoan diseases including surra, babesiosis, theileriosis and anaplasmosis. More than 56 faecal samples were collected for parasitic examination and screened for endo parasites. Among these faecal samples, 85.71% were positive for endoparsites which were provided therapeutic dose of Fendendazole. In goats, no suspected cases of PPR was reported during the period from these area. A total of 47 animals were provided treatment of specific diseases diagnosed and prophylaxis against FMD, HS and BQ using combined vaccine provided to animals except those in advance stage of pregnancy.

Fig. 18.11. Animal health camp in a remote village

Impact assessment was done with 203 respondents in terms of increase in milk yield post intervention. It was found that average increase in milk yield was 0.59± 0.047 litres.

Molecular Epidemiology and Therapeutic Management of Bovine Theileriosis

During the reported period (April to December, 2019), more than 250 animals were evaluated for bovine theileriosis. The acute phase response was evaluated by measuring serum amyloid A (SAA) protein and tumor necrotic factor alpha (TNF α) in Theileria sp. negative animal and different grades of Theileria sp. infected animals. We observed significantly (P<0.05) higher levels of acute phase response of SAA in cattle with clinical theileriosis (41.28±14.97 mg/L) with high percentage of infected RBCs in Giemsa stained blood smear (GSBS) while non-significantly higher (12.58±7.09 mg/L) in non-symptomatic theileriosis with mild to traces infected RBCs in GSBS compared to health control cattle (6.78±1.22 mg/L) with GSBS and PCR negative results. It was also observed that TNF α was significantly higher (1.89±0.64) in clinical theileriosis and value was positively correlated with severity of parasitized red blood cells compared to health control cattle (0.31±0.12 mg/L). The findings is attributed to higher cytokine production (especially TNF-alpha) by stimulated parasitized macrophages and erythrocytes as a protective mechanism to control the parasitaemia. However, it also induces toxic lesions, leading to death. These acute phase responses might be responsible for inducing the major clinical symptoms of acute tropical theileriosis.

Further, we could develop molecular diagnosis of theileriosis using recombinant spm2 partial protein by cloning, expression and purification of spm2 of *T. annulata* **(Fig. 18.12)**.Western blot analysis of spm2 against theileriosis infected and uninfected cattle blood serum samples. Recombinant spm2 protein was detected using the sera collected from Theileria infected cattle and the detection was specific as serum samples obtained from uninfected bovine did not show any detection of spm2 protein. This suggested that spm2 can be used as a potential diagnostic antigen for tropical theileriosis.

Diagnostic ELISA was attempted based on this recombinant protein. Total 109 serum samples divided as per categories of positive, negative and doubtful. The true negatives based on negative microscopic GSBS examination and PCR amplification were used to calculate the cutoff value. The true positives were analyzed for percent sensitivity. The absorbance values obtained more than the cutoff for the doubtful serum samples were considered as ELISA positive. All absorbance values of the doubtful samples obtained below the cutoff were considered as ELISA negative. The cut-off of spm2 protein was calculated to be 0.2895755876 with 100% sensitivity and specificity at 450nm.

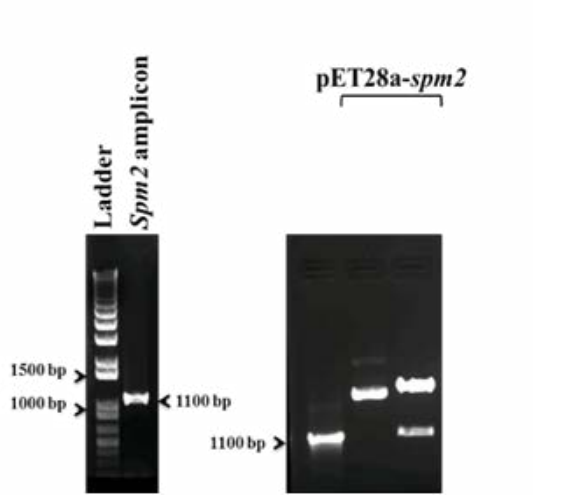


Fig. 18.12: Cloning of recombinant *spm2 partial gene* of *T. annulata*

Assessing Genetic Variability in Duck of Eastern States

Blood sample we collected from West Bengal (n= 25) and Odisha duck (n=25). Mitochondrial and genomic DNA was isolated. Primers were designed for amplification of growth hormone and prolactin gene. Using suitable pairs of primers designed on the basis of bovine and bubaline gene sequences, with optimized PCR programme and reaction conditions, 403bp fragment of prolactin gene comprising partial intron 4, exon 5 and partial 3' untranslated region (3'UTR) **(Fig. 18.13)** were amplified for all the birds used under study.

Restriction fragment length polymorphism (RFLP) were used for identification of allelic variants of amplified prolactin gene fragment. XbaI restriction enzyme is used for RE digestion of PCR product. RFLP revealed two genotypes AB with three distinct bands (403 bp, 250 bp and 153 bp) and BB with two distinct bands (250 bp and 153 bp) were observed in West Bengal and Odisha duck **(Fig. 18.14)**. Least squire analysis revealed

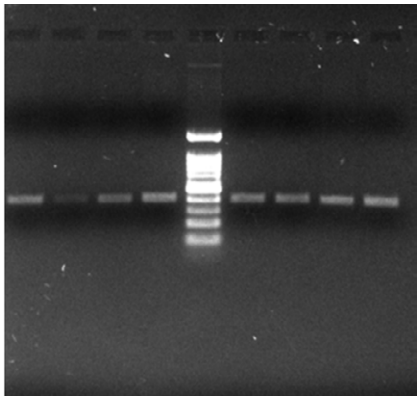


Fig. 18.13: PCR amplification of 403 bp

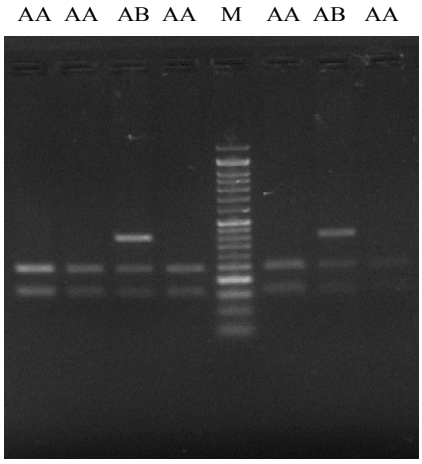


Fig. 18.14: RFLP pattern of Prolactin gene

that genotype has no significant effects on egg length, egg width, albumin height, yolk diameter and yolk height in West Bengal Duck. However, they have significant effect (P≤0.05) on egg weight, shell thickness, albumin weight and diameter and yolk weight **(Table 18.4**).

Table 18.4. Effect of genotype on egg quality traits in West Bengal duck

Trait	Genotype	
	AA	AB
Egg wt. (gm)*	58.42±4.34	60.19±3.55
Shell wt. (gm)*	6.37±0.68	5.91±0.84
Shell thickness (mm)*	0.55±0.09	0.48±0.01
Albumin wt. (gm)*	27.9±2.45	29.79±1.64
Albumin diameter (cm)*	7.56±0.58	7.11±0.78
Yolk wt. (gm)*	21.02±2.66	19.1±1.19

Least square analysis revealed that West Bengal duck having AB genotype had superior egg weight and egg quality. AB genotype had higher albumin weight but lower yolk weight than the duck having AA genotype. Therefore, *prolactin gene* can be used as marker for improving egg weight and egg quality traits in West Bengal duck.

Epidemiological Study of Respiratory Viral Diseases in Calves

The diseases affecting cattle and buffalo calves were recorded upto one year of age. A spectrum of pathological conditions were observed in calves. Out of 134 calves examined, 34 (25.37%) calves were affected with diarrhea, 22 (16.41%) calves showed respiratory disease symptoms, 17 (12.68%) with naval ill or joint ill, 2 with scabies (1.49%) and 26 with pyrexia of unknown origin (19.40%), 4 calves (2.98%) with coccidiosis 3 (2.23%) calves with urinary tract obstruction, 7(5.22%) calves with FMD lesions, helminthic parasites in 16 animals (11.94%) and three calves (2.23%) were affected with injury.

The nasal swabs and faecal samples collected from 85 calves showing respiratory distress and/or diarrhea as well as four necropsy lung samples were found negative by PCR for bovine paramyxoviruses and coronaviruses.

Outreach Programme on Zoonotic Diseases

Prevalence study of Brucellosis

Epidemiological study was conducted to know the current status of Brucellosis in Bihar. Serum and milk samples were collected to study the prevalence of Brucellosis in bovine and caprine species from nine districts in four agro-climatic zones of Bihar. In Bihar, 7.42% of bovine samples (n=377) was sero-positive by indirect ELISA test. The highest sero-positivity was found in agro-climatic zone III B where Brucella sero-positivity was 9.0 %. All the pooled milk samples (n=32) collected from urban areas in Patna district were found negative by milk ring test. In caprine, 4.58% samples (n=317) were found positive by Rose Bengal plate test.

Standardization of conventional PCR assay for detection of Brucella organisms

Genus and species specific reported primers were selected for identification of *Brucella abortus* organisms. Brucella cell surface protein (*BCSP31*)

gene as described by Baily *et al.* (1992) was selected for Genus specific detection of Brucella species and insertion sequence (*IS 711*) gene as described by Kartik *et al*. (2014) was selected for identification of *B. abortus* species.

Standardization of PCR assay for BCSP31 gene and IS711 gene

The PCR assay for *BCSP31 gene* was standardized using primers and method described by Baily *et al.* (1992) with slight modifications. A 223 bp product was obtained after amplification **(Fig. 18.15**).

Similarly, PCR assay for *IS711 gene* was standardized using primers and method described by Kartik *et al.* (2014) at annealing temperature of 59^{0}C. A product of 498 bp was obtained after amplification **(Fig. 18.16)**.

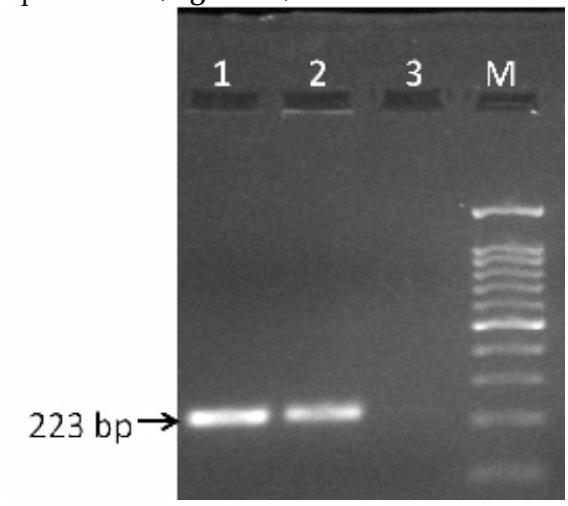


Fig. 18.15. Gel electrophoresis for PCR of BCSP31 gene: Lane 1 and 2: Positive controls, Lane 3: negative Control, M: 100bp marker

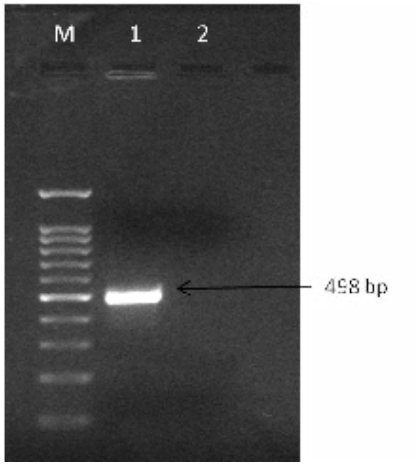


Fig. 18.16. Gel electrophoresis for PCR for IS711 gene of B abortus, Lane 1: Positive control, Lane 2: negative control, M: 100bp marker

B. abortus strain-19 was used as positive control and DNA from a field isolate of *Staphylococcus aureus* was used as negative control in both the protocols.

Assessment of Different Fodder Crop Rotation for Round the Year Production with Carrying Capacity and Soil nutrient Dynamics

Multi-cut sorghum-berseem crop rotation yielded 21.53, 31.44 and 21.68% higher dry biomass (DM), protein (CP) and gross energy (GE) than annual rye-sorghum rotation. The highest water productivity of 3.12±0.01 kg DM/m^3 was recorded in berseem-sorghum crop rotation followed by annual rye-sorghum rotation (2.83±0.02 kg DM/m^3). Nutritional water productivity (kg CP/m^3 or Mcal/m^3) was also the highest in berseem-sorghum crop rotation. Depletion of soil nitrogen was the highest in sorghum-berseem crop rotation; however, depletion of phosphorus was the highest in maize-annual rye crop rotation (**Fig. 18.17**). Potash depletion was almost similar in all the crop rotations in both crop sequences. Berseem-sorghum crop rotation showed the organic carbon level below the critical value (0.5%). Preceding crop had impact on soil fertility and productivity of succeeding crop. So, it may be recommended that multi-cut varieties of sorghum and berseem may be rotated for round the year fodder production which can sustain 15-16 adult cattle per ha considering the feeding of 20 kg green fodder per head per day.

Fig. 18.17. Growth of maize in experimental plot

Effect of feeding interval on growth performance of crossbred (T x D) pigs

An experiment on feeding interval was conducted with 24 crossbred (T x D) pigs comprising 12 female and 12 male divided into 4 equal groups of 90 days age with average body weight 31.22 kg were assigned four treatments (**Table 18.5**). Equal amount of feed with different frequency per day was offered @ 2.00 kg/pig/day on dry matter basis to different groups. During 60 days trial it was observed that all the groups differed in body weight gain. The maximum weight gain was observed in control group T1 fed twice a day followed by T2, T3 and T4. Same trend was followed in average daily weight gain (**Fig. 18.18**). The maximum weight loss with increasing level of feeding interval may be due to maximum non availability of feed for metabolic activity in the body during feeding time.

Table 18.5. Effect of feeding interval on growth performance of crossbred (T x D) pigs

Parameters	T_1 (2 times/ day)	T_2 (1 times/ day)	T_3 (3 times/ day)	T_4 (4 times/ day)
Initial body weight (kg)	31.0 ± 0.21	31.4 ± 0.23	31.3 ± 0.19	31.1 ± 0.16
Final body weight (kg)	63.3 ± 0.30	63.8 ± 0.23	63.5 ± 0.34	61.0 ± 0.23
Average daily gain (kg)	0.54 ± 0.21	0.53 ± 0.19	0.52 ± 0.12	0.50 ± 0.21
Total body weight gain (kg)	31.7± 0.44	32.2 ± 0.59	30.7 ± 0.73	30.0 ± 0.56

Fig. 18.18. Experimental T x D pigs at Ranchi

FISHERIES

Optimization of Production Efficiency in Livestock–Fish Integrated Farming System

The main objective of integrated fish farming is to recycle by-products generated from livestock unit (faeces, urine and spoiled feeds) as inputs to fish culture in the form of fertilizer, feed etc. in order to achieve higher productivity and to reduce the cost of production.

The study was carried out during 2018-19 in eight identical fish ponds (800 m^2). Six integrations were attempted *viz.* cattle- fish, buffalo–fish, goat-fish, duck–fish, poultry–fish and pig-fish along with artificial feed (commercial culture) and a control (without application of feed and manure). All the ponds were applied with livestock manure on daily basis. Out of 10 month culture period, highest production was achieved in cattle-fish integration followed by buffalo-fish and pig-fish integration (**Fig.18.19**) whereas highest survivability was observed in pig-fish (76%) followed by duck-fish (74.91%) and poultry-fish (74.5%). Supplementary feed-based control showed marginally higher production of 5.9 t/ha.

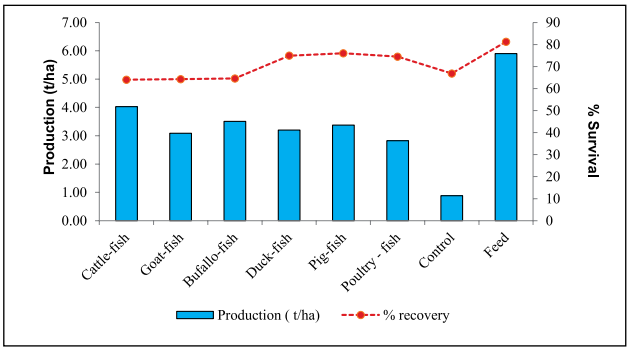


Fig. 18.19. Fish production under different integrated farming system

Soil and water quality parameters and primary productivity from different integrated fish farming system

Soil and water quality parameters play important role in enhancing productivity of a fish pond. Nitrogen (N), phosphorous (P), potassium (K) and pH concentration of soil in different integrations were estimated (**Fig. 18.20**). Average N content of soil varied between 103.6-225.87 mg/kg, P content ranged between 8.9-46.23 mg/kg and K between 68-232.53 mg/kg of soil in all integrations while

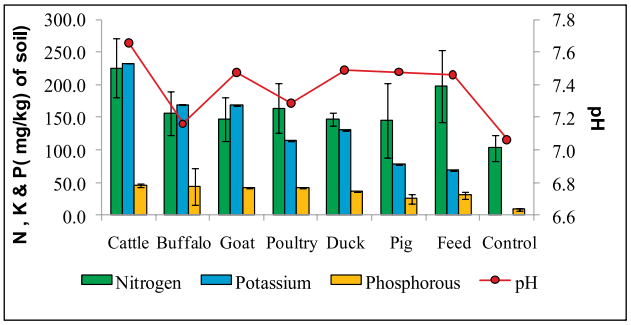


Fig. 18.20. N, P, K and pH concentration in soil of different integrations

pH of pond soil varied from 7.06-7.66 in all the integrations.

Primary production can be an indicator, used to evaluate the effect of different fertilizer treatments on organic production. Gross primary productivity (GPP) was recorded highest in fish-pig integration (0.18g C/m^3/h) followed by cattle-fish integration (0.17g C/m^3/h). However, Net primary productivity (NPP) was almost similar in duck-fish, cattle-fish and pig- fish integrations (0.07 g C/m^3/h), while the respiratory quotient was higher in buffalo-fish integration (0.12 g C/m^3/h) (**Fig. 18.21**). Overall condition were more promising in cattle-fish and pig-fish integration compared to other integrations. The most abundant and frequently recorded planktonic organisms were Chlorophytes, Cladocerans, Rotifers, Copepods, Diatoms, Blue-Green algae, and Euglenoids etc. (**Fig. 18.22**). Abundance of zooplankton is associated with the application of organic manure.

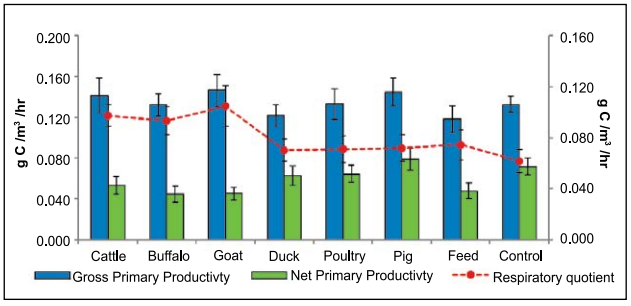


Fig. 18.21. Primary productivity (GPP, NPP and RQ) from different integrated fish farming system

Water quality parameters in different fish livestock based integrated farming systems are depicted as **Fig. 18.23, 18.24** and **18.25**. Water quality parameters was recorded. The ammonia nitrogen was in the range of 0.004-0.017 ppm, nitrite 0.014-0.029 ppm and phosphate 0.23-0.45 ppm in all integrations. Other water quality parameters like pH, dissolved oxygen (DO), temperature, total alkalinity and hardness were estimated within the acceptable limit in all the integrations.

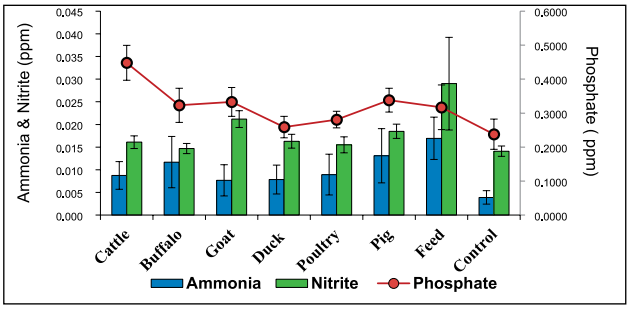


Fig. 18.23. Average ammonia, phosphate and nitrite from different integrated fish farming system during September 2018 - June 2019

Alkalinity and hardness were also recorded within the acceptable limits in all the ponds (**Fig. 18.24**). The temperature and pH of pond water ranged between 24.4-25.3°C and 7.40-7.82 ppm (**Fig. 18.25**) and no abrupt changes in pH have been recorded. Dissolved oxygen (DO) was maintained between 5.84 - 7.08 ppm, which is ideal for survival and growth of fish. Based on these findings, it can be concluded that livestock-based integration did not show any deterioration in water quality parameters.

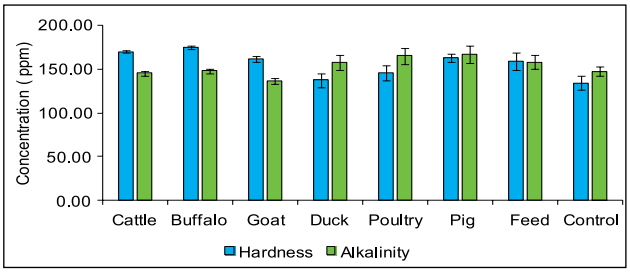


Fig. 18.24. Alkalinity and hardness level (ppm) in different livestock-fish based integrated farming systems during September 2018 - June 2019

Fig. 18.22. Different zooplankton species identified during sampling

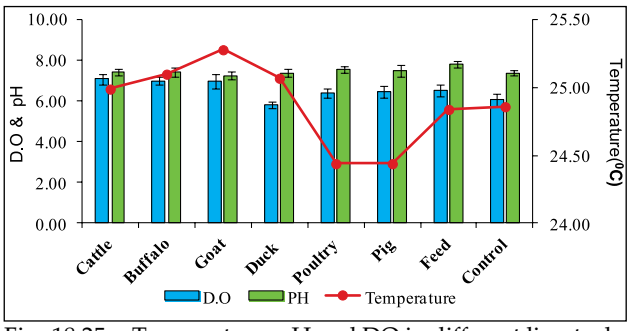


Fig. 18.25. Temperature, pH and DO in different livestock-fish based integrated farming systems during September 2018 - June 2019

Formulation of Mineral Mixture for Indian Major Carp (IMC) based on Soil-Water and Fish Continuum

To understand the mineral composition in IMC, samples (fish, water and soil) were collected from water bodies of Patna, East Champaran, Supaul, Madhubani, Darbhanga, Samastipur, Rohtas, Muzaffarpur and Sitamarhi districts of Bihar. The macro and micro mineral concentration of Catla, Rohu and Mrigal are illustrated in **Table 18.6**.

Comparative Study on Growth Performance of Naturally and Artificially Bred *Clarias batrachus*

Among the indigenous catfishes, *Clarias batrachus* (L.), commonly known as 'magur', is one of the commercially important species in India. The major constraint for wide spread aquaculture of this species is non availability of quality seed both from hatcheries and natural resources. In the present study, commercially available hormone Wova-FH® was used as inducing agent for breeding purpose. Specimens of same weight and length were used for artificial and natural breeding experiment. In artificial breeding, after the hormonal injection male specimens were sacrificed and testis tissue suspension was prepared and used for fertilization with eggs from already induced female. In case of normal breeding, 6 pairs of male and female were injected and released in the already prepared small earthen pond of about 1.2 m depth surrounded by paddy field. Both the breeding experiment were conducted during rainy days. In the artificial breeding system, sampling was done at 30, 60, 90 and 120 days and average weight gain was recorded as 0.09±0.003, 4.63±0.11 and 26.09±1.44 g, respectively (**Fig. 18.26**). For feeding of magur larvae, egg custard was provided, which was followed by finely powered supplementary feeding (33-42% protein level). In case of natural breeding system, 90 days fingerlings were collected from the paddy field and surrounding areas by hand pick. It was found that in artificial breeding, average weight was 12.7±0.37 g while in natural condition

Table 18.6. Variations in the mineral concentrations in different organs of Indian major carps from different districts of Bihar

Species	Mineral concentration (mg/100g)								
	Organ	Ca	Mg	P	I_2	Fe	Mn	Zn	Cu
Rohu	Bone	90.43±17.88	345.04±11.27	4.39±0.42	37.74±2.6	6.53±0.68	1.34±0.25	5.54±0.27	3.22±0.49
	Gill	49.97±2.34	356.54±17.54	4.53.54±0.36	34.95±1.59	23.48±1.83	1.24±0.14	14.85±1.58	1.14±0.18
	Liver	85.23±10.01	478.81±20.95	12.26±0.61	48.95±3.63	122.38±8.12	10.53±1.11	10.67±1.67	6.69±0.64
	Muscle	43.19±2.68	287.43±6.06	3.41±0.5	32.12±0.69	4.87±0.20	1.83±0.33	1.57±0.29	1.76±0.25
	Blood	55.11±6.51	52.30±4.72	0.32±0.045	4.08±0.32	1.31±0.19	0.3±0.03	0.24±0.04	0.32±0.04
Catla	Bone	308.66±19.02	332.06±18.11	5.48±0.61	36.04±1.06	10.66±1.07	1.88±0.17	3.49±0.33	0.71±0.04
	Gill	67.30±7.49	433.38±20.17	4.13±0.205	37.18±1.47	15.45±1.32	1.14±0.13	13.53±1.17	0.9±0.08
	Liver	435.23±23.14	504.78±57.29	7.22±1.39	50.48±4.47	58.43±3.06	1.37±0.11	15.59±2.20	5.47±0.68
	Muscle	239.56±14.01	381.55±18.19	4.15±0.44	37.88±2.21	16.16±1.28	1.01±0.16	2.77±0.42	0.81±0.23
	Blood	53.19±3.82	54.34±4.49	0.41±0.04	3.06±0.30	1.33±0.17	0.24±0.03	0.26±0.03	0.4±0.05
Mrigal	Bone	62.65±4.31	351.25±19.58	3.84±0.44	36.81±1.85	3.49±0.33	1.37±0.14	4.62±0.34	3.48±0.35
	Gill	56.98±6.4	467.52±10.87	5.15±0.23	46.88±2.66	26.68±1.68	1.93±0.27	5.67±0.24	8.33±0.57
	Liver	167.48±8.41	453.66±22.96	6.15±0.93	39.90±3.38	167.54±7.28	5.38±0.78	11.65±0.60	11.59±1.05
	Muscle	55.79±4.63	299.05±17.41	3.65±0.31	30.50±1.01	7.92±0.80	1.68±0.25	1.26±0.14	3.15±0.42
	Blood	60.30±5.4	62.23±5.2	0.32±0.04	3.91±0.46	1.63±0.18	0.28±0.03	0.22±0.02	0.39±0.03

average weight of fish was 10.6 ±0.89 g (**Fig. 18.27**). Higher weight gain in artificial breeding system may be due to better care in the hatchery system.

Fig. 18.26. *Clarias batrachus* fingerlings

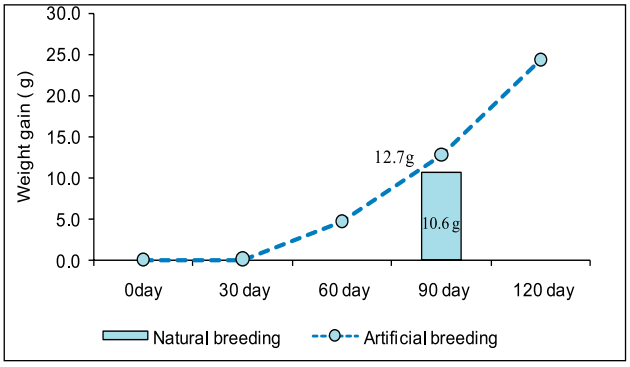


Fig. 18.27. Performance of Clarias batrachus under natural and artificial breeding system

Studies on Effect of Supplementary Feeding on Growth of Minor Carp, *Labeo gonius*

Minor carp species can be considered as alternative to the cultivable major carp species for diversification in freshwater aquaculture. *Labeo gonius* is a medium carp of Cyprinidae family, commonly known as 'Kuria labeo' or 'Gonius'. It is distributed in Assam, West Bengal, Odisha, Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh and Punjab in the major freshwater rivers, reservoirs, lakes, jheels and tanks. The study was initiated to find out the growth performance of fry under supplementary feed (SF) and traditional feed (TF). Four types of feeding were used: SF with 5% and 10% body weight and TF with 5% and 10 % body weight. The fry (seed) of *L. gonius* (18-20mm) were brought from ICAR NEH, Barapani. All the seeds were stocked in cemented tank @ 300 numbers in each tank. At the time of stocking average length and wet body weight of fish was recorded at 0.067±0.005g and 19.11±0.37 mm, respectively (**Fig. 18.28**). Regular sampling was done and growth achieved till 100 days is illustrated in the **Fig. 18.29 & 18.30**. It was found that pelleted feed with 38% protein level and feeding at 10% body weight showed better growth compared to other feeding regime.

Fig. 18.28. *Labeo gonius* seed before release to the experimental ponds

Fig. 18.29. *Labeo gonius* after 100 days rearing

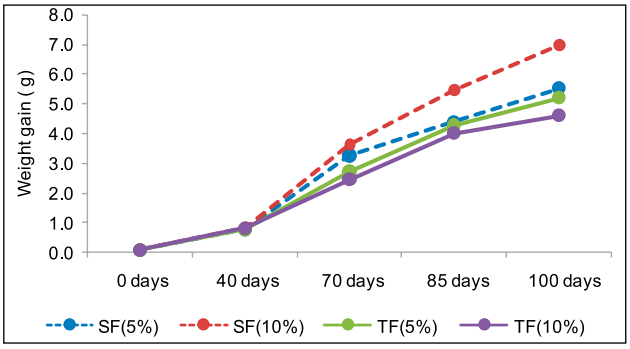


Fig. 18.30. Growth performance of *Labeo gonius* under different feeding regime

Assessment of Fish Diversity and Production Potential in Lentic Inland Ecosystems of North Bihar

Fish Diversity Museum at Research Centre for Makhana (RCM), Darbhanga

The purpose of the creation of Fish diversity museum at RCM, Darbhanga is to collect, preserve, catalogue and to display the species mainly found in the freshwater environments of North Bihar. The Museum of the center offers a glimpse of the biodiversity of North Bihar fishes collected from the chaur, maun and rivers (**Fig. 18.31**). The collections have been arranged systematically for a better understanding of the fisheries resources and their management for human benefit. So far, 35 fish species have been collected and archived in the museum (**Table 18.7**).

Fig. 18.31. Fish diversity museum at RCM, Darbhanga

Table 18.7. Numbers of fish species and their families

Family	No. of fish species
Cyprinidae	15
Anabantidae	1
Sisoridae	1
Channidae	4
Ambassidae	4
Claridae	1
Gobiidae	1
Bagridae	2
Mastacembelidae	3
Notopteridae	1
Belonidae	1
Siluriformes	1

Production potential in lentic inland ecosystems

The productivity of the wetland ecosystem can be increased and sustained through the introduction of diverse fish species and commercial aquatic crops. The study on production potential of pond ecosystem under controlled condition was intiated at the RCM, Darbhanga. The two aquatic commercial crops namely water chestnut (*Trapa natans* L. var. *bispinosa*) and makhana (*Euryale ferox* Salisb.) are commonly found in the natural water bodies of north Bihar. The seedlings of these crops were transferred in the month of May from the nursery to the ponds and subsequently were transplanted at a spacing of 1m x 1m and maintained a distance of 2 m away from the embankment of the ponds as per the 'Peripheral Vacant Space' design of makhana cum fish culture.

The fishes were introduced in the makhana and water chestnut growing ponds during the period between their vegetative growths and flowering stages, respectively (**Fig. 18.32**). During the selection of fishes, due care was taken to ensure the exclusion of macro-vegetation feeder and surface feeder fishes. Thus, only *rohu* (*Labeo rohita*) and *mrigal/naini* (*Cirrhinus mrigala*) were introduced in the first year of the experiment. Fingerlings were released in the month of September, at an average size of 46–77 mm, weight 2–6 g at a density of 1 fingerling/m^2 in the pond system. The average growth rate of fish recorded in makhana and water chestnut cum fish ponds was found higher compared to sole fish pond culture system.

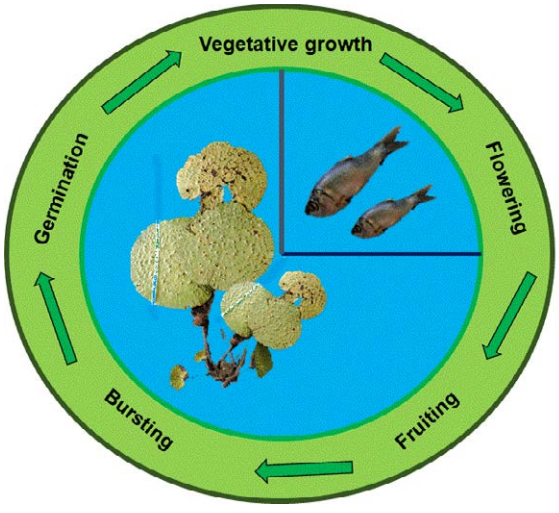


Fig. 18.32. Suitable stage of makhana crop life cycle to introduce of fish fingerling

19. Transfer of Technology

Livelihood Improvement through Technology Demonstration on Integrated Farming System and Mushroom Cultivation in Eastern Hills and Plateau Region

Under the DBT Biotech-KISAN Project, the activities have been initiated in three villages (Sarwal, Koiribeda and Hahap villages of Khijri Block) of Ranchi district and one village (Govindpur village of Mandu block) of Ramgarh district during 2019. Rainfed rice- fallow is the major cropping system under low land and medium land conditions whereas uplands in the homestead are used for raising vegetables. Among the animal component, goatry and backyard poultry are major sources of income whereas cattle are mainly used for draft and cow dung. In the first year of the project, three numbers of exposure visits were undertaken in which a total of 103 numbers of farmers visited the experimental farm of ICAR RCER FSRCHPR, Ranchi. Two numbers of animal health camps were organized in which a total of 246 numbers of animals were treated for control of endo and ecto parasite and location specific mineral mixture was provided to 110 numbers of farmers. Three numbers of training programmes of one day duration were conducted in which a total of 100 numbers of farm women were provided training on mushroom cultivation and technology demonstration on oyster mushroom (Fig 19.1). For improving the income from vegetable cultivation, technology demonstration on improved varieties of vegetables *viz.* cabbage, cauliflower, bitter gourd, French bean, onion, tomato, brinjal, amaranthus, potato has been conducted on 160 farmers' fields covering a total area of 2.42 ha. For effective management of rice-fallow, technology demonstration on wheat and chickpea cultivation has been done on 50 farmers' fields.

Transfer and adoption of improved agricultural technologies

In order to suggest the most appropriate method of transfer of technology, studies were initiated on generating information on the present level of technology adoption and technology transfer mechanisms in selected areas of Bihar and Jharkhand. Data were collected from 102 farmers of Araria, Madhepura, Purnea, Supaul and Saharsa districts of Bihar through interview schedule. Majority of the farmers (74%) were small and marginal.

Adoption of improved variety was the highest (96%) in maize due to hybrids. In wheat, only 43 percent farmers use recommended or improved varieties (**Table 19.1**). Most of the farmers keep indigenous breeds of cattle (82%) and buffalos (83%). Financial problem and lack of awareness about the technologies are the major constraints in adoption of improved technologies by the farmers. Fifty six percent farmers use either vermicompost or compost or both organic sources for their crops.

Growth and instability in production of principal crops in Eastern India

To study the growth and instability in production of principal food grain crops in Eastern India, more than thirty years secondary data since

Fig. 19.1. Capacity building of farmers' through training and demonstration of Mushroom cultivation

Table 19.1. Adoption of improved crop varieties

Crops	Improved Variety	Adoption of improved / recommended varieties (%)
Rice	Shankar Dhan, Rajendra mansuri,, Rajendra Sweta, Pioneer hybrid	81
Wheat	PBW 343, HD 2967, Rajeswari, Shree Ram 402	43
Maize	Pioneer, Shaktiman, Syngenta hybrids	96
Moong	Pusa Vishal, SML 668	75
Sarson	Rajendra Sarson, Swarna	90
Rai / Mustard	Pusa Bold	90

1981 on area, production and yield of major crops were collected and analyzed. During 2019, the data for Assam and West Bengal were collected and analysed. Results showed a declining trend in area under rice in both the states. In Assam, rice was grown on about 22 lakh hectares in 1981 and increased to about 25 lakh hectares. However, there was a marginal decline in rice area during the last five years. Despite decline in rice area, the production increased by about one per cent annually during 2010-16. It was possible due to increase in rice productivity by 1.54 per cent. However, Assam seems to have achieved stability in rice production because instability ranged from 5.32% to 10.92% during period under investigation.

Area under maize was around 20 thousands hectares during TE 1981 to TE 2011 but it increased to 29 thousands hectares at TE 2016. Maize production during the period was increased by 6 folds. Pulses and oilseeds were not important crops in Assam in seventies and eighties but these two crops observed increasing trend with some see-saw behavior of growth in area and production. Productivity of pulses and oilseeds increased by more than 50% during 1981-2016.Cropping intensity also increased from 125 to 144 during the study period. In West Bengal, rice is the most important crop cultivated on an area of 50.97 lakh hectares in 1981. The area increased to 58.85 lakh hectares at TE 2001, but declined to 54.65 lakh hectares at TE 2016. However, the rice production observed a continuous increasing trend during 1981-2016 due to increase in its productivity from 1254 kg/ha in 1981 to 2801 kg/ha in 2016.

Wheat was grown on less than 5% GCA in West Bengal but per hectare productivity observed increasing trend from 1670 kg at TE 1981 to 2771 kg at TE 2016. Maize area increased by more than three folds during 1981-2016 and its production increased by more than 10 folds. Per hectare productivity of maize increased by more than 4 times from 1129 kg to 4457 kg during 1981-2016. It shows huge potential of West Bengal in maize production. Area and production of pulses are declining in the state; however oilseeds are getting ground in West Bengal with continuous increase in its area. Oilseeds are now grown on about 9 lakh hectares area, next to rice. Its production has increased by more than 6 folds and productivity by more than two times during the period under study. Jute area observed declining trend but area under vegetables is increasing in most of the districts of West Bengal.

Production and Value Chain Analysis of Makhana

Survey of makhana wholesalers and retailers was done in Marufganj mandi in Patna district of Bihar, Kharibowli in New Delhi and Nayaganj mandi in Kanpur The price of fresh popped makhana was found to be lower in both local as well as national markets which hovered around Rs 350-400 per kg. Several brands of makhana *viz.*, Radhe Govind Makhana, Murli Makhana, Hare Krishna, Raj Hansh, Ram Bhog, P.K. Gold, Raja Sahab, Maharaja, Shyam Rasgulla, Chhapan Bhog, etc., were available in the market with a pack of 100 g and 250 g. Most of the brands lacked MRP on the pack due to varying price of lava around the year. It was also observed that moisture is the biggest enemy of makhana and if stored at moist godown, its quality goes down drastically. Several wholesalers reported that they had to sell their stock at lower price before start of fresh harvest because popped lava quality gets deteriorated after one year storage.

Value Addition by Size Grading

Popped makhana prepared by the processors is a mix lot having different sizes of *lava*. Normally, processors are not involved in any grading based on size and they sell mix *lava* to wholesalers. Most of the wholesalers do size grading of *lava* either by manual labours or through use of makhana graders. Handpicked larger size of *lava* having diameter 18-20 mm is exported to different

Fig. 19.2. Different brands of makhana

countries by the large wholesalers. *Lava* having size of <10 mm are the lowest quality called *Thurri*, and 10-11 mm are called *Murra*. *Thurri* are priced at Rs 40-50 per kg while *Murra* had a price range of 100-120 per kg in local market. *Lava* having size of 11-13 mm are called *Olhua* or L-1 which can be called makhana *lava*. Many companies grade their product into Classic, Gold and Platinum category based on increasing size. A comparison of different grades of popped makhana and its price is worked out based on information collected from primary and secondary sources (Fig. 19.3).

Grades	Prices (Rs/kg)
Thurri	40-50
Murra	100-110
Olua (L1, NATURAL)	550
L 2 (CLASSIC)	775
L 3 (GOLD)	860
L 4 (PLATINUM)	940

Fig. 19.3. Comparing different grades of popped makhana with respective price

Mapping of value chain actors

In a makhana value chain, a large number of actors are involved at various stages from production of makhana seed/gudi to its processing, distribution and marketing. Mapping of actors involved in value chain at each stage from input service to production, processing and marketing was studied along with their role (**Fig. 19.4**). At input stage fisheries cooperative societies, research institutes, fertilizer and pesticide companies play major role. Producers of makhana have limited role to play only till production of seed. Harvesting of seed is done by another group of expert *mallah* labours. Processing is done by third group who are specially skilled for processing of seed into popped *lava*. Processors sell popped makhana mostly to large wholesalers at local market directly or through commission agents. Some retailers directly purchase *lava* from processors and sell it to consumers. Most of the wholesalers stock popped makhana and send it to distant wholesalers located at major mandi at Delhi, Kanpur, Gwalior, Varanasi, Lucknow, Allahabad, Amritsar etc. From various market across the country, makhana is sold to final consumers through retailers. A large portion of makhana is also exported to foreign countries through sea routes from Mumbai and Gujarat. Very less quantity of makhana is sold through super-market in the form of value added products where companies like Shakti Sudha, Mr. Makhana etc.

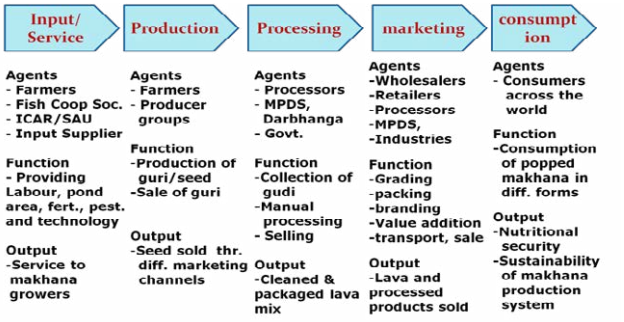


Fig. 19.4. Mapping of value chain actors of makhana

Status of Food and Nutritional Security of Farm Households in Eastern India

Total 105 households from Purnea and Katihar Districts of Bihar, and Ramgarh of Jharkhand were surveyed. Household dietary diversity was measured by using Simpson Index. It was found that the cereal contributes maximum (~39-45%) source of energy for all income groups, followed by the vegetables (~15-27%) and milk products (~7-23%) in diet. Simpson's Index for Dietary Diversity (SIDD) score was the highest in higher income group (0.76), followed by middle income (0.69) and lower income groups (0.66) (**Fig. 19.5**).

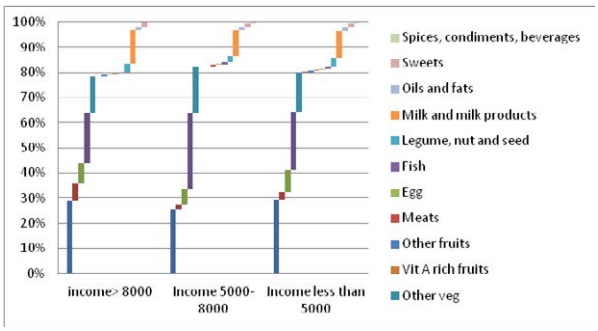


Fig. 19.5. Dietary diversity of different income groups

Enhancing Food, Nutritional and Livelihood Security of Marginal and Small Farmers in Jharkhand through Need Based Agricultural Technologies

Under the Farmer FIRST Project four villages situated in the peri-urban areas of Ranchi city (at distance of 10 to 12 km from Ranchi city) have been selected. Principal component analysis of data on land holding pattern and contribution of income from different components of farming system from the sampled farm households indicated five different farmer typologies in the project villages *viz.*, Group 1. Marginal farmers and landless labourers (25.6%), Group 2. Cereal dominated small farmers (19.8%), Group 2.1. Cereal based medium farmers (5.8%), Group 3. Integrated farming system based small farmers (10.5%), Group 4. Livestock based marginal farmers (14.0%) (Table 19.2). The average gross annual income of the farmers range between Rs 0.80 lakh (marginal farmers and landless labourers) to Rs 1.82 lakh (IFS based small farmers). Among the different sources of income, the contribution of agricultural, non-agricultural and animal husbandry and fishery was recorded to be the highest in case of IFS based small farmers (78.4%), marginal farmers and landless labourers (70.8%), and livestock based marginal farmers (35.5%).

During the year 2019, technological demonstrations were undertaken in a total area of 107.8 ha involving 186 number of farm families. The details of major technologies demonstrated and their performances are mentioned in **Table 19.3**.

• Demonstration of black-gram variety PU 31 in Rainfed uplands

• Cultivation of bottle gourd variety Swarna Sneha in rice-fallow

• Demonstration of drip irrigation of vegetables

Table 19.2. Land holding pattern, gross annual income and % contribution from different sources of income of farmers belonging to different typologies

Farmer group	Land holding pattern (Acres)				Gross annual income (Rs. in lakh)	% Contribution of different sources of income		
	Up land	Low land	Total area	Total area under cereals		Agricultural income	Non-agricultural income	Animal and fishery
Group 1: Marginal farmers and landless labourers	0.30	0.50	1.35	0.94	0.80	29.18	70.82	8.61
Group 2: Cereal dominated small farmers	0.50	1.00	2.50	2.00	1.22	62.34	37.66	11.78
Group 2.1: Cereal based medium farmers	1.04	2.70	5.08	4.22	1.46	79.43	20.57	8.82
Group 3: IFS based small farmers	1.00	1.00	3.00	2.00	1.82	78.43	21.57	27.74
Group 4: Livestock based marginal farmers	0.50	0.15	1.13	0.62	1.12	61.59	38.41	35.47

Table 19.3. Performance of major technologies demonstrated in farmers' fields

Technology	Number of farmers	Area (40 m^2)	Production (tonnes)	Consumed by farmers (tonnes)	Income from sale of produce (Rs in lakh)
Direct seeded rice	8	800	4.8	0	0.76
Short duration rice variety Sahabhagi for rice-fallow management	150	24000	81.0	60	3.36
Crop diversification in rainfed uplands through blackgram variety PU 31	120	300	2.4	1.2	0.60
Crop diversification in rainfed uplands through ragi variety Birsa Ragi (A 404)	5	5	0.125	0.125	0
Crop diversification in rainfed uplands through sesamum variety Birsa Til 1	5	5	0.020	0.02	0
Rainy season cultivation of tomato variety Swarna Sampada and brinjal variety Swarna Pratibha	120	210	11.6	3.9	1.67
Cultivation of leguminous vegetables (French bean varieties HAFB 4 and HAPB 2, cow pea varieties Swarna Mukut, Swarna Shweta)	120	305	3.40	0.85	0.72
Cultivation of wheat variety HD 2967 in rice-fallow	20	200	1.60	1.60	0
Cultivation of chickpea variety Pusa 0547 in rice-fallow	16	120	0.70	0.70	0
Cultivation of cucurbits like bottle gourd (Swarna Sneha), bitter gourd (Swarna Yamini), sponge gourd (Swarna Prabha), cucumber (Swarna Sheetal), water melon (Arka Manik) in rice-fallow	75	145	4.8	1.60	0.62

National Agricultural Innovation Fund (NAIF)

Plant variety Registration

- Acknowledgement received for approval of Swarna Safal (Faba bean) registration from PPV&FRA, New Delhi: REG/2018/597.
- Acknowledgement received for approval of application for registration of Plant variety under PPV&FRA, New Delhi for Swarna Ratan (Tomato): REG/2019/131, Swarna Praphulya (chilli): REG/2019/132, Swarna Tejaswi (chilli): REG/2019/129, Swarna Atulya (capsicum): REG/2019/133, Swarna Sneha (bottle gourd) REG/2019/134, Swarna Yamini (bitter gourd): REG/2019/130 and Swarna Sawani (ridge gourd): REG/2019/135.
- Annual maintenance of 14 plant varieties under PPV&FRA
- Under Farmers' variety alternate denomination: Lal Gulaab was renamed as Suphal Neelanchal (Bacterial wilt resistant germplasm of brinjal) for registration under PPV&FRA; REG/2017/1897

'SWARNA' trademark

- Accepted for registration under provisions of section 20(1) of Trade Marks Act, 1999.

Material Transfer Agreement (MTA)

- One MTA signed with Ms Kumar Sarika, Assistant Professor, Lovely Professional University, Punjab for tomato germplasm on 15.01.2019
- One MTA signed with Dr (Mrs) G. Sangeeta, Principal Scientist, ICAR-IIHR, CHES, Bhubaneswar for pointed gourd germplasm on 16.09.2019

Linkages

Besides having linkages with leading ICAR institutions, SAUs and State Govt. of various eastern states, the details of other linkages is mentioned below:

International Collaborations

Research areas	Collaborating institutes
Conservation Agriculture	CIMMYT
Climate resilient cropping systems	CIMMYT
Improving water use for dry season agriculture	CIMMYT
Sustainable and resilient farming system intensification for EIGP	CIMMYT
Development of submergence tolerance rice varieties for flood plain and flood prone areas of eastern region	IRRI
Development of drought tolerance rice varieties for eastern region	IRRI
Restoration of degraded lands, water congested areas and carbon sequestration	World Agroforestry Centre
Developing suitable pulse varieties of lentil, grass pea and pigeonpea for drought tolerance in eastern states	ICARDA
Small ruminants improvement and production system	ILRI

Other Collaborations

Research areas	Collaborating Institutes/ Regional Centres
Integrated Farming System	IVRI RC, Kolkata; CSWCRTI, Koraput; IARI RS, Pusa (Bihar); CIFRI; CPRS RS, Patna, IIFSR, Modipuram and NBSS&LUP
Tribal Farming System	CSWCRTI, Koraput, Odisha, and NBSS&LUP
Quality brood management, fish seed, enclosure culture and wetland rehabilitation	CIFA; CIFRI; CRRI; NRC (Pig); AAU and CTCRI
Livestock & Avian Production System	IVRI; NRC (Pig); NDRI; AAU; UBKV; BAU (Bihar); BAU (Ranchi) and CARI
Seed production of agri-horti crops including production technology	DSR, Mau; IARI RS, Pusa; BISA (CIMMYT) Pusa; CRRI; BAU (Bihar & Ranchi); RAU, Pusa; IIVR; CTCRI; CHES; NRC, Litchi; CSISA; DMR; CPRS-RS, Patna & UBKV.

20. Trainings and Capacity Building

Following employees of the Institute have undergone training during 2019

Table 20.1. List of employees undergone training

Category	Total No. of employees	No. of trainings planned for each category during 2019-20 as per ATP	Total No. of employees undergone training during April to December 2019	% realization of trainings planned during 2019-20
Scientist	66	30	6	20.00
Technical	67	12	2	16.67
Administrative & Finance	25	7	1	14.29
SSS	50	0	0	0
Total	208	49	9	18.37

Feedback of trainees were collected, consolidated and sent to ICAR, New Delhi.

HRD fund allocation and utilization (Rs. in Lakh)

BE 2019-20 for HRD	Actual expenditure up to December, 2019	% Utilization
10.00	3.88	38.80

Sponsored training programmes

- Training programme on '**Land and water management, climate change and its impact on agriculture**', sponsored by ATMA, Araria at ICAR-RCER, Patna during 4-8 February, 2019.
- Training programmes on '**Recent advances in goat production and management**', sponsored by Koshi Basin Development Project, Govt. of Bihar organized at ICAR-RCER, Patna during 13-5, 19-21 and 25-27 June, 2019.
- Training Programme for **'Undergraduate agriculture students'**, sponsored Jharkhand Rai University, Ranchi organized at ICAR-RCER, FSRCHPR, Ranchi during 22 June to 3 July, 2019.
- Training programme on '**Selection and operation of farm implements for improving crop productivity**', sponsored under CRP on FM & PF project organized at KVK, Buxar during 4-6 July, 2019.
- Training programme on '**Scientific cultivation of Papaya**', sponsored by AICRP fruits organized at ICAR-RCER, FSRCHPR, Ranchi on 25 July, 2019.
- Training programme on '**Recent Advances in integrated fish farming**', sponsored by Dept of Fisheries, Banka, Govt. of Bihar organized at ICAR-RCER, Patna during 2-6 August, 2019.
- Training programme on '**Selection and operation of farm implements for improving crop productivity**', sponsored under CRP on FM & PF project organized at KVK, Ramgarh during 5-7 August, 2019.
- Training programme on '**Selection and operation of farm implements for improving crop productivity**', sponsored under CRP on FM & PF project organized at ICAR-RCER, Patna during 21-23 August, 2019.
- Training programme on '**Popularization of women friendly farm tools and equipment**', sponsored under CRP on FM & PF project organized at ICAR-RCER, FSRCHPR, Ranchi during 30-31 August, 2019.
- Training programme on '**Recent Advances in integrated fish farming**', sponsored by Dept of Fisheries, Lakhisarai, Govt. of Bihar organized at ICAR-RCER, Patna from 3-7 September, 2019.
- Training on **'Recent innovations in climate smart technologies in agriculture and its upscaling strategies',** sponsored by MANAGE, Hyderabad organized at ICAR-RCER, Patna during September 18-22, 2019.
- Short course on '**Conservation agriculture for climate resilient farming & doubling farmers' income**', sponsored by ICAR, New Delhi organized at ICAR-RCER, Patna during 14-23 October 2019.
- Field day-cum-training programs on **'**/kku dk ivky çc/ku **'**, under 'Scaling up Climate Smart

Agriculture (CSA) through Mainstreaming Climate-Smart Villages (CSVs) in Bihar' project on 25th October 2019.

- Training programme on '**Recent advances in management practices in horticultural crops**', sponsored by ICAR-IINRG, Namkum organized at ICAR-RCER, FSRCHPR, Ranchi during 12-16 November, 2019.
- Training programme on '**Zero Tillage in Wheat**' under 'CRP on FM & PF and Scaling up Climate Smart Agriculture through Mainstreaming Climate Smart Village in Bihar' projects organized at ICAR-RCER, Patna during 18-21 November, 2019.
- Training programme on '**Recent advances in management practices in horticultural crops**', sponsored by ICAR-IINRG, Namkum organized at ICAR-RCER, FSRCHPR, Ranchi during 26-30 November and 3-7 December, 2019.
- Training on '**Mushroom cultivation**', under 'DBT Biotech KISAN Hub' project organized at ICAR-RCER, FSRCHPR, Ranchi on 26, 27 and 29 November, 2019.
- Model training course on '**Advances in marketing and supply chain management of agricultural produce**', sponsored by the Directorate of Extension Education, Ministry of Agriculture & Farmers Welfare organized at ICAR-RCER, Patna during December, 10-17, 2019.
- Model training course on '**Recent advances in horticulture and post-harvest technologies for livelihood security**', sponsored by the Directorate of Extension Education Ministry of Agriculture & Farmers Welfare organized at ICAR-RCER, Patna during December 19-26, 2019.

Trainings attended by the employees during 2019

International

- B.P. Bhatt, Director. Executive Development Programme on Developing Effective Organizational Leadership for Senior Officers of ICAR held at Netherlands, Belgium, Germany and Switzerland from 21-30 September, 2019.
- Santosh Kumar, Sr. Scientist. Training programme on Characterization of physiological responses of drought tolerant and drought susceptible genotypes in variable environments across different sites held at International Rice Research Institute (IRRI), Los Banos, Philippines during 24th May to 5th June 2019.

National

- Arti Kumari, Scientist. Professional Attachment Training at NBSS&LUP, Nagpur from 25 May - 24 August, 2019.
- Arti Kumari, Scientist. Short course on Conservation agriculture for climate resilient farming and doubling farmer's income organized at ICAR-RCER, Patna during 14-23 October, 2019.
- Arun Kumar Singh. Training Programme on Intellectual Property Valuation and Technology Management held at ICAR-NAARM, Hyderabad during 15-19 October, 2019.
- B.P. Bhatt, Director. Executive Development Programme on Developing Effective Organizational Leadership for Senior Officers of ICAR held at Administrative Staff College of India, Hyderabad during 2-4 August, 2019.
- Bal Krishna Jha, Pr. Scientist. Pre RMP on Leadership Development organized at NAARM, Hyderabad during 2-13 December, 2019
- Kirti Saurabh, Scientist. Training programme on Advancements in soil, water and plant analysis techniques using sophisticated equipments with respect to salinity and sodicity management held at ICAR- CSSRI, Karnal during 16-21 September, 2019.
- Nongmaithem Raju Singh, Scientist. Short course on Conservation agriculture for climate resilient farming and doubling farmer's income organized at ICAR-RCER, Patna during 14-23 October, 2019.
- Virendra Kumar Yadav, Pr. Scientist. Training programme on Innovative practices in Extension Research and Evaluation held at NAARM, Hyderabad during 5-8 November, 2019.
- Pushpanayak, Chief Admin. Officer. Workshop on e-office organized at ISTM, New Delhi during 4-5 April, 2019.
- A.K. Soni, Sr. Admin. Officer. Sensitization Workshop on ICAR ERP-FMS and Other Financial Issues held at ICAR-IASRI, New Delhi on 31 October, 2019.
- Ravi Shankar, Assistant. Sensitization Workshop on ICAR ERP-FMS and Other Financial Issues held at ICAR-IASRI, New Delhi on 31 October, 2019.
- Sarfaraj Ahmad, Technical Officer. Sensitization Workshop on ICAR ERP-FMS and Other Financial Issues held at ICAR-IASRI, New Delhi on 31 October, 2019.

- Sanjay Kumar, Technical Assistant. J-Gate@ CeRa Regional Training program held at OUAT, Bhubaneshwar on 9 August, 2019.

Participation in Conferences/Seminars/ Workshops/Symposia/Meetings

- Bhatt BP. 2019. Farming System Research in India: A Better Option for Doubling Farmers' Income lecture delivered in 13th Uttarakhand State Science & Technology Congress (USSTC) 2018-19 held at Vigyan Dham, Jhajra, Dehradun during 26-28 February, 2019.
- Bhatt BP. 2019. Integrated Farming System for Irrigated Eco-systems with Special Reference to Rice-Wheat System and Diversification. Lecture delivered in XIV Agriculture Science Congress held at NASC Complex, New Delhi during 20-23 February, 2019.
- Bhatt BP. 2019. International Conference on Crop Residue Management held at Gyan Bhawan, Patna during 14-15 October, 2019 and chaired the Technical Session on Crop Residue Burning: Practical Approaches and Farmers Perspective as Co-Chairman.
- Bhavana P. 2019. 3rd World Clean Environment Summit held St Xavier's College, Ranchi from 19-21 August, 2019.
- Bhavana P. 2019. International Conference on Vision 2022-The Way Forward Towards Sustainable Development organized at Jharkhand Rai University, Ranchi from 1-2 June, 2019.
- Chakrabarti Asit. 2019. National Conference on Doubling Farmers Income for Sustainable & Harmonious Agriculture (DISHA- 2019) held at Birsa Agricultural University, Ranchi, Jharkhand during 10-11August, 2019.
- Choudhary AK. 2019. National Seminar on Sustainable Production of Pulses through Bio-agents" organized by Gramin Vikas Kendra at Bihar Sharif (Nalanda) during 16-17 October, 2019.
- Choudhary AK. 2019. Harvest Plus Stakeholder Meeting for Promotion of Bio-fortified Wheat (zinc), Rice (zinc) and Lentil (iron) held at The Lemon Tree Hotel, Patna on 02 March, 2019.
- Choudhary AK. 2019. National Seminar on Recent Advances in Agriculture for Sustainable Rural Development (RAASRD-2019) organized at Veer Kunwar Singh College of Agriculture, Dumraon, Buxar during 15-17 March, 2019.
- Das Bikash and Choudhary JS. 2019. National Conference on Integrated Plant Health Management in Fruit Crops held at ICAR-National Research Centre on Litchi, Muzaffarpur, during 03-04 September, 2019.
- Koley TK. 2019. First Expert Consultation Meeting of ICAR Metabolomics Research Group held at NASC Complex in New Delhi on 8 July, 2019.
- Koley TK. 2019. National Seminar on "Cultivation, Conservation and Sustainable Utilization of Medicinal Plants for Livelihood Improvement organized at UBKV, Coochbehar, West Bengal from 20-21 November, 2019.
- Kumar Sanjeev. 2019. Annual Group Meeting for AICRP-IFS held at JAU, Junagarh (Gujrat) during 27-29 November, 2019.
- Kumar Santosh. 2019. QRT meeting of ICAR-IIRR, Hyderabad held at BHU, Varanasi during 05-06 April, 2019.
- Maurya S. 2019. XXIth Annual AICRP on Mushroom Workshop held at ICAR-Directorate of Mushroom Research, Solan, HP during 28-29 June, 2019.
- Mishra JS and Koley TK. 2019. Progressive Horticulture Conclave held at Lucknow, Uttar Pradesh 8-10 December, 2019.
- Mishra JS, Kumar Santosh and Rao KK. 2019. Division committee meeting for monitoring and reviewing the progress of foreign aided projects for the period Jan-Jun 2019, held at CSSRI Karnal on 18 July, 2019.
- Mishra JS. 2019. National conference on Integrated Plant Health Management in Fruit Crops, held at ICAR-NRC on Litchi, Muzaffarpur during 3-4 September, 2019.
- Mishra JS. 2019. Conference of Addressing Climate Change Challenges to Livelihoods in Rural Areas of Bihar at Patna on 16 October, 2019.
- Mishra JS. 2019. Cost committee meeting of NASF project 'Developing Precision Nutrient Management Protocols for Predominant Cropping Systems in Indo-Gangetic Plains' held at ICAR New Delhi on 6 August, 2019.
- Mishra JS. 2019. Expert committee meeting of NASF project 'Developing Precision Nutrient Management Protocols for Predominant Cropping Systems in Indo-Gangetic Plains' held at NASC Complex, New Delhi on 6 May. 2019.
- Mishra JS. 2019. Workshop on Enhancing Resilience and Productivity of Rice-Based System through Precision Agronomy, Machine Learning, and ICT Based Tools, held at Chandigarh during 24-26 August, 2019.

- Mishra JS. 2019. Workshop on ICT-Based Decision Tool for Field-specific Weed Management for Rice and Wheat, held at Ganjam, Odisha on 27 December, 2019.
- Mondal S. 2019. International Conference on Crop Residue Management organized by Bihar Agricultural University (BAU), Sabour, Bihar, India from 14-15 October 2019.
- Mondal S. 2019. International Conference on Soil and Water Resource Management for Climate Smart Agriculture, Global Food and Livelihood Security held at NASC, New Delhi, India from 05-09 November, 2019.
- Naik SK. 2019. Doubling Farmer's Income by 2022- Pathways and Strategies. Workshop on Doubling farmer's income-Challenges and Strategies organized at Ramakrishna Mission Ashram, Morabadi, Ranchi on 22 August, 2019.
- Sarkar B and Sundaram PK. 2019. Farm machinery Entrepreneurship Seminar held at BAMITI, Patna on 4thSeptember, 2019.
- Singh Arun Kumar. 2019. International Conference on Innovative Horticulture and Value Chain Management-Shaping Future Horticulture organized at DRPCAU Pusa, Samastipur, Bihar from 28-31 May, 2019.
- Singh SK and Kumari Arti. 2019. Workshop on Hazard Risk Vulnerability Assessment of the State of Bihar held at Hotel Chanakya, Patna during 19-20 September, 2019.
- Singh SK. 2019. National Seminar & Annual Meet on Improving Sheep & Goat Production & Utilization held at Dashrath Manjhi Training Institute, Patna on 14 February, 2019.
- Sundaram PK. 2019. 53rd Annual Convention of ISAE and International Symposium on Engineering Technologies for Precision and Climate Smart Agriculture held at, Banaras Hindu University, Varanasi from 28-30 January, 2019.
- Sundaram PK. 2019. 8th Asian-Australasian Conference on Precision Agriculture held at Punjab Agricultural University (PAU), Ludhiana from 14-17 October, 2019.

21. Events Organized

Farmers Training on Recent Advances in Goat Production and Management

Three training programmes (each of 3 days) sponsored by the Kosi Basin Development Program were conducted for stake holders of Kosi region during 13-15, 19-21 and 25-27 June, 2019. A total of 83 farmers were trained under the programme. Recent developments in goat rearing for augmenting goat productivity vis-à-vis endurance of livelihood security was discussed with the participating farmers. Few important topics covered under the programme included housing management of goats, goat feeding and nutrition, round the year fodder productivity, breeds and breeding techniques in goats, and economically important diseases of goats and health care management. Apart from classroom discussion, the farmers were taken to the institute goat farm and were shown scientific practices of managing goats for higher profitability.

Training Programme for Undergraduate Agriculture Students

A ten-day training programme on "Soil testing and nutrient management in horticultural crops" for B. Sc. (Ag) students from Jharkhand Rai University, Ranchi was organized at ICAR-RCER, FSRCHPR, Ranchi during 22 June to 3 July, 2019 for improving their knowledge, skill and understanding of nutrient management in horticultural crops. Twenty four students participated in the training.

Celebration of International Yoga Day

ICAR Research Complex for Eastern Region, Patna celebrated 5th International Yoga Day on 21st June, 2019. To mark the occasion, Director ICARRCER, Patna along with the scientists and staff of the institute performed Yoga from 8:00 AM to 9:00 AM under the instruction of Dr. J.J. Gupta, Principal Scientist and Yoga Expert of the institute. He also briefed about the importance of practicing yoga in controlling an individual's mind, body and soul. An essay competition on a topic "Role of yoga in the context of Indian Agriculture" was organized among the employees of the Institute. Yoga day was also observed at its research centers at Ranchi and Darbhanga, and KVKs at Buxar and Ramgarh.

Training Programme on Selection and Operation of Farm Implements for Improving Crop Productivity

A three-day training programme on selection and operation of farm implements for improving crop productivity was organized at ICAR-Research Complex for Eastern Region, Patna under Consortia Research Platform on Farm Mechanization and Precision Farming during 21-23 August, 2019. A total of 31 farmers from Nalanda district of Bihar participated in the training programme. Participants were briefed about setting up of custom hiring centres and its benefits for the farming community in the region. They were also trained in calibration of seed cum fertilizer drill.

Recent Innovations in Climate Smart Technologies in Agriculture and its up-scaling strategies

A five-day training course on "Recent innovations in climate smart technologies in agriculture and its up-scaling strategies" sponsored by MANAGE, Hyderabad was organized by ICAR-RCER, Patna during 18-22 September, 2019. The training was inaugurated on 18 September, 2019 by the Chief Guest, Dr Jitendra Prasad, Director, Bihar Agricultural Management & Extension Training Institute (BAMETI), Patna. Dr Shailendra, Deputy Director (Behavioural Sciences), MANAGE, Hyderabad was also present along with other faculties of the institute. All the dignitaries interacted with participants on climate related issues and adaptation and mitigation strategies for climate smart agriculture. A total 17 numbers of field level extension functionaries from Bihar and Uttar Pradesh attended the training.

Short Course on Conservation Agriculture for Climate Resilient Farming & Doubling Farmers Income

A ten-day short course on "Conservation Agriculture for Climate Resilient Farming & Doubling Farmers Income" sponsored by ICAR, New Delhi was organized at ICAR-Research Complex for Eastern Region, Patna during 14-23 October, 2019. Dr R.C. Agrawal, DDG (Education), ICAR-New Delhi and Registrar General, PPV & FRA was the Chief Guest of the function. Dr S.S. Singh, Director, ATARI-Kolkata and Dr V.K. Singh, Head, Division of Agronomy, Indian Agricultural Research Institute, New Delhi were the Guests of honour. Dr B.P. Bhatt, Director, ICAR-RCER Patna highlighted that the Institute is involved in developing, refining and popularizing the RCTs for climate resilience and increasing farmers' income in eastern IGP since its inception. Dr R.C. Agrawal, the Chef Guest of the function, in his inaugural address emphasised on the importance and need of such training programmes for the scientists of SAUs and ICAR institutions. He further emphasised on the importance of resource conservation as well as conservation of genetic resources for development of stress tolerant crop varieties. He also shared his experiences of working in PPV& FRA related to

conservation of genetic stock/materials/cultivars. This training was attended by 17 participants from the different states like Tamil Nadu, Karnataka, Rajasthan, Jharkhand, Uttar Pradesh and Bihar.

Policy Dialogue on Role of Livestock and Fisheries in Doubling Farmers' Income in Eastern India

A policy dialogue on "Role of Livestock and Fisheries in Doubling Farmers' Income in Eastern India" was organized at ICAR-Research Complex for Eastern Region, Patna on 24th October, 2019. Sh. Giriraj Singh, Hon'ble Minister for Fisheries, Animal Husbandry and Dairying, Govt. of India was the chief Guest of this programme. Sh. Giriraj Singh, in his address stressed upon production and use of earthworms as feed supplement for low input poultry production. He also urged to research institutions to adopt low input livestock production system and add value to the manure, cow urine and crop-by product through technological intervention. During his interaction with all the scientists, he shared his experiences on production of earthworms using cow dung and use of whey- water and moringa leaves for increasing milk yield if fed to cattle and buffaloes. He reiterated that moringa leaves can be utilized as organic fertilizer as it contains sufficient amount of nitrogen. On this occasion a training manual on "Conservation Agriculture for Climate Resilient Farming & Doubling Farmers Income" was also released by Hon'ble minister. Earlier, Sh. Giriraj Singh monitored the field experiments being conducted at ICAR-RCER, Patna and appreciated the efforts made by the scientists. He suggested for large scale plantation of moringa tree in the campus and experimentation of fresh water prawn culture. Among various fish species, he stressed on popularization of indigenous fish, especially Mangur in eastern part of India.

At the outset, Dr BP Bhatt, Director, ICAR-RCER, Patna welcomed the Chief Guest, Sh. Giriraj Singh and made a brief presentation on activities and achievements of Institute focusing on livestock and fisheries sector. Nearly 50 Scientists from ICAR-RCER, Patna and Bihar Animal Sciences University, Patna participated in this programme.

Field Day-cum-Training Program

Field day-cum-training programs on "धान का पुआल प्रबंधन" was organized by ICAR Research Complex for Eastern Region (ICAR-RCER), Patna under the project "Scaling up Climate Smart Agriculture (CSA) through Mainstreaming Climate-Smart Villages (CSVs) in Bihar" on 25th October 2019 at two villages namely Lodipur (Nagarnausa cluster) and Dasturpar (Chandi cluster) of Nalanda district. More than 50 farmers participated in each villages. Farmers were apprised about the management practices followed in growing direct-seeded rice. The youth facilitators, as well as farmers, were also apprised about the grave situation of stubble burning, paddy straw management, use of happy seeder and zero tillage machines. Addressing the farmers, Dr. J.S. Mishra, Head, Division of Crop Research, ICAR RCER, discussed the benefits of DSR and its agronomic management. Dr. Abhay Kumar, Principal Scientist, ICAR RCER, gave detailed information about the management of paddy straw and advised farmers to shun from

burning the paddy stubble. Sh. Tarkeshwar Ram, Block Agriculture officer, Nagarnausa was also present and informed farmers about the subsidies and other benefits provided by state Government to farmers. Dr. Prem K Sundaram, Dr. Anirban Mukherjee, and Dr. N. Raju Singh, were also present and discussed farmers on various issues. Participating farmers shared their experiences and provided valuable feedbacks also.

Training Programme on Zero Tillage in Wheat

Four days training programme on 'Zero Tillage in Wheat' was organized during 18-21 November, 2019 for farmers of four blocks of Patna and Nalanda districts at ICAR-Research Complex for Eastern Region, Patna under Consortia Research Platform on Farm Mechanization and Precision Farming (CRP on FM & PF) and Scaling up Climate Smart Agriculture through Mainstreaming Climate Smart Village in Bihar. Total of 88 farmers: 26 from Fatuha block and 23 farmers from Daniyawan block of Patna district; 21 farmers of Nagarnausa block and 18 from Noorsarai block of Nalanda district actively participated in the training programme. The programme was inaugurated by Dr. J. S. Mishra, Head, Division of Crop Research. He appraised the farmers about the conservation agriculture and crop residue management in wheat. Dr. P.K. Sundaram emphasized about the importance of ZT concept and its importance in rice-wheat cropping system. Farmers were imparted training on calibration, operation, maintenance of zero tillage machine and benefits of zero tillage in wheat.

Field day on Zero-till Wheat

Three field days were organized on 'Zero-till Wheat' at villages Kopwaon and Mungaon (Dumraon block) and Hukahan (Sondhiya block) in Buxar district during 25-27 November 2019 under CRP on

FM & PF project funded by ICAR. Scientists from ICAR RCER Patna, KVK, Buxar and state officials briefed the farmers about the benefits of using ZT in wheat. Dr. P.K. Sundaram, Scientist from ICAR RCER, Patna appraised the farmers about the operation, maintenance and calibration of ZT seed drill. Live demonstration of the ZT seed- cum fertilizer drill was also conducted at farmers' field. Also, extension folders published under the project on zero seed cum fertilizer drill were distributed among farmers. Sh. K.M. Chaudhary (BAO), Sh. S.D. Yadav (AC), Dr. Ramkewal (SMS) and Dr. Deokaran (SMS) from KVK, Buxar also interacted with the farmers. They motivated the farmers to use this machinery for the sowing of wheat in larger area. Total of 105 farmers participated in the training program/field day.

Model Training Course on Advances in Marketing and Supply Chain Management of Agricultural Produce

ICAR Research Complex for Eastern Region, Patna organised an eight-days Model Training Course during 10-17 December, 2019 for officials of development departments from different states. The training was sponsored by Directorate of Extension, Ministry of Agriculture and Farmers Welfare, Govt. of India. Seventeen agricultural and

horticultural officers from Bihar, Gujrat, Haryana, Ladakh, Punjab and Sikkim participated in this training programme. The training was inaugurated on 10th December 2019 by Chief Guest, Prof Hemnath Rao H, Senior Professor and Director, Development Management Institute. Professor Rao appreciate effort of the institute for the organizing such national level event with limited resources. He emphasized on development of techno-managerial approach.

Model Training Course on Recent Advances in Horticulture and Post-harvest Technologies for Livelihood Security

An eight-day Model Training Course on "Recent advances in horticulture and post-harvest technologies for livelihood security" was organized by the ICAR-Research Complex for Eastern Region, Patna from 19-26 December 2019. The programme sponsored by the Directorate of Extension, Ministry of Agriculture & Farmers Welfare, Government of India. Nineteen officials from the Agriculture/ Horticulture Departments of Gujarat, Bihar, Punjab, Uttar Pradesh, Dadar Nagar Haveli and Laddakh participated in the course. Mr. Sunil Kumar Pankaj, Joint Director, Horticulture, Patna (Bihar) and Chief Guest, inaugurated the programme on 19 December 2019. Mr. Pankaj highlighted the importance of horticulture in Eastern India and also stressed the current rate of adoption of recent technology by farmers. Chief Guest also released a training manual based on the training course.

During training programme, in addition to conventional topic various new techniques such as, vertical farming, microgreens, use of solar energy in horticulture, technologies for the cold arid zone, vegetable grafting, etc has been discussed. This training also included field visits of commercial strawberry cultivation in Nagarnausa, Nalanda and exposure to centre of excellence on Horticulture at Chandi, Nalanda, Bihar.

Training programme on Recent Advances in Integrated Fish Farming

ICAR-Research Complex for Eastern Region (ICAR-RCER), Patna organised two 5-days farmers' training programme on "*Recent Advances in Integrated Fish Farming*" during 2-6 Aug 2019 and 03-07 September 2019 sponsored by Directorate of Fisheries, Govt. of Bihar. The main purpose of the training was to develop the skills and to make aware the farmers about integrated fish farming practices. A total of 60 trainees from Bunka and Lakhisarai districts (Bihar) participated in the training programme. The trainees were provided hands-on training on designing of fish farm, seed rearing, fish seed stocking, pond management, water quality management, management of livestock and different aspects of integrated fish farming.

Awareness Programme on Fish Disease Surveillance and Management in Bihar

Two awareness programmes on 'Fish Disease surveillance and Management in Bihar' were organized at village Baghat, Manigachhi block, District Darbhanga and Mutlupur village, Muzaffarpur, on 29 March, 2019 and 04 August, 2019, respectively, in collaboration with department of fisheries, District Darbhanga and Muzaffarpur under the "National Surveillance Program for Aquatic Animal Diseases" project. The main objective of the program was to sensitize fish farmers about the fish diseases and its management strategies. A total of 96 participants attended the programme.

QRT Meeting

The 3rd QRT meeting of the Institute was held during 10-11 September 2019 at ICAR-RCER, Patna under the Chairmanship of Dr. A.N. Mukhopadhyay, Former Vice Chancellor, AAU, Jorhat. The other QRT members Dr. P.K. Mahapatra, Dr. V.V. Sadamate and Dr. Kusumakar Sharma also attended the meeting. The QRT visited the Institute research farms, and monitored ongoing research activities and interacted with the scientists. The team appreciated the maintenance and management of farm and research activities of the institute. They have also reviewed the research progress of the institute since 2012-2017 and gave valuable suggestions. QRT advised both the KVKs (Buxar and Ramgarh) to expand their reach in the district through linkage with the state departments, input agencies and farmers organization.

Stakeholder's meeting with QRT

A Stakeholder's meeting with the QRT members was organized at ICAR Research Complex for Eastern Region, Ranchi and Patna on 5th and 7th November 2019 under the Chairmanship of Dr. A.N. Mukhopadhyay, Chairman QRT, to understand the research, extension and developmental activities going on across the organizations, and how best the ICAR RCER can collaborate in such activities. The meetings were also attended by the QRT members Dr. V.V. Sadamate and Dr. P.K. Mahapatra, Dr. R.C. Srivastava, Vice Chancellor, DRRPCAU, Pusa, Samastipur, Dr. R.S. Kureel, Vice Chancellor, Birsa Agricultural Univeristy, Ranchi, Director ATARI Patna, Director ICAR- Research Complex for Eastern Region Patna, and representatives from various ICAR Institutes & SAUs, Government representatives from Jharkhand, Bihar, Odisha, UP and Chhattisgarh , NGOs and progressive farmers.

Members of QRT expressed that ICAR RCER has a strong presence in two States, namely the

Bihar and Jharkhand. However, as per the Institute's mandate, emphasis should also be given to address the researchable issues, linkage and coordination with the other eastern states like Eastern UP, Chhattisgarh, Odisha, West Bengal and Assam. It was anonymously suggested and agreed to initiate collaborations research work with the SAU and other organisations, so that scientist from of Eastern Region can be benefited. For proper identification of research and extension priorities, MOU between premier institutes and collaborative research/extension projects of common issues need to be developed so that problems can be tackled in a comprehensive manner and results and outcome can be shared for the benefit of the society. Members also advised to develop deeper linkages with ongoing schemes of various departments of state government for wide scale out-scaling of the technologies developed by institute. There is also a need to develop data base to avoid duplicacy in research in the region as well as to develop an inventory of technologies developed for Eastern Plateau and Hill region for undertaking OFT and FLD at farmers' fields. Members also suggested initiating work for development of tribal farmers as well as mapping of food habits of tribal farming communities. It was also decided to prepare the success stories of progressive farmers in the form of videos for larger scale percolation of technologies among massess.

22. Krishi Vigyan Kendra

Krishi Vigyan Kendra, Buxar

Cluster Demonstration on Oilseeds & Pulses

Krishi Vigyan Kendra, Buxar organized Cluster Demonstrations on oilseeds and pulses during 2019 under Nat ional Food Security Mission (NFSM) and National Mission on Oilseed and Oil Palm (NMOOP). Details of crops, varieties, area, beneficiaries and demo sites are given below:

Crop	Technology	Area (ha)	No of beneficiaries	Village covered
Pigeonpea	Variety IPA 203 + seed treatment with fungicide, insecticide and rhizobium (FIR) + foliar spray of micronutrient (MO and B) @1 ml/lit water before flowering and management of legume pod borer (*Maruca vitrata*) using emamectin benzoate 10 g/ 15 l water (Fig 22.1).	20	55	Pandeypatti, Chousa, Kamarpur, Pavni, Chunni,
Chickpea	Variety GNG 1581 + seed treatment with FIR + foliar spray of micronutrient (MO and B) @1ml/l water before flowering and management of gram pod borer (*Helicoverpa armigera*) by using bioinsecticide.	10	40	Majhariya, Jigna, Mahdah, Karuaj, Vishrampur, Chotki Basouli
Lentil	Variety PL 8 + seed treatment with FIR + management of aphid (*Aphis craccivora*) by using bioinsecticide	10	32	Pandeypatti, Kukurah, Lalganj, Jagdishpur, Dafa Dehri, Bishrampur
Mustard	Variety RH 406 + soil application of sulphur 20 kg/ha and management of aphid (*Lipaphis erysimi*) by using bioinsecticide	150	185	Pandeypatti, Kukurah, Lalganj, Jagdishpur, Bishrampur, Dafa Dehri Majhariya, Jigna, Mahdah, Karuaj, Vishrampur, Chotki Basouli, Niyazipur, Badka Rajpur
Green gram	IPM + seed treatment with FIR + foliar spray of micronutrient (MO and B) @1ml/l water before flowering and management of white fly by using thaimathoxam 5g/15 lit water or acetamiprid 15 g/15 l water.	10	40	Rajapur, Sondhila, Hukha, Barri,

Fig. 22.1. Field view of pigeonpea, chickpea and lentil

Training Programmes Organized

Following trainings were conducted for farmers, rural youth and extension functionaries

Off campus training

Topic	Date	No of beneficiaries
Community rice nursery production	01-02/07/2019	25
Annual contingent crop planning	08-09/07/2019	25
Identification, nature of damage and control measure of storage insects and pests	07-08/08/2019	25
Application method and precaution during uses of chemical pesticides	09-10/08/2019	30
Soil borne diseases, their symptoms and management through summer ploughing & soil solarization	16-17/08/2019	30
Weed management in paddy	16-17/08/2019	25
Quality seed production of paddy	24-26/08/2019	25
Best management practices for rice production	27-28/08/2019	25
Organic farming for sustain production sustainability	29-30/08/2019	25
Quality seed production of okra	29-30/08/2019	25
Insects and disease of summer vegetables and their management	29-30/08/2019	25
Insects and diseases of rice nursery and control measures.	31/08/2019-01/09/2019	30
Integrated crop management in pigeonpea	04-05/09/2019	25
Scientific cultivation of pearl millet, finger millet and *kodo*	12-13/09/2019	25
Integrated weed and nutrient management for maize production	18-19/09/2019	25
Quality seed production of maize	31/09/2019 & 02/10/2019	26
Integrated disease management in rice	03-04/10/2019	26
Disease caused by nutritional deficiencies and their management	15-16/10/2019	29
Seed borne diseases of cereals and pulses and their management	17-18/10/2019	25
Insect and disease management in oil seed crops	19-20/10/2019	31
Eco-friendly management of insect & pest in pulses	29-30/10/2019	30
Application of microbial pesticide for management of insect-pest	30/10/2019 – 01/11/2019	30
ZT in wheat sowing	25-27/11/2019	120
Quality seed production of heat tolerant variety of wheat	30/11/2019 - 02/12/2019	28

On campus training

Topic	Date	No of beneficiaries
Insect-pest of orchard and their management	15-18/11/2019	25

Training for extension functionaries

Topic	Date	No of beneficiaries
Productivity enhancement in field crops	11-12/11/2019	25
IPM: principles and practices	05-07/12/2019	25

Training for rural youth

Topic	Date	No of beneficiaries
Doubling farmers income through integrated farming system	19-23/11/2019	25
Mushroom production	04-08/11/2019	20

Skill development training

Topic	Date	No of beneficiaries
Operation and maintenance of primary and secondary tillage implements	04-06/07/2019	26

On farm trials

Topic	No of beneficiaries	Village covered
Effect of water and boron management on terminal heat of late sown ZT wheat	5	Badka Rajpur, Mahdah, Chotki Basouli
Assessment of different crop establishment method on yield of lentil in rice-lentil cropping system	10	Pandeypatti, SOndhila Mahdah, Hukha, Dafa Dehri
Assessment of new molecules for the management of rice stem borer (*Scirpophaga incertulas*)	5	Jagdishpur
Yield enhancement of pigeonpea through nutrient management.	10	Pavni, Chunni

Front line demonstrations

Crop	Technology	Area (ha)	No of beneficiaries	Village covered
Rice	Medium duration scented rice variety Rajendra Kasturi	10	35	Mahdah, Dumraon, Barri, Bocsa, Chunni, Pavni, Kukurah
Rice	Drought tolerance rice variety Swarna Shreya	2	5	Chotki basouli, Rajapur, Dumrao
Rice	Scented variety CR 909	5	13	Pavni, Mahdah, Chotki Basouli, Rampur, Yogiya
Wheat	ZT sowing of wheat variety HD 2967	8	21	Rajapur, Dhansoi, Mahdah, Chougai, Geruabandh, Dumrao, Chotka Rajpur
Wheat	Zinc bio-fortified variety BHU 31 & BHU 25	5	15	Hukha, Bocsa, Nidhua, Mahdah, Ahirouli
Wheat	IARI outreach programme HD 2967, HD 3118, HD 2985	2	10	Dullahpur, Pandeypatti, Turkpurva, Mahdah, Lalganj
Waste Decomposer	Decomposition of rice crop residue	125	500	Chunni, Pavni, Sondhila, Geruabandh, Lohandi, Kukurah

Seed hub programme

In the year 2016 Ministry of Agriculture and Farmers welfare started programme "Creation of seed hubs for increasing indigenous production of pulses in India" under National Food Security Mission. Under participatory seed production mode chickpea seed production was started at farmer's field in *Rabi* season covering an area of 11.13 ha among 14 farmers field, and 4.30 ha at KVK, Farm using chickpea variety GNG 1581 (Fig 22.2).

Fig. 22.2. Field view of seed production plot at KVK Farm

Besides pulse seed hub, KVK Buxar also produced the foundation, certified and TL seed of paddy, wheat, field pea and pigeonpea. Details are given below:

Crop	Variety	Quantity of seed (q)	Non Seed (q)	Area (ha)	No. of farmers to whom seed provided
Paddy	MTU 7029	19.80	10.55	1.3	84
	BPT 5204	21.60	6.00	1.8	101
	Rajendra Sweta	6.42	1.00	0.8	21
	Rajendra Kasturi	6.50	2.5	1.0	20
Wheat	HD 2967	45	0	1.5	65
Field pea	DFP 1	1.5	0	0.2	10
Pigeonpea	IPA 203	2.12	0	0.2	40
Chickpea	GNG 1581	45	1.5	4.2	145
Grand Total		147.94	21.55	11.0	486

Field Day on Rice, Oilseeds and Pulses

KVK Buxar organized seven field days on oilseed (mustard) and different pulses (pigeonpea, chickpea, lentil and field pea) to popularize the demonstrated technology amongst the farmers. In each field day scientific staff, technical staff, social workers, members of FPO and progressive farmers (Fig 22.3) and farm women's participated to know about the demonstrated technology in the different crops. Details of these field days are give below:

Field day organized	Date	Place	No. of farmer partici-pated
Field day on pigeonpea	14/02/2019	Pawani	100
Field day on chickpea	08/03/2019	Rajdiha	100
Field day on lentil	05/03/2019	Badka Rajpur	100
Field day on field pea	06/03/2019	Niyazi-pur	100
Field day on mustard	28/02/2019	Lalganj	100
Field day on rice "Shwarna Shreya"	08/11/2019	Lalganj	75
Field day on rice "CR 909"	16/11/2019	Pavni	60

Fig. 22.3. Field day on pigeonpea, rice and chickpea

Scientific Advisory Committee meeting

The 10th Scientific Advisory Committee (SAC) meeting of KVK Buxar was held on 7th September, 2019 at KVK, Buxar under the Chairmanship of the Director, ICAR-RCER Patna (Fig 22.4). The meeting was also attended by Dr Ujjwal Kumar, Head DSEE, ICAR RCER, Patna., Sri Krishna Nand Chakravarti, District Agriculture Officer (Buxar), Sh. Devnandan Ram, Project Director (ATMA, Buxar), Dr. Trivedi Prakash Narayan, Mobile Van Veterinary Officer (Buxar), Dr Ajay Kumar, Principal VKS COA, Dumraon, PC and SMS/Staffs of KVK Buxar, progressive farmers/ member of this meeting and officials from State Agriculture Department/ other department.

Fig. 22.4. Scientific Advisory Committee meeting

Training on operation and maintenance of primary and secondary implements

Three days training programme on operation and maintenance of primary and secondary implements was organized from 4-6 July, 2019 (Fig. 22.5). The programme was inaugurated by Dr Ajay Kumar, Principal VCSCOA, Dumraon and District Agriculture Officer Shri Krishna Nand Chakravarti. Total number of 26 rural youth participated in the programme.

Fig. 22.5. Training programme on operation and maintenance of primary and secondary implements

World Soil Health Day cum *Rabi Kisan Gosthi*

KVK Buxar celebrated world soil day cum *Kisan Gosthi* on 5th Dec, 2019 at its premises (Fig. 22.6). Kisan leader Parshuram Chaturvedi, District Agriculture Officer, PD ATMA, Kisan Shri Vinod Singh and PC, KVK jointly inaugurated the programme. Total number of 55 farmers participated in the programme. Scientists of the KVK advised the farmers to avoid the crop residue burning and use waste decomposer for easily decomposition of crop residue.

Fig. 22.6. Celebration of World Soil Health Day

Extension activities

Name of programme	Date	No. of Participants
Kisan chaupal	25/06/2019	26
Kisan chaupal	24/07/2019	6
Gajar ghas jagrookta	22/08/2019	30
National animal disease control programme (NADCP) for foot & mouth disease and brucellosis	11/09/2019	85
Swachchta hi seva	11/09/2019 to 02/10/2019	290
Vrihad plantation programme	17/09/2019	60
Kisan gosthi on "fasalo me jal prabandhan taknik"	02/10/2019	86
Krishak jagrookata karyakram "balance use of fertilizer"	22/10/2019	205
Awareness programme on "citizens duties including fundamental duties" at Foundation Public School	03/12/2019	62
Awareness Programme on "Citizens duties including Fundamental Duties" at DAV Public School	04/12/2019	62

Station trials

Topic	Area (ha)	Place
Evaluation aerobic and drought tolerant rice genotypes	0.2	KVK, Buxar, Chotki Basouli
Participatory varietal selection (PVS) trial (DSR & transplanted)	0.2	KVK, Buxar, Chotki Basouli
Evaluation of conservation agricultural practices under rice-fallow system of eastern Region	0.25	KVK, Buxar, Kukurah
Improving rice-wheat cropping system productivity using different crop establishment methods	0.25	KVK, Buxar, Chotki Basouli, Geruabandh, Mahdah

On farm trials under KVK-CSISA project

Topic	No of beneficiaries	Place
Improving rice-wheat cropping system productivity using different crop establishment methods	10	Rajapur, Konawali, Basahi, Bocsa, Chotki Basouli, Mahdah, Mango Dehri, Chougai, Geruabandha
Comparative performance of rice establishment methods in different ecologies of Bihar and eastern UP	10	Indapur, Rajapur, Mahdah, Chotki Basouli, Geruabandha
Impact of age of rice nursery on the growth and yield of transplanted rice	5	Konawali, Mango dehri, Geruabandha
Performance of conventional till DSR with and without presowing irrigation	5	Bocsa, Mahdah, Geruabandha, Diwan ka Badkagaon
Weed management in direct seeded rice dominated *Cyperus rotundus* based mixed weed flora	7	Rajapur, Konawali, Basahi, Bocsa, Chotki Basouli, Mahdah, Mango Dehri, Chougai, Geruabandha
Performance of short-duration and long-duration variety under different sowing schedules across ecologies.	10	Rajapur, Konawali, Basahi, Bocsa, Chotki Basouli, Mahdah, Mango dehri, Chougai, Geruabandha

Topic	No of beneficiaries	Place
Assessing the role of additional irrigation during terminal heat stress period during rain filling stage to beat the heat stress and its effect on wheat productivity.	5	Bocsa, Mahdah, Geruabandha, Diwan ka Badkagaon
Impact of herbicide application technology on the performance of herbicide in wheat.	5	Rajapur, Geruabandha, Mahdah, Chotki Basouli
Boron deficiency induced sterility in wheat and its effect on the yield and yield attributes of wheat.	5	Bocsa, Mahdah, Geruabandha, Diwan ka Badkagaon, Rajapur
Residue management in rice-wheat system	3	Jogiya, Geruabandha, Kukurah

Krishi Vigyan Kendra, Ramgarh

Cluster Demonstration on Oilseeds & Pulses

Krishi Vigyan Kendra, Ramgarh organized Cluster Demonstrations on oilseeds and pulses during 2019 under National Food Security Mission (NFSM) and National Mission on Oilseed and Oil palm (NMOOP). All demonstrations were laid in cluster approach emphasizing on rice fallow and new released varieties (Fig. 22.7). Farmers were advised to adopt the good agronomic practices, balanced fertilization and IPM practice to reduce the cost of cultivation to get better economic returns. KVK also demonstrated the cafeteria for each crop at their farm to popularize the varieties and production technology of pulse and oilseeds among the farmers. Details of crops, varieties, area and beneficiaries are given bellow:

Crop	Technology	Area (ha)	No. of beneficiaries
Pigeonpea	Variety LRG-41@20kg/ha + seed treatment with *Trichoderma viridi* & *Rhizobium* culture + line sowing + need based chemical spray	10	50
Horsegram	Variety Birsa Kulthi 1 + seed treatment with *Rhizobium* culture + line sowing + foliar spray of NPK 19:19:19 and use of neem oil	10	40
Groundnut	Variety Dharni + seed treatment with carbendazim 2.5 g/kg + foliar spray of NPK 19:19:19 and use of neem oil	10	40
Niger	Seed treatment with *Trichoderma viridi* + line sowing + IPM + foliar spray of NPK 19:19:19 and use of neem oil	10	45
Sesame	Variety RT-351 + seed treatment with *Trichoderma viridi* + line sowing + IPM	10	24
Black gram	Variety PV-31 + *Rhizobium* culture seed treatment + line sowing + foliar spray of NPK 19:19:19 and use of neem oil	10	28
Fieldpea	Variety DFP1+ *Rhizobium* culture seed treatment + line sowing + foliar spray of NPK 19:19:19 and use of neem oil	10	110
Mustard	Variety Pusa-30 @5 kg/ha + line sowing, (30 x 10cm) application of sulphur and foliar spray of NPK 19:19:19: @ 2.5 kg/ha + spray of neem oil at the time of flowering @ 5ml/l water + sulphur @2 g/l water	130	167
Lentil	Variety HUL 57 @25 kg/ha + *Rhizobium* culture seed treatment + line sowing + foliar spray of NPK 19:19:19 and use of neem oil	10	40

Fig. 22.7. Field view of pigeonpea, chickpea and fieldpea

Training for Practicing Farmers, Rural Youth and Extension Functionaries

Following trainings were conducted for farmers, rural youth and extension functionaries

Off campus training

Topics	Date	No. of beneficiaries
Uses of herbicides for weed management in *Kharif* cereal crops	05-06/08/2019	50
Strategy and planning for contingent cropping	22-23/08/2019	50
Prepared of *Trichoderma viridi* based compost for control of wilt disease in vegetables	28-29/08/2019	25
Uses of herbicides for weed management in *Kharif* vegetables	08-09/08/2019	25
Strategy and planning for contingent cropping	23-24/08/2019	25
Awareness about seed replacement	14-15/10/2019	25
Adoption method for new technology of vegetable cultivation	23-24/10/2019	25
Improved technologies for cultivation of turmeric and marketing	01-02/11/2019	25
Improved techniques for kitchen garden development	19-20/08/2019	25
Use of agro forestry in rainfed agriculture	21-22/08/2019	25
Nursery raising and management techniques in papaya	28-29/08/2019	25
Improved technologies for cultivation of leguminous crops	23-24/09/2019	25
Healthy seedling productions of seasonal vegetables	25-26/09/2019	25
Improved technologies for cultivation of cole crops	04-05/10/2019	25
Use of herbicides for weed management in *Kharif* cereal/Pulse crops	07-08/11/2019	25
Use of herbicides for weed management in *Kharif* vegetables	23-25/11/2019	25
Storage pest management method in cereals and pulses	20-21/11/2019	25
Improved techniques for vegetable cultivation on rice fallow land	28-29/11/2019	25
Lac cultivation by SHG and rural youth	07-09/12/2019	25
Improved technologies for cultivation of turmeric and marketing	26-27/08/19	25
Importance of SHG for livelihood security	31/08/2019 to 02/09/2019	25
Importance of animal husbandry for Ramgarh district farmers by in coal mining effected area	05-06/09/2019	50
Enhancing income through Integrated farming of SHG	21-22/08/2019	25
Soil fertility management by composting of crop residue	29-30/10/2019	25
Improved technologies multitier fruit orchard establishment	30-31/08/2019	25
Production technology of marigold and rose	03-05/09/2019	25
Techniques for planning, layout and establishment of fruit orchard	13-14/09/2019	25
Techniques for propagation of mango plant	20-21/09/2019	25
Improved technology for crop production in rain fed areas	17-18/10/2019	25

On campus training

Topics	Date	No. of beneficiaries
Trichoderma viridi based compost for control of wilt disease in vegetables	28-29/08/2019	25

Training for rural youth

Topics	Tentative Date	No. of beneficiaries
Oster mushroom production and management	11-15/11/2019	50
Production technology of vermicompost and vermi wash	11&13-16/11/2019	25
Improved techniques of plant propagation of fruits	22-26/10/2019	25

Training for extension functionaries

Topics	Date	No. of beneficiaries
Role of Extension functionary for formation of farmers group and its monitoring	18-22/11/2019	25

Front line demonstrations

Crop	Variety	Area (ha)	No. of farmers
Paddy	Sahbhagi	5	10
Footyam	Gajendra	5	10

On-farm trials conducted at farmer's field for assessment of suitable technologies for Ramgarh district

Thematic Area	Title	Treatment	Area (ha)	No. of farmers
INM	Application of balanced dose of nutrients for good results	**TO_1:** Farmers practice: Farmers/ local variety with traditional management practices (NPK-20:30:0) **TO_2:** Shree bhadra + RDF (NPKB): 60:60:60:05 **TO_3:** Shree bhadra + STCR (NPKB)	1.0	6
Mushroom production	Training, audio visual aids, leaflets/ folder/ mobile advisory	**TO_1:** Farmers practices: Traditional method **TO_2:** Audio visual aids + leaflets/ folders + mobile advisory **TO_3:** Audio visual aids + leaflets + hands on training + Market linkage	10 unit	10
IPM	Organic module and IPM module for pest complex	**TO_1: Farmers Practice:** (Spray of triazophos 40% EC @2 ml/l at 35-40 days DAT, spray of chloroentraprinole @ 0.3 ml/l spray at 7 days interval of 60 DAT) **TO_2: Bio module** Weekly clipping of infested shoots and fruits from the appearance of pests, eraction of pheromone traps @10 traps ha for mass trapping, First spray of *Verticillium lecanii* @4 g/l + cow milk @5 ml/l (spray at evening hours) at 30 DAT Second spray of Neemastra @10 ml/ltr at 40 DAT, third spray of *B. bassiana* @4g/l at 50 DAT Third spray of *B. bassiana* @4 g/l at 60 DAT Fourth foliar spray of emmamectin benzoate 25WG @0.4 g/l 60DAT **TO_3:** Weekly clipping of infested shoots and fruits from the appearance of pests, eraction of pheromone trap @100 traps/ha for mass trapping of BFSB Use of fipronil 0.3% GR @12.5 kg /ha at 35 DAT First foliar spray of azadirachtin (10000ppm) @5ml/l 70 DAT Second foliar spray of rynaxypyr 18.5 SC @0.3 ml/l 50 DAT Third and fourth foliar spray of emmamectin benzoate 25WG @0.4 g/l 60 DAT and 80 days	1.0	10
IPM	Bio-intensive package for insect pest complex in tomato	**TO_1: IPM module** Erection of yellow sticky traps@10/ha traps for sucking pests First spray of *B. bassiana* @4 g/l + cow milk @5 ml/l (spray at evening hours) at 30 DAT Second spray of neemastra @10 ml/l at 40 DAT Third spray of *Bt* formulation @2 g/l at 50 and 70 DAT Fourth spray of *B. bassiana* @4 g/l at 60 DAT **TO_2: Bio-intensive module** Sowing of marigold as trap crop @one after 10 row of tomato, eraction of yellow sticky trap @10 traps/ha for sucking pests First foliar spray of azadiractin (10000ppm) @5 ml/l at 70 DAT Second foliar spray *Bt* formulation @ 2g/l at 60 DAT Third foliar spray of imidacloprid 200SL @0.5 ml/l at 40 DAT Fourth foliar spray of spinosad 45 SC @0.3 ml/l at 50 DAT	1.0	10

Celebration of important programmes

Name of Programme	Date	No. of Partici-pants	Name of special guest presented
Jal shakti abhiyan	03/08/2019	45	Mr. Upendra Kumar Sah, DDM, NABARD, Ramgarh
Gajar ghas unmulan	22/08/2019	40	Mr. Chintaman Mahto (Vard Parshard 06, Ramgarh)
Rashtiya poshan saptah	06/09/2019	61	Dr. Radha Prasad (Kasturba Gandhi Avasiya Vidhya-laya, Mandu)
Rashtiya pasurog niyantran programme	11/09/2019	110	Mr. Jay Prakash Patel(MLA, Mandu)
Plant and Plant distribution programme	17/09/2019	105	Mr. Upendra Kumar Sah, DDM, NABARD, Ramgarh
Animal health camp	23/09/2019	42	Dr. Vimla Kumari
Fertil-izer use awareness program	22/11/2019	210	Mr. Sanjay Kumar, District Agri. Of-ficer , Ramgarh

Other extension activities

Nature of extension activity	No. of activi-ties	No. of par-ticipants
Field day	1	40
Kisan gosthi	6	195
Exposure visit	2	52
Film show	2	320
Advisory service	125	680
Technology week	1	35
Swachhata hi seva	15 (05 villages)	210
News paper coverage	34	-
Radio talk	6	-
T.V. telecast	5	-
Extension literature	2	-

Seed production at KVK's farm

Crop	Variety	Area (ha)	Production (q)
Chikpea	Jaki-9218	0.5	6.5
Moong	IPM-2-3	0.5	4.0

Production of planting materials

Commodity	Quantity (Nos.)
Vegetable seedling	1000
Fruit sapling	1000
Medicinal/ aromatic plants	65
Others (Fodder agroforestry)	1200

Distribution of Soil Health Cards

No. of sample analyzed	No. of vil-lage	No. of Soil health cards distributed
222	5	90

Celebration of Jal Shakti Abhiyan

Jal Shakti Abhiyan were celebrated in two phases. First phase from 1st July to 15 September, 2019 and 2nd phase between 1st October to 30th November, 2019 for state with retiring monsoon.

There were 5 key interventions:

- Water conservation and rain water harvesting.
- Renovation of traditional and other water bod-ies/tank.
- Reuse of water and recharging of structure.
- Water shed development.
- Intensive aforestation.
- Awareness-cum-training was organized at KVK, Ramgarh (Fig. 22.8) and scientists gave training to farmers and other persons on water conservation, use of water for irrigation by mulching with drip irrigation method, con-struction a water body structure for rain water harvesting. Special training has also been given for SHGs workers at different village level for renovation of traditional and other bodies/tanks reuse bore well recharge structure, water shed

Fig. 22.8. Training of farmers on water conservation technology

development, intensive aforestation. During the period of training farm visit was also carried to demonstration unit of water conservation, soil and water conservation through mulching and drip irrigation and agroforestry model.

Live telecast of Animal Disease Control Programme, Artificial Insemination and *Swachahhata hi sewa hai*

A nationwide live telecast of "Animal disease control programme (FMD & brucellosis), artificial insemination and *swachahhata hi sewa hai* 2019" launched by Hon'ble PM, Shri Narendra Modi from Mathura (U.P.) was organized at Krishi Vigyan Kendra Ramgarh premises (Fig. 22.9). Mr. Jay Prakash Patel, Hon'ble MLA Mandu, Ramgarh (Jharkhand) was the Chief guest of the programme. He briefed the farmers about importance of vaccination, A.I. and health of animal. Smt. Phulmati Devi, Mukhiya Mandu Chatti Panchyat briefed about the role and importance of animal husbandry to doubling the farmer's income up to 2022. A vaccination camp and *kisan gosthi* were also organized in which 107 farmers and farm women of different villages of Ramgarh participated.

Fig. 22.9 Live telecast of Animal Disease Control Programme

Brihad Vriksharopan Abhiyan evam Krishak Sangosthi Karyakaram

A plantation awareness programme and *Kisan gosthi* was organized on 17th September 2019. Mr. Upendra Kumar Sah, DDM, NABARD, Ramgarh (Jharkhand) was the Chief guest of the programme. He emphasized on the importance of plantation and KCC loan. Dr. Indra Jeet, SMS (Agriculture extension), KVK, Ramgarh briefed about soil and water conservation. Dr. Dharamjit Kherwar, SMS (Horticulture) KVK, Ramgarh told about the contribution of tree plantation for a healthy and sound

Fig. 22.10. Celebration of *Brihad Vriksharopan Abhiyan*

environment. Mr. Sunny Ashish Balmuchu, SMS (Agro meteorology) advised farmers to cope with the changing climate scenario with respect to their agricultural practices. Mr. Sunil Lakra, Director, PNB, RSETI, Ramgarh told about crop insurance. In this programme, a tree plantation campaign and distribution of fruits and agroforestry plants to the farmers was also started. In this programme 120 farmers and farm women of different places of Ramgarh participated.

Live telecast of Fertilizer Application Awareness Programme

The live telecast of 'Fertilizer Application Awareness Programe' was organized at Krishi Vigyan Kendra Ramgarh premises. The programme was inaugurated by, Mr. Sanjay Kumar, District Agriculture Officer, Ramgarh (Jharkhand) as a Chief guest. He addressed to the farmers about balanced used of fertilizers and various government schemes.

Dr. Dushyant Kumar Raghav, I/c PC, KVK, Ramgarh welcomed all the farmers and the Chief guest and told about macro and micro plant nutrients and their role in plant growth and development. Dr. Indra Jeet, SMS, Agriculture extension spoke about new fertilizers type and response of soil to fertilizer application. Dr. Dharamjit Kherwar, SMS, Horticulture advised the farmers about use of soil health cards, right type and amount of fertilizers for crops. Mr. Sunny Ashish Balmuchu, SMS, Agro Meteorology explained about the present changing climate scenario and methods for sustainable production in adverse weather conditions. A *Kisan Gosthi* was also organized during the programe. More the 200 farm woman and farmers were participated from different villages of the district.

23. Awards and Recognitions

Awards and Recognitions

Anil Kumar Singh, '**Fellow of Indian Society of Plant Genetic Resources',** by the Indian Society of Plant Genetic Resources**,** New Delhi.

Arun Kumar Singh, '**Bidwat Alankaran Award**', by the Akhil Bharatiya Bidwat Parishad, Varanasi.

Asit Chakrabarti, '**Best Scientist in Livestock Production Management Award**', by the Udyaniki Krishi Anushandhan Samiti, Lucknow.

Asit Chakrabarti, '**Distinguished Scientist Award**', by the Science & Technology Society for Integrated Rural Improvement, Thorrur, Mahabubabad, Telengana.

BP Bhatt, '**Fellow of National Academy of Biological Sciences, Basic Science (Botany)-2018**', by the National Academy of Biological Sciences, Chennai.

Pankaj Kumar, '**Associateship of National Academy of Veterinary Sciences'**, by the National Academy of Veterinary Sciences, New Delhi.

SK Dwivedi, the '**R.D. Asana Gold Medal Award-2019'**, by the Indian Society for Plant Physiology, New Delhi.

TK Koley, '**Himadri Young Scientist Award',** by the Indian Society for Horticultural Research and Development, Almora.

Best Paper/Poster/Presentation Awards

Asit Chakrabarti, '**Agricultural Science Digest Reviewer Excellence Award'**, by the Agricultural Research Communication Centre, Karnal.

Asit Chakrabarti, '**Best Oral Presentation Award**' by the Science & Technology Society for Integrated Rural Improvement, Thorrur, Mahabubabad, Telengana in the National Conference on Doubling Farmers Income for Sustainable and Harmonious Agriculture, at BAU, Ranchi, Jharkhand during 10-11th August, 2019.

Asit Chakrabarti, '**Indian Journal of Animal Research Reviewer Excellence Award'**, by the Agricultural Research Communication Centre, Karnal.

Jaipal Singh Choudhary, '**Best Oral Presentation Award**' during the National Conference on Integrated Plant Health Management in Fruit Crops, held at ICAR- NRC on Litchi, Muzaffarpur, during 03-04th September, 2019.

JS Mishra, '**Indian Journal of Agricultural Research Reviewer Excellence Award',** by the Agricultural Research Communication Centre, Karnal

JS Mishra, **'Legume Research Reviewer Excellence Award'**, by the Agricultural Research Communication Centre, Karnal

Rajani Kumari, '**Best Oral Presentation Award**' in the National Seminar on "Biotechnological Advances for improving Animal Health and Productivity" held at College of Veterinary Science and Animal Husbandry, NAU, Navsari during 5-6th December, 2019.

Rajni Kumari, '**Best Oral Presentation Award**', by the Indian Society for Sheep and Goat Production and Utilization in the National Seminar on Current and Future Strategies for Augmenting Productivity of Small Ruminants, organized at BASU, Patna during 14-16th February, 2019.

Reena Kumari Kamal, '**Best Oral Presentation Award',** by the Indian Society for Sheep and Goat Production and Utilization in the National Seminar on Current and Future Strategies for Augmenting Productivity of Small Ruminants, organized at BASU, Patna during 14-16th February, 2019.

S Mondal, '**Best Paper Award**' in the International Conference on Soil and Water Resource Management for Climate Smart Agriculture, Global Food and Livelihood Security, organized by SCSI, New Delhi at NASC, New Delhi, India during 05-09th November, 2019.

SS Mali, '**Innovative Article Award**', by the Agriculture and Food: E-newsletter.

24. Publications

Research Papers

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able Increase in the Production of Pulses through Bio-agents at Bihar Sharif, Nalanda organized by Gramin Vikas Kendra, Bihar Sharif during 16-17 October, 2019.

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Singh AK, Kumar PR, Das B, Pan RS, Mali SS, Bhavana P, Yadav VK and Bhatt BP. 2019. Impact of agriculture research centre on vegetable cultivation scenario of eastern plateau and hill region of India: a case study. Paper presented in International Conference on Innovative Horticulture and Value Chain Management - Shaping Future Horticulture organized at DRPCAU Pusa, Samastipur, Bihar from 28-31 May, 2019.

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25. Personnel

Division of Crop Research

Scientists

Dr. J.S. Mishra, Pr. Scientist (Agronomy) & Head
Dr. A.K. Choudhary, Pr.Scientist (Plant Breeding)
Dr. Sanjeev Kumar, Pr. Scientist (Agronomy)
Dr. Shivani, Pr. Scientist (Agronomy)
Dr. Md. Monobrullah, Pr. Scientist (Entomology)
Dr. Narayan Bhakta, Pr. Scientist (Plant Breeding)
Dr. Santosh Kumar, Sr. Scientist (Plant Breeding)
Dr. Rakesh Kumar, Scientist (Agronomy)
Dr. S.K. Dwivedi, Scientist (Plant Physiology)
Mr. Ved Prakash, Scientist (Agril. Meteorology) (on study leave)
Mr. Karnena Koteswara Rao, Scientist (Soil Science)
Dr. Kirti Saurabh, Scientist (Soil Science)
Mr. Abhishek Kumar Dubey, Scientist (Plant Pathology)
Dr. N. Raju Singh, Scientist (Agroforestry)
Ms. Manisha Tamta, Scientist (Agricultural Meteorology)
Dr. Kumari Shubha, Scientist (Vegetable Science)
Dr. Rachna Dubey, Scientist (Environmental Science) w.e.f. 02.12.2019

Division of Livestock and Fishery Management

Scientists

Dr. Kamal Sarma, Pr. Scientist (Fishery) & I/c Head
Dr. A. Dey, Pr. Scientist (Animal Nutrition)
Dr. J.J. Gupta, Pr. Scientist. (Animal Nutrition) upto 31.10.2019
Dr. S. Dayal, Sr. Scientist (Animal Genetics & Breeding)
Dr. Pankaj Kumar, Sr. Scientist (Veterinary Medicine)
Dr. P.C. Chandran, Sr. Scientist (Animal Genetics and Breeding)
Dr. P. K. Ray, Scientist (Veterinary Pathology)
Dr. Rajni Kumari, Scientist (Animal Biotechnology)
Dr. Reena Kumari Kamal, Scientist (LPM)
Dr. Tarkeshwar Kumar, Scientist (Aquaculture)
Dr. Manoj Kumar Tripathi, Scientist (Animal Physiology) (on study leave)
Mr. Surendra Kumar Ahirwal, Scientist (Fisheries Resource Management)
Ms. Bavithra R, Scientist (FRM)
Sh. Jaspreet Singh, Scientist (FRM)
Dr. Jyoti Kumar, Scientist (Vet. Microbiology) w.e.f. 25.11.2019

Technical Officer

Dr. S. K. Barari, Chief Technical Officer
Sh. Dev Narayan, Technical Officer

Division of Land and Water Management

Scientists

Dr. S. K. Singh, Pr. Scientist (Agronomy) & I/c Head
Dr. A. Upadhyaya Pr. Scientist (SWCE)
Dr. A. Rahman, Pr. Scientist (Physics)
Dr. Anil Kumar Singh, Pr. Scientist (Agronomy)
Dr. Bikash Sarkar, Pr. Scientist (FMPE)
Dr. Ajay Kumar, Pr. Scientist (SWCE)
Dr. Manibhushan, Sr. Scientist (Comp. App.)
Dr. P.K. Sundaram, Scientist (FMP)
Dr. Surjit Mondal, Scientist (Soil Science)
Dr. Pawan Jeet, Scientist (L&WME)
Er. Akram Ahmed, Scientist (L&WME)
Mrs. Mridusmita Debnath, Scientist (L&WME)
Mrs. Arti Kumari, Scientist (L&WME) w.e.f. 12.04.2019

Division of Socio-Economics and Extension

Scientists

Dr. Ujjwal Kumar, Pr. Scientist (Agril. Extension) & Head
Dr. Abhay Kumar, Pr. Scientist (Agril. Statistics)
Dr. R.C. Bharati, Pr. Scientist (Agril. Statistics)

Dr. N. Chandra, Pr. Scientist (Agril. Economics)
Dr. Tanmay Kumar Koley, Scientist (Horticulture)
Dr. Dhiraj Kumar Singh, Scientist (Agril. Extension)
Dr. Anirban Mukherjee, Scientist (Agril. Extension)
Dr. Rohan Kumar Raman, Scientist (Agril. Statistics) w.e.f. 02.12.2019

Technical Officer

Mr. Sanjay Rajput, Technical Officer

Prioritization Monitoring & Evaluation Cell

Dr. Abhay Kumar, Pr. Scientist (Agril. Statistics) I/c PME Cell

Technical Officer

Mr. Sarfaraj Ahmad, Technical Officer (Computer)

ARIS Cell

Dr. R.C. Bharati, Pr. Scientist (Agril. Statistics) I/c ARIS

Technical Officer

Sh. Anil Kumar, Senior Technical Officer

Farm Section

Mr. Abhishek Kumar, Assistant Chief Technical Officer
Mr. P.K. Singh, Sr. Technical Officer
Mr. R.K. Tiwari, Technical Officer
Mr. A.S. Mahapatra, Technical Officer

Workshop and Estate Section

Sh. M.L. Swarnkar, Chief Technical Officer

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

Scientists

Dr. A.K. Singh, Pr. Scientist (Horticulture) & Head
Dr. R.S. Pan, Pr. Scientist (Horticulture)
Dr. B.K. Jha, Pr. Scientist (Horticulture)
Dr. Bikash Das, Pr. Scientist (Horticulture)
Dr. S. K. Naik, Pr. Scientist (Soil Science)
Dr. V.K. Yadav, Pr. Scientist (Agril. Extension)
Dr. P.R. Kumar, Pr. Scientist (Seed Technology)
Dr. S. Maurya, Sr. Scientist (Plant Pathology) upto 12.12.2019
Dr. Asit Chakrabarti, Sr. Scientist (LPM)
Dr. S.S. Mali, Sr. Scientist (SWCE)
Dr. P. Bhavana, Sr. Scientist (Plant Breeding)
Dr. J.S. Choudhary, Scientist (Entomology)
Ms. Reshma Shinde, Scientist (on study leave)
Mr. P.K. Sarkar, Scientist (Agroforestry)
Mr. M.K. Dhakar, Scientist (Fruits Science)
Dr. Tania Seth, Scientist (Vegetable Science) up to 15.11.2019

Technical Officers

Dr. G. P. Singh, Chief Technical Officer
Mr. Y.N. Pathak, Assistant Chief Technical Officer
Mr. Paul Sanjay Sircar, Assistant Chief Technical Officer (Computer)
Mr. Om Prakash, Senior Technical Officer (Civil)
Mr. Suresh Kumar, Senior Technical Officer (Farm)
Mr. Ganga Ram, Senior Technical Officer (Lab.)
Mr. Chandrakant, Senior Technical Officer (Lab.)
Mr. Chandra Shekher Prasad, Senior Technical Officer (Lab.)
Mr. B. P. Mishra, Senior Technical Officer (Farm) upto 30.11.2019.
Mr. Dhananjay Kumar, Technical Officer (Farm)
Mr. Arun Kumar, Technical Officer (Electrical)
Mr. Pradip Kumar Singh, Technical Officer (Lab.)
Mrs. Anima Prabha, Technical Officer (Press & Editorial)
Mr. Vijay Kumar Singh, Technical Officer (Lab.)
Mr. Manual Lakra, Technical Officer (Farm)
Mr. Dev Charan Kujur, Technical Officer (Mechanical)

ICAR RCER, Research Centre for Makhana, Darbhanga

Dr. I.S. Singh, Pr. Scientist (Soil Science) & I/c Head
Dr. B.R. Jana, Scientist (Horticulture)
Dr. Manoj Kumar, Scientist (Soil Science)
Mr. Shailendra Mohan Raut, Scientist (FRM)

ICAR RCER, Krishi Vigyan Kendra, Buxar

Subject Matter Specialists

Dr. V. Dwivedi, Sr. Scientist & PC upto 09.12.2019
Dr. Deokaran, SMS (Soil Science)
Mr. Ramkewal, SMS (Plant Protection)
Dr. Mandhata Singh, SMS (Agronomy)
Dr. Hari Govind Jaiswal, SMS (Plant Breeding)

Technicals

Mr. Arif Parwez, Farm Manager (T-5)
Mr. Afroz Sultan, Programme Assistant (Lab. Tech.)/ T-5
Mr. Vikash Kumar, Programme Assistant (Computer)/T-5

ICAR RCER, Krishi Vigyan Kendra, Ramgarh

Subject Matter Specialists

Dr. Dushyant Kumar Raghav, SMS (Plant Protection) & I/c PC
Dr. Indrajeet, SMS (Agril. Extension)
Dr. Dharmjeet Kherwar, SMS (Agroforestry/ Horticulture)

Technical

Shri Sunny Kumar, Farm Manager

Administration & Finance Section

Mr. Pushpanayak, Chief Administrative Officer
Mr. Ajay Kumar Soni, Sr. Administrative Officer
Mr. Vipul Raj, Administrative Officer
Mr. K.K. Lal, Junior Account Officer
Mrs. Prabha Kumari, AAO (P)
Mr. Ravi Shankar, Assistant
Mr. Rakesh Mani, Assistant
Mr. Md. Sajid Mustaque, Assistant
Mr. Madan Paswan, Assistant
Ms. Divyadarshini, Assistant
Mr. Nagendra Kumar, Assistant w.e.f. 01.10.2019

New Joining

Scientists

Mrs. Arti Kumari, Scientist w.e.f. 12.04.2019
Dr. Jyoti Kumar, Scientist (Vet. Microbiology) w.e.f. 25.11.2019
Dr. Rachana Dubey, Scientist (Environmental Science) w.e.f. 02.12.2019
Dr. Rohan Kumar Raman, Scientist (Agril. Statistics) w.e.f. 02.12.2019

Technical

Mr. Sanjay Kumar, Technical Assistant (Library) w.e.f. 04.05.2019

Administration

Mr. Nagendra Kumar, Assistant w.e.f. 01.10.2019
Mr. Keshav Kumar, Assistant w.e.f. 14.10.2019

Promotion

Scientists

Dr. Manibhushan, Scientist (Computer Application) promoted to Scientist (Level-13A) w.e.f. 30.12.2013
Dr. Pankaj Kumar, Sr. Scientist (Vet. Med.) promoted to Sr. Scientist (Level- 13A) w.e.f. 08.01.2019
Dr S.J. Pandian, Scientist (Ve. Med.) promoted to Scientist (Level-12) w.e.f. 08.01.2017
Dr. S.S. Mali, Scientist (SWCE) promoted to Sr. Scientist (Level- 12) w.e.f. 12.06.2017.
Dr. P. Bhavana, Scientist (Plant Breeding) promoted to Sr. Scientist (Level- 12) w.e.f. 21.04.2018.
Dr. Santosh Kumar, Scientist (Plant Breeding) promoted to Sr. Scientist (Level- 12) w.e.f. 23.06.2018
Dr. P.K. Sundaram, Scientist (FMP) promoted to Scientist (Level- 11) w.e.f. 15.12.2014

Technicals

Mr. Abhishek Kumar, Sr. Technical Officer promoted to Assistant Chief Technical Officer w.e.f. 05.04.2016
Late Sunil Rajak, Sr. Technical Assistant promoted to Technical Officer w.e.f. 15.09.2017

Transfers

Dr. Tania Seth, Scientist (Vegetable Science) transferred to ICAR-CIBA, Bhubaneshwar w.e.f. 16.11.2019
Dr. V. Dwivedi, Sr. Scientist & PC, KVK, Buxar transferred to KVK, Bhadoi w.e.f. 10.12.2019
Dr. S. Maurya, Scientist (Plant Pathology) transferred to ICAR-IVRI, Varanasi w.e.f. 13.12.2019.

Retirements

Dr. J.J. Gupta, Pr. Scientist. (Animal Nutrition) upto 31.10.2019
Dr. S.K. Singh, Pr. Scientist (Agronomy) upto 31.12.2019
Mr. B. P. Mishra, Senior Technical Officer (Farm) upto 30.11.2019
Mr. Bisheshwar Oraon, SSS w.e.f. 30-06-2019
Mrs. Bigni Kachhap, SSS w.e.f. 31.07.2019
Ms. Sumi Lakra, SSS w.e.f. 31.08.2019
Mrs. Ratni Toppo, SSS w.e.f 31.12.2019

26. On-going Research Projects

Theme wise Ongoing and New Institute Research Projects 2019

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start Year	Comp. Year	Funding agency
Theme 1. Farming System research including Climate resilient agriculture						
1	**Integrated Farming System and Cropping system for Eastern Region**					
1.1	ICAR-RCER/ AICRP/ IFS/EF/ 2010/ 25(i)	Development of location specific Integrated Farming System models for small and marginal farmers of Bihar	Sanjeev Kumar A. Dey U. Kumar N. Chandra R.K. Kamal K.K. Rao Kirti Saurabh	June 2010	Mar. 2020	IIFSR, AICRP (Externally funded)
1.2	ICAR-RCER/ RC Ranchi/ 2011/ 25(iii)	Development of location specific Integrated Farming System models for rainfed eco-system of Eastern Plateau Hill region	M.K. Dhakar P.R. Kumar S.K. Naik A. Chakrabarti	June 2011	July 2019 Extd. 2020	ICAR RCER
1.3	ICAR-RCER/ DLWM/ 2016-17/ 182	Evaluation and optimization of IFS	Manibhushan Sanjeev Kumar S.S. Mali R.C. Bharati Akram Ahmed	2016	2019 Extd Aug 2020	ICAR RCER
1.4	ICAR-RCER/ RC Makhana/ 2014-15/ 157	Introduction of sweet flag and tuber vegetable crop under wetland ecosystem with makhana crop for north Bihar	B.R. Jana	July 2014	June 2019 Extd 2020	ICAR RCER
1.5	ICAR-RCER/ RC Ranchi/ 2014/147	Development of multi-tier cropping system for rainfed uplands of eastern plateau and hills	M.K. Dhakar Bikas Das	Sept. 2014	Sept. 2019 Extd. 2020	ICAR RCER
1.6	ICAR-RCER/ DLWM/ 2016/ 193	Eco-energetic analysis of different cropping system in Eastern India.	Bikash Sarkar Ajay kumar S.S. Mali Rakesh Kumar	July 2016	June 2019 Extd 2020	ICAR RCER
1.7	ICAR-RCER/ DCR/2019/ **204**	Structure and functioning of agro-forestry systems in middle IGP	N. Raju Singh S. K. Naik A. Raizada	2018	2021	ICAR RCER
1.8	New	Evaluation of Zero Budget Natural Farming (ZBNF) for Eastern Plateau and Hill Region	B.K. Jha S.K. Naik S. Maurya J.S. Choudhary	2019	2024	ICAR-RCER
2	**Resource Conservation Technology**					
2.1	ICAR-RCER/ DCR/EF/2015/ **40**	Evaluation of Conservation Agricultural (CA) practices under Rice-fallow system of Eastern Region	J. S. Mishra K. K. Rao S. K. Singh B. K. Jha S. K. Naik S.S. Mali Rakesh Kumar	2015	2020	Consortium Research Platform on CA (ICAR)

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start Year	Comp. Year	Funding agency
2.2	ICAR-RCER/ DCR/ 2011/ **104**	Evaluation of different production system for Carbon sequestration potential	S.K. Naik S. Maurya Shivani K.K. Rao	July 2011	June 2017 Extd 2020	ICAR RCER
2.3	ICAR-RCER/ DCR/ 2017/ **192**	Nitrogen and carbon mineralization dynamics of rice-wheat system in EIGP	Kirti Saurabh Rakesh Kumar	July, 2017	June, 2019 Extd 2020	ICAR RCER
2.4	ICAR-RCER/ DCR/EF/2016	Cereal Systems Initiative for South Asia (CSISA) Phase III	J.S. Mishra Md. Monobrullah Rakesh Kumar S.K. Dwivedi Kirti Saurabh Surajit Mondal M. Debnath	2016	2020	CIMMYT
2.5	ICAR-RCER/ RC Ranchi/2011/ **196**	Evaluation of leaching loss of nutrients in acidic soils of Jharkhand under different cropping systems	S. K. Naik S. S. Mali	Oct 2018	Sept, 2021	ICAR RCER
2.6	New	Network project on Conservation of lac insect genetic resources (NPCLIGR)	Md. Monobrullah	Jan 2019	Mar 2020	ICAR
2.7	New	Impact of tillage, residue manage-ment and crop rotation on soil health and crop productivity in rice-fallow system of Eastern India	Kirti Saurabh J.S. Mishra	2019	2021	ICAR-RCER
3	**Climate resilient agriculture**					
3.1	ICAR-RCER/ RC Ranchi/ 2011/**29**	Understanding the changes in host-pest interactions and dynamics in mango under climate change scenario (NICRA)	Bikash Das J.S. Choudhary S. Maurya S.S. Mali M.K.Dhakar	Jan. 2011	Mar. 2019	NICRA (Externally funded)
3.2	ICAR-RCER/ EF/ 2011/**29**	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)	N. Bhakta J.S.Mishra K.K. Rao S.K. Dwivedi Manisha Tamta	July 2014	Mar 2020	NICRA (Externally funded)
3.3	ICAR-RCER/ DCR/ 2016-17/ **181**	Diversification of rice-wheat system through climate resilient cropping in Eastern India.	Rakesh Kumar J.S. Mishra N. Chandra R.S. Pan Kirti Saurabh	2016	2019 Extd 2020	ICAR RCER
3.4	ICAR-RCER/ DCR/EF/2016	Developing and defining climate smart agriculture practices portfolios in South Asia (CCAFS)	K.K. Rao Rakesh Kumar Manoj Kumar	2016	Dec. 2019	CIMMYT
3.5	ICAR-RCER/ DCR/EF/2016	Development of climate resilient farming system models for livelihood improvement	Md. Monobrullah Sanjeev Kumar Bikash Das Pankaj Kumar Manoj Kumar Ravi Kumar D.K. Singh A. Raizada Manisha Tamta Pawan Jeet	Nov. 2016	Dec. 2019	NMSA, DAC & FW, Ministry of Agriculture & Farmers' Welfare, Govt. of India

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start Year	Comp. Year	Funding agency
3.6	ICAR-RCER/ RC Ranchi/ 2018/ **214**	Diversification of existing upland production systems with tuber crops in eastern Plateau and Hill region	R.S. Pan Tania Seth S.K. Naik	July 2018	June 2021	ICAR RCER
3.7	ICAR-RCER/ DCR/ 2018/ **208**	Effect of drought and heat stress on wheat : changes in plant physiological traits and yield attributes	S.K. Dwivedi Santosh Kumar Manisha Tamta M. Monobrullah	2018	2021	ICAR RCER
3.8	ICAR-RCER/ DCR/ 2018/ **213**	Simulating production potential of rice and wheat under changing climate over Bihar	Manisha Tamta R.C. Bharati Shivani S.K.Dwivedi Pawan Jeet	2018	2021	ICAR RCER
Theme- 2. Genetic Resource Management and Improvement of Field, Horticultural and Aquatic crops						
4	**Varietal Development**					
4.1	ICAR RCER/ FF /2011/ **30**	Evaluation and development of drought tolerant rice for Eastern region (STRASA Phase-III)	Santosh Kumar S. K. Dwivedi J.S. Mishra N. Bhakta K.K. Rao Rakesh Kumar Abhishek Dubey M. Monobrullah Mandhata Singh	April 2014	Feb. 2019 Extd 2020	IRRI (Externally funded)
4.2	ICAR-RCER / HARP/ 2001/ **03**	Plant genetic resource and improvement of fruit and ornamental crops	M.K. Dhakar Bikash Das J. S. Choudhary D. Kherwar S. Maurya	2001	Long term	ICAR RCER
4.3	ICAR-RCER/ DCR/ 2014/**160**	Breeding for submergence tolerance in rice	N. Bhakta Santosh Kumar S. K. Dwivedi	July 2014	June 2019 Extd 2020	ICAR RCER
4.4	ICAR-RCER/ RC Ranchi/ 2015/**171**	Improvement of seed quality of solanaceous and cucurbitaceous vegetables	P. R. Kumar S. Maurya	Aug 2015	Aug 2020	ICAR RCER
4.5	ICAR-RCER/ RC Ranchi/ 2015/**172**	Genetic improvement for yield and biotic stress resistance in pigeonpea under eastern plateau and hill region	P. Bhavana A.K. Choudhary S. Maurya J.S. Chaudhary	July 2015	June 2019 Extd 2020	ICAR RCER
4.6	ICAR-RCER/ RC Ranchi/ 2015/**173**	Collection, evaluation and development of bacterial wilt resistant germplasm of brinjal	P. Bhavana A. K. Singh S Maurya	Aug. 2015	Dec 2019	ICAR RCER
4.7	ICAR-RCER/ RCM/ 2015/	Evaluation of different genotypes of water chestnut	B.R. Jana I.S. Singh Manoj Kumar	2015	2020	ICAR RCER
4.8	ICAR-RCER/ RC Ranchi/ 2017/**215**	Genetic resource management in vegetable crops	A.K. Singh P. Bhavna R. S. Pan V.K. Yadav	Sept 2017	Long term project	ICAR RCER
4.9	ICAR-RCER/ DCR/EF 2017/	Identification of traits, genes, physiological mechanisms to develop climate smart varieties for unfavourable environment	S.K. Dwivedi Santosh Kumar	2017	2022	IRRI
4.10	New	Development of nutrient rich lines of pulse legumes for eastern India	A.K. Choudhary Kirti Saurabh	Sep. 2019	Aug. 2022	ICAR-RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start Year	Comp. Year	Funding agency
4.11	New	Evaluation, characterization and identification of rice genotypes for combine tolerance to drought and submergence	Santosh Kumar N. Bhakta S.K. Dwivedi	July 2019	June 2023	ICAR-RCER
4.12	New	Development of multiple disease resistant hybrids in solanaceous vegetables	P. Bhavana P.K. Sarkar	2019	2024	ICAR-RCER
4.13	New	Collection Characterization and Evaluation of Water Spinach (Kalmi), Malabar Spinach (Basella) and Pigweed (Bathua) genotypes in Eastern India	Tania Seth Kumari Shubha R.S. Pan	2019	2023	ICAR-RCER
Theme- 3. Improved Production and Protection Technologies for Agri-Horti Crops						
5	**Production Technologies**					
5.1	ICAR-RCER/ RC Ranchi/ 2014/**151**	Standardization of basin enrichment in high density orchards of bael, sapota and guava under eastern plateau and hill region	Bikash Das S.K. Naik S. Maurya M.K. Dhakar	Aug. 2014	July 2017 Extd 2020	ICAR RCER
5.2	ICAR-RCER/ DCR/ 2015/**163**	Integrated weed manage-ment in rice-wheat system.	Sanjeev Kumar J.S. Mishra	2015	2020	ICAR RCER
5.3	ICAR-RCER/ DLWM/ 2016/ **194**	Ergonomic study of farmers' friendly farm implements in Eastern region.	Bikash Sarkar Rakesh Kumar P.K.Sundaram	2016	2019	ICAR RCER
5.4	ICAR-RCER/ DCR/ 2017/ **212**	Diversification of rice-wheat system with vegetables	Shivani Kirti Saurabh Shubha Kumari	2017	2021	ICAR RCER
5.5	--	Creation of seed hubs for increasing indigenous production of pulses in India	A.K. Choudhary P.R. Kumar (RC, Ranchi) I.S. Singh (RCM, Darbhanga) Hari Govind (KVK, Buxar)	2016	2020	ICAR
5.6	ICAR-RCER/ RC Ranchi/ 2018/**206**	Development of year round seed production techno-logies in chillies (*Capsicum annum* L.) for Jharkhand	P. R. Kumar	Apr 2018	Mar 2020	NABARD (Externally funded)
5.7	ICAR-RCER/ RC Ranchi/ 2018/	Enhancing food, nutritional and livelihood security of marginal and tenant farmers in Jharkhand through need based agricultural technologies	Bikash Das P. R. Kumar S. Murya V.K. Yadav	June 2018	Mar 2020	Farmer FIRST Project (Externally funded)
5.8	ICAR-RCER/ DSEE/ 2018/	Performance evaluation of medicinal and aromatic plant in EIGP	T.K. Koley N.Raju Singh N.A.Gajbhiye (DMAPR, Anand)	July 2018	June 2021	ICAR-RCER
5.9	New	Scope of low cost vertical farming with particular reference to microgreens	T.K. Koley N. Raju Singh	Sep. 2019	Aug. 2022	ICAR-RCER
5.10	New	Response of nutrients on productivity of water chestnut and Indian lotus	I.S. Singh Manoj Kumar	Aug 2019	July 2022	ICAR-RCER
5.11	New	Effect of different intercultural practices on biochemical constituents of makhana seed	B.R. Jana Manoj Kumar	Aug 2019	July 2022	ICAR-RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start Year	Comp. Year	Funding agency
5.12	New	Effect of secondary and micronutrients on yield and quality of makhana in field condition	Manoj Kumar I.S. Singh S.M. Raut	Aug 2019	July 2022	ICAR-RCER
5.13	New	Enhancing nutritional security of rural households through vegetable based Nutri garden in Bihar	Kumari Shubha T.K. Koley	Oct. 2019	Sep. 2022	ICAR-RCER
6.0	**Protection Technologies**					
6.1	ICAR-RCER/ RC Ranchi/ 2018/**199**	Management of wilt complex in leguminous and cucurbitaceous crops of eastern region	S. Maurya A.K. Dubey	2018	2021	ICAR-RCER
6.2	ICAR-RCER/ RC Ranchi/ 2018/**198**	Seasonal incidence and evaluation of management strategies against insect- pests of cauliflower and chilli	Jaipal Singh Choudhary D.K. Raghav Md. Monobrullah Rakesh Kumar	2018	2021	ICAR-RCER
6.3	ICAR-RCER/ DCR/ 2018/**217**	Development of native *Trichoderma* based bioformulations for management of soil-borne diseases	A.K. Dubey A.K. Choudhary Kirti Saurabh	2018	2021	ICAR-RCER
6.4	New	Studies on weed and seed bank dynamics in different cropping systems in the middle Indo Gangetic Plains	Sanjeev Kumar J.S. Mishra Rakesh Kumar N. Raju Singh	Nov. 2019	Oct. 2022	ICAR-RCER
Theme- 4. Integrated Land & Water Management						
7.0 Land & Water Management						
7.1	ICAR-RCER / DLWM/ 2015S/**178**	Development of bio-drainage in participatory mode under waterlogged area	S.K. Singh S.K. Dwivedi Ajay Kumar	July 2014	June 2022	ICAR RCER
7.2	ICAR-RCER / DLWM/ 2014/**176**	Solar energy utilization in agriculture (i) Design and assessment of solar powered aerator for fish pond (ii) Assessment of solar energy operated micro-irrigation system in mango and guava orchards (iii) Design and assessment of solar humidifier for animal shed (iv) Design and assessment of solar watering system for animal shed.	A. Rahman Kamal Sarma Ajay Kumar B. Sarkar	Aug. 2014	July, 2019 Extd 2020	ICAR RCER
7.3	ICAR-RCER /RC Ranchi/ 2014/**150**	Rehabilitation of coal mine affected areas through agroforestry interventions	M.K. Dhakar S.S. Mali Bikash Das D. Kherwar	Sept 2014	Aug 2019 Extd 2020	ICAR RCER
7.4	ICAR-RCER/ RC Ranchi/ 2018/**197**	Study on growth stage based fertigation pattern and crop geometry in cucurbits in EPHR condition	B. K. Jha S. S. Mali S. K. Naik	2018	2021	ICAR-RCER
7.5	ICAR-RCER/ RC Ranchi/ 2018/210	Design, development and performance evaluation of solar powered agricultural equipment	S.S. Mali J.S. Choudhary P.K. Sundaram	2018	2021	ICAR-RCER
7.6	ICAR-RCER/ DLWM/ 2018/ **205**	Water productivity assessment in major cropping systems of Eastern India	M. Debnath J. J. Gupta Rakesh Kumar Santosh Kumar N Bhakta Akram Ahmed	July 2018	June 2021	ICAR-RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start Year	Comp. Year	Funding agency
7.7	ICAR-RCER/ DLWM/ 2018/	Design and development of peripatetic fish vending cart with solar aerator	P.K Sundaram B. Sarkar A. Rahman S.K. Ahirwal	July 2018	June 2021	ICAR-RCER
7.8	ICAR-RCER/ DLWM/ 2018/	Improving rabi/ summer maize productivity through efficient land and water management	Anil. K. Singh A. Upadhyaya Manoj Kumar	July 2018	June 2021	ICAR-RCER
7.9	ICAR-RCER/ DLWM/ 2018/**211**	Assessment of land use and land cover change for crop planning using remote sensing and GIS of East Champaran district.	Manibushan A. Raizada A.K.Singh	2018	2021	ICAR-RCER
7.10	ICAR-RCER/ DLWM/ 2018/	Water conser-vation under different irrigation and tillage management in rice based cropping system	S. Mondal Rakesh Kumar	Oct. 2018	Sep. 2021	ICAR-RCER
7.11	ICAR-RCER/ DLWM/ 2018/	Optimization of cropping pattern to maximize water productivity	A. Upadhyaya Akram Ahmed Anil K. Singh S. Mondal	Jan. 2019	June 2022	ICAR-RCER
7.12	ICAR-RCER/ DLWM/ 2018/	Studies on irrigation water pricing and influencing factors	A. Upadhyaya Pawan Jeet M.Debnath S. Mondal	Jan. 2019	June 2022	ICAR-RCER
7.13	--	Evaluation of irrigation system and improvement strategies for higher water productivity in Sone Canal Command (AICRP on Water)	Ajay Kumar S.K. Singh A. Rahman Manibhushan Pawan Jeet Mani Kumar (WALMI)	Dec 2014	Mar 2020	ICAR
7.14	New	Standardization of fertigation schedule in high density guava under middle Gangetic plains	Akram Ahmed Ajay Kumar	Oct 2019	Sep 2022	ICAR-RCER
Theme- 5. Livestock & Fisheries Management						
8.0 Livestock and Avian Management						
8.1	ICAR-RCER / DLFM / 2011/ **106**	Formulation of area specific mineral mixture for Bihar based on Soil-plant-animal continuum	A. Dey J.J. Gupta S.K. Naik P. K. Ray	Aug. 2011	July 2019 Extd 2021	ICAR RCER
8.2	ICAR-RCER / DLFM/EF/ 2011/ **31**	Network project on Buffalo improvement	P.C. Chandran A. Dey Pankaj Kumar R.K. Kamal M.K. Tripathi P.K. Ray	June 2012	Dec. 2020	ICAR RCER
8.3	ICAR-RCER / DLFM/ 2013/ **135**	Characterization of lesser known breeds of farm animals in Eastern India	P.C. Chandran Shanker Dayal Reena K.Kamal	July 2013	June 2019 Extd 2021	ICAR RCER
8.4	ICAR-RCER/ DLFM/ 2015/**165**	Meso level animal health interventions and evaluating economic losses from animal diseases	Pankaj Kumar P.K. Ray Abhay kumar S.K. Barari	Aug 2015	July 2019	ICAR RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start Year	Comp. Year	Funding agency
8.5	ICAR-RCER/ DLFM/ 2015/**175**	Characterization and evaluation of duck germplasm in Eastern region.	Reena K.Kamal P.C. Chandran P. K. Ray	Aug 2015	Aug 2020	ICAR RCER
8.6	ICAR-RCER/ DLFM/ 2018/**202**	Assessing genetic variability in ducks of eastern states	S. Dayal P.K. Ray Rajni Kumari R. K. Kamal	2018	2022	ICAR RCER
8.7	ICAR-RCER/ DLFM/ 2018/**209**	Molecular epidemiology and therapeutic management of bovine Theileriosis	Pankaj Kumar P.K. Ray NIAB, Hyder-abad IIT, Guwahati,	2018	2021	ICAR RCER
8.8	--	Studies on development of method for early pregnancy diagnosis in buffalo	Rajni Kumari S. Dayal P.C. Chandran Scientist from BASU, Patna	2018	2022	ICAR RCER
8.9	--	AICRP on goat	A. Dey P.C. Chandran P.K. Ray R.K. Kamal	2018	2020	Exter-nally funded
8.10	--	Outreach programme on zoonotic diseases	P.K. Ray Rajni Kumari Scientist from BASU, Patna	2018	2020	IVRI (Ex-ternally funded)
8.11	New	Development of meat and egg strains of duck suitable for backyard farming	P.C. Chandran R K Kamal A. Dey Rajni Kumari A.R. Sen	2019	2024	ICAR-RCER
8.12	New	Effect of genetic and non-genetic factors on prolificacy of Bengal goat	R. K. Kamal A. Dey P.C. Chandran Rajni Kumari P.K. Ray	Aug. 2019	July 2023	ICAR-RCER
8.13	New	Evaluation of different tree leaves as fod-der for goats	A. Chakrabarti P.K. Sarkar	2019	2022	ICAR-RCER
9.0 Fisheries Management						
9.1	--	National Surveillance Programme for Aquatic Animal Disease (NSPAAD)	Kamal Sarma Dr. Tarkeshwar Kumar Dr. P.K. Ray S.K.Ahirwal	Nov. 2015	Sep. 2019	NFDB
9.2	ICAR-RCER/ DLFM/ 2016/**183**	Formulation of mineral mixture for Indian Major carps based on soil-water and fish continuum	Tarkeshwar Kr Kamal Sarma Ravi Kumar S.K.Ahirwal Bavithra R.	2016	2019 Extd 2020	ICAR RCER
9.3	ICAR-RCER/ DLFM/ 2016/**185**	Assessment of Ichthyofaunal biodiversity and stock assessment of the selected fish species from wetland ecosystems.	Ravi Kumar Tarkeshwar Kr S.K. Ahirwal	2016	2019	ICAR RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start Year	Comp. Year	Funding agency
9.4	ICAR-RCER/ DLFM/ 2018/**201**	Culture potential of selected Indian minor carp	S.K. Ahirwal T. Kumar Ravi Kumar Kamal Sarma Jaspreet Singh	2018	2021	ICAR RCER
9.5	New	Biofloc technology: Exploring production optimization and economic viability for the Eastern region	Jaspreet Singh Bavithra R.	Sep 2019	Aug 2022	ICAR-RCER
9.6	New	Economic feasibility of integrated prawn cum fish farming in Polyculture system in Eastern region	Bavithra R. Jaspreet Singh	Sep. 2019	Aug. 2022	ICAR-RCER
9.7	New	Assessment of fish diversity and production potential in lentic inland ecosystems of North Bihar	S.M. Raut I.S. Singh Ravi Kumar Jaspreet Singh	Aug 2019	July 2022	ICAR-RCER
Theme- 6. Socio-Economics, Extension and Policy Research						
10.0 Socio-economic Research						
10.1	ICAR-RCER/ DSEE/ 2014/**184**	Growth and instability in production of principal crops in Eastern India	Abhay Kumar N. Chandra R.C. Bharati Dhiraj K.Singh	July, 2017	June, 2021	ICAR RCER
10.2		Socio-economic characterization of farmers in Bihar & Jharkhand	V. K. Yadav Pankaj Kumar Ujjwal Kumar R. C. Bharati	2017	2020	ICAR RCER
10.3	ICAR-RCER/ DSEE/ 2017/**189**	Production and value chain analysis of makhana	D.K. Singh Abhay Kumar N. Chandra I.S. Singh	2017	2020	ICAR RCER
10.4	ICAR-RCER/ DSEE/ 2018/**207**	Transfer and adoption of improved agricultural technologies	Ujjwal Kumar D.K. Singh Sanjeev Kumar M.K. Dhakar J.S. Choudhary	2018	2021	ICAR RCER
10.5	ICAR-RCER/ DLWM/ EF/ 2018/ **41**	Evaluation of farm implements and tools for small land holders	Bikas Sarkar Ujjwal Kumar P.K. Sundaram S.S. Mali Ramkewal D.K. Raghav	2018	2020	ICAR RCER
10.6	--	Value addition of principal food grains by farmers of Bihar	N. Chandra Ujjwal Kumar D.K. Singh P.K. Sundaram R.C. Bharati	2018	2021	ICAR RCER
10.7	ICAR-RCER/ DSEE/ 2018/**216**	Status of food and nutritional security of rural households in Eastern India	A. Mukherjee Shubha Kumari V.K.Yadav Tania Seth	Oct. 2018	Sep. 2021	ICAR-RCER

10.8	--	Establishment of Biotech-KISAN Hub at ICAR RCER	Pawan Jeet B. Das S. Mondal A. Mukhrjee N. Raju Singh P.K. Ray Reena K. kamal S. Maurya J.S. Choudhary S.S. Mali D.K. Raghav, KVK Ramgarh Indrajeet, KVK Ramgarh D. Kherwar, KVK Ramgarh R.K. Singh, KVK, Hazaribagh S.K. Singh, KVK, Hazaribagh S.L. Yadav, KVK, Hazaribagh Ajit K. Singh, KVK, Ranchi B. Mahto, KVK, Ranchi	July 2019	June 2021	DBT
10.9	New	Status of utilization of digital tools in agriculture sector in Eastern India	R.C. Bharati Ujjwal Kumar N. Chandra D.K. Singh R.K. Raman PC, KVK Buxar Indrajeet, SMS, KVK Ramgarh	Oct. 2019	Sep. 2024	ICAR-RCER

New and ongoing activities- 2019

Sl. No.	Title of Activities	PI
New Activities		
1.	Effect of 2-combination of organic waste on water quality & fish productivity	Kamal Sarma
2.	Evaluation and identification of rice genotypes for tolerance to drought stress at different growth stages.	Santosh Kumar
3.	Fe and Zn fortification in rice (*Oryza sativa* L.) varieties under drought condition for nutritional security in Eastern India	Kirti Saurabh
4.	Effect of seed size of makhana with respect to its production potential	I.S. Singh
5.	Maintenance of advance breeding lines of cool season pulses	A.K. Choudhary
6.	Seed production and evaluation of T&D breeds of pigs in Jharkhand	A. Chakrabarti
7.	Evaluation of backyard poultry farming	A. Chakrabarti
Ongoing Activities		
8.	Genetic enhancement of Tomato for nematode and bacterial wilt resistance through Molecular markers	P. Bhavana
9.	Development of Farm Machinery Information System	P.K. Sundaram
10.	Design and development of makhana grader	P.K. Sundaram
11.	Design and development of low cost irrigation system for smart farming	Akram Ahmed
12.	Multi-objective optimization of integrated farming system	Akram Ahmed
13.	Assessment of soil health under different land use systems	Surajit Mondal

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