Annual Report
2018-19

भाकृअनुप
ICAR

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 bring out the 18th Annual Report of ICAR Research Complex for Eastern Region, Patna for the year 2018-19, highlighting the significant research achievements and activities of the Institute. The Institute undertakes multi-commodity and multi-disciplinary research to enhance the productivity of agricultural production systems, efficient management of available natural resources and dissemination of developed technologies in diverse agro-climatic zones of eastern region.

To address the emerging needs of the farmers, 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 2018-19, 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, crop diversification, water productivity enhancement, ergonomic studies of farm tools, weed management, restoration of degraded lands, solar energy application in agriculture, characterization of lesser known breeds of livestock, poultry and duck, animal health, disease diagnosis and management, development of area-specific mineral mixtures, fish-based integrated farming systems, etc. Integrated farming systems have been developed for rainfed, irrigated, hill and plateau and waterlogged situations. Hybrid model has been developed for predicting the incidence of mango hoppers in South Konkan region.

In order to strengthen the plant genetic resource management, promising genotypes of different fruits like, tamarind, sapota, jackfruit, and improved lines of makhana, water chestnut, and pulses like pigeonpea, lentil, chickpea and grass pea have been identified. Underutilized leafy vegetables from West Bengal, Odisha and Jharkhand have been collected and characterized for nutritional quality. 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 viz., *Medini* cattle and *Medini* goat of Jharkhand was studied and characterized. Milk production of Black Bengal goat was studied in relation to litter size. 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 grid connected Solar Rooftop Power Plant of capacity 100 kWp was installed on the rooftop of office building.

The institute has also been providing technological support to the farmers, extension workers and state officials through its extensive extension network. 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 144 training programmes, 25 Front Line Demonstrations, and 10 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 125 nos. of research papers in the journals of national and international repute, 05 books, 40 book chapter, 03 bulletins, and 21 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 on 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 2018-19 are summarized below:

- Eight rice genotypes *viz.*, IR 90257-B-577-1-1–B, IR 95817-5-1-1-2, IR 107891-B-B-447-3-1, IR14L157, IR 107891-B-B-1284-2-1, IR14L362, IR 106312-50-1-1-1and IR14L613 have been found promising for drought tolerance at reproductive stage with productivity range of 3.32-4.05 t/ha compared to check variety Sahbhagi Dhan (3.03 t/ha).
- Thirty two rice genotypes were evaluated under direct seeded aerobic condition. Rice genotypes IR84899-B-179-13-1-1-1, IR 88964-24-2-1-4 , IR14L572, IR14L360, Swarna Shreya, IR 84899-B-184-16-1-1-1, IR 84899-B-185-8-1-1-1, IR 93827-29-1-1-3, IR 97073-26-1-1-3, and IR84898-B-165-9-1-1were identified promising for aerobic condition with productivity range of 5.33-5.69 t/ha.
- Under rainfed shallow lowland, rice genotypes RP5366-13 (7.58 t/ha) and RP5377-9 (7.10 t/ha) performed significantly better than the highest yielding check Swarna (6.81 t/ha). These genotypes have been nominated to AICRIP as RCPR67-RP5484 and RCPR67-RP5366, respectively.
- Six genotypes *viz.*, IR 95817-5-1-1-2, IR 107891-B-B-1216-1-1, IR 106312-50-1-1-1, IR14L613, IR 93827-29-1-1-4 and IR14L157 have been identified as tolerant to false smut; brown spot, sheath rot, sheath blight, bacterial leaf blight and leaf blast.
- Weed suppressing ability of rice genotypes was evaluated under field conditions. Hybrids *viz.*, Arize 6444, Arize Dhani and Arize 6129 were more tolerant to increase in weed pressure and produced higher grain yield (3.97-4.37 t/ha) as compared to varieties *viz.*, Swarna Shreya, Rajendra Sweta and MTU 7029 (1.66-2.30 t/ha).
- Pigeonpea genotypes RCEA-14-1, RCEA-14-5 and RCEA-14-6 showed cleistogamous with non-diadelphous condition of stamens and no out crossing was reported in them. IPA-203 recorded the highest yield of 6.0 t/ha followed by Type-7 (5.48 t/ha).
- The advance chickpea breeding lines namely 'DBGC 1', 'DBGC 2', 'DBGC 3' and 'DBGC 4' with seed yield of 2.78-2.87 t/ha have been found resistant to wilt (*Fusarium ciceri*). Similarly grass pea genotypes 'RCEGP 16-2' with seed yield of 1.3 t/ha was found promising for North East Plain Zone. A white flowered genotype 'RCEGP 16-1' (an spontaneous mutant selected from an ICARDA line 63101) recorded the lowest ODAP content (0.13%).
- Tamarind genotype ICAR RCER TS 3/1, sapota variety Murabba and jackfruit genotypes ICAR-RCER JS 6/3, 3/8, 7/7 and 10/3 have been found promising in Eastern Plateau & Hill Region.
- In tomato, crosses *viz.*, HAT-296 x HAT-311, Swarna Lalima x HAT-311 and HAT-296x HAT-310 were promising in terms of yield, quality and resistance to bacterial wilt and root knot nematode.
- In garden pea, test entries 2016/PEVAR-6 (21.22 t/ha) and 2016/PEVAR-2 (20.42 t/ha) for early season and 2016/PMVAR-5 (22.52 t/ha) and 2016/PMVAR-4 (20.67 t/ha) for the mid season were found promising in respect of marketable green pod yield.
- Underutilized leafy vegetables from West Bengal, Odisha and Jharkhand were collected and characterized for nutritional quality. Leafy vegetables *Celosia argentea, Leucas plukenetii, Bacopa monnieri* (West Bengal collection), *Leucas aspera* (cultivated) and *Bacopa monnieri* (Jharkhand collection) recorded the highest antioxidant properties whereas, *Alternanthera sessilis* and *Celosia argentea* recorded the highest mineral content.
- Makhana germplasm 'Superior Selection-1' has been identified as promising for the wet land ecosystem of North Bihar.
- Resource recycling in integrated farming system (IFS) revealed that 71.5 kg nitrogen, 46.5 kg phosphorus and 57.4 kg potash in 2 acres IFS model and 57.5 kg nitrogen, 35.5 kg phosphorus and 45.0 kg potash in 1 acre IFS model were added into the soil.

- A prototype of hand operated makhana grader has been designed and developed with a circular drum and cylindrical bars. This equipment could grade makhana seeds in five sizes *viz*., 14 mm, 12 mm, 9 mm, 7 mm and less than 7 mm diameter.
- In SRI, soil test based nutrient recommendation through 5.0 t/ha FYM + green manure (*dhaincha*) + azolla, additionally with three mechanical weeding using conoweeder and saturated water management throughout has been found promising with grain yield of 6.0 t/ha.
- In view of higher population of smallholders in eastern region, shallow groundwater depth and ample solar radiation availability, the solar pumps of power ratings 750-2250W, operated by 1200-3000Wp solar arrays were evaluated for total dynamic head ≤ 10 m. The groundwater extraction on a cloud free day (35-170 m^3 per day) was sufficient to irrigate 600-2850 m^2 cropped area per day by flood method of irrigation.
- In rice-lentil-mung bean system, zero tilled mung bean produced significantly higher seed yield (1.15t/ha) as compared to conventional tillage (0.88 /ha). Irrigation at IW: CPE=0.4 recorded maximum seed yield (1.27/ha) and water productivity (1.60kg/m^3).
- Quality seed of 2.35 t rice (Swarna Shreya), 11.75 t lentil (HUL 57, KLS 218, PL 8, IPL 220), 2.5 t field pea (DFP 1), 35.15 t chickpea (Pusa 3043, Shubhra, GNG 1581), 0.52 t pigeonpea (IPA 203), 4.60 t greengram (Samrat, Virat, IPM 02-3,IPM 02-14) was produced during 2018-19. In addition, 2.66 t vegetable seed and 2, 60, 017 nos. of quality planting materials of fruits and flowers was also produced.
- Two new livestock population, including a type of cattle (*Medini* cattle) and a goat (*Medini* goat) was noticed and characterized in Mehdininagar, Garhwa and Latehar districts of Jharkhand.
- Studies on milk production performance of Black Bengal goat and its effect on weight of kids revealed that single kid had the highest weight at birth (1.21± 0.06) followed by twins (1.11±0.05), triplets (1.07±0.03), quadruplets (1.01±0.04) and quintuplets (0.90±0.06) kg. The average milk productions up to 12 weeks of parturition of goats having 1, 2, 3, 4 and 5 litter were 0.33±0.03, 0.45±0.03, 0.54±0.05, 0.70±0.06 and 0.79±0.03 kg/day, respectively.
- The overall mean body weight under backyard system of poultry rearing was significantly higher in Grampriya and Vanaraja than Kadaknath. The age at first egg in Kadaknath, Gramapriya and Vanaraja was recorded as 180, 165 and 178 days, mean egg weight of 42.5, 48 and 50 g, respectively. Mortality was comparatively less in Kadaknath (8%) as compared to Gramapriya (16%) and Vanaraja (20%).
- The highest fish production was achieved with cattle-fish integration (5.05t/ha) followed by pig-fish and buffalo-fish (3.57 t/ha) integration. Supplementary feed-based control showed marginally higher production of 5.31t /ha. The annual average plankton density was recorded to be the highest in fish-pig integration (1194.44 no./lit) followed by fish-cattle (1105.56 no./lit.) and fish-duck (1050.00 no./lit.) integrations.The lowest plankton population (888.89 no./lit) was recorded in fish-buffalo integration.
- Among various water quality parameters, ammonia (NH_3-N) content was maximum in fish-buffalo, fish-pig as well as in feed-based integration, whereas, nitrite (NO_2-N) concentration (0.02 ppm) was the highest in feed based farming followed by fish-goat (0.018 ppm). Phosphate (PO_4^{-2}) level was highest in fish-cattle (0.53 ppm) followed by feed-based farming (0.37 ppm).
- A grid connected Solar Rooftop Power Plant of capacity 100 kWp was installed on the rooftop of office building of ICAR Research Complex for Eastern Region, Patna, under the RESCO Model. This power plant is expected to generate average power in the range of 250-400 unit of electricity per day depending upon the month and solar radiation on a bright sunshine day.
- During the period under report, the Institute published 125 nos of research papers in journals of national and international repute, 05 books, 40 book chapters, 03 technical extension bulletins and 21 popular articles.
- During the year 2018-19, thirty seven villages of six districts of Bihar and Jharkhand were covered under *Mera Gaon Mera Gaurav*, and 2125 farmers were directly benefitted through various activities like training, demonstration, supply of quality planting materials, etc.
- Further, total of 144 training programmes, 25 Front Line Demonstration and 10 On Farm Trials have been conducted for the farmers and the State Government officials.

2. Introduction

The Eastern region comprises of plains of Assam, Bihar, Chhattisgarh, Eastern Uttar Pradesh, Jharkhand, Odisha and West Bengal, representing 21.85% of the geographical area of the country and supporting 33.62% of country's population. 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. In spite of the natural resource endowments in terms of fertile soils, water resources and solar radiation, the productivity and per capita income of the farmers is very low. However, this region holds promise for 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, a multidisciplinary Institute, came into existence on the 22nd February 2001 to address diverse issues relating to land and water resources management, crop husbandry, horticulture, agroforestry, aquatic crops, fishery, livestock and poultry, agro-processing and socio-economic aspects in holistic manner for enhancing research capability and providing a backstopping for improvement in agricultural productivity and sustainability. The research activities are facilitated by 4 divisions, 2 research centres (Ranchi and Darbhanga), 2 Krishi Vigyan Kendras (Buxar and Ramgarh), and linkages with various national and international institutes. The present campus of the institute is located about 8 km west of Patna Railway Station, and adjacent to Patna Airport. Geographically, the Institute is located at 25°35'30" N latitude, 85°05'03" E longitude, at an altitude 52m above mean sea level.

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.

The organizational setup of the complex is given in Fig. 2.1.

Finance

Summary of allocation and expenditure during the financial year 2018-2019 (Table 2.1) and staff position of the complex are depicted in Table 2.2.

Table 2.1. Financial allocation and expenditure during the year 2018-19 (Rs. in Lakhs)

Head of accounts	Budget allocation	Actual expenditure
Establishment charges	2440.82	2440.91
TA	28.84	28.84
HRD	4.95	4.95
Works	14.49	14.49
Other charges	1125.34	1101.56
Total	3614.44	3590.75

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

Staff	Position	
	Sanctioned	Filled
Scientific*	91	66
Technical	61	54
Administrative	37	21
Skilled Supporting Staff	63	57
Total	252	198

*Including Director

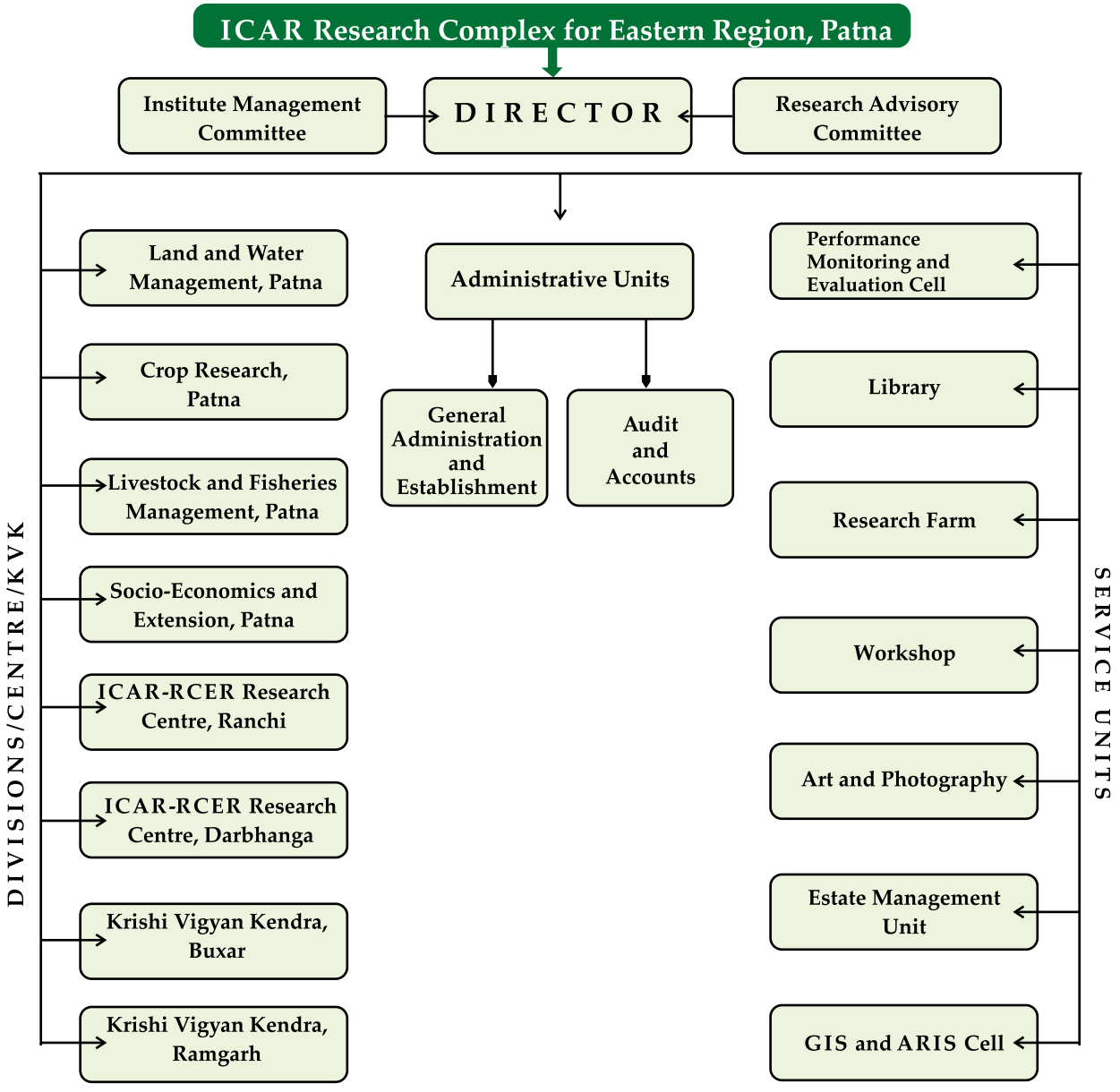


Fig. 2.1. Organogram of ICAR Research Complex for Eastern Region, Patna

3. Weather

Weather parameters *viz.* air, temperature, relative humidity, bright sunshine hours (BSSH), 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 17.9 °C during January to 36.4 °C during June. Similarly the mean monthly minimum temperature varied from 7.4 °C during January to 27.9 °C during June. Mean monthly relative humidity was found to be the lowest in March (49.4 %) and the highest in August (79.6 %). There was almost nil or very little rainfall during winter and summer seasons but water loss in the form of evaporation remained active during these months, as mean monthly bright sunshine hours that was more during March (6.9 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 maximum during May (11.6 km/hr) due to land heating and increasing temperature. These mean monthly variations for 2018 have also been depicted in Fig. 3.1.

Year 2018 was also reported as a deficit year based on total amount of rainfall received throughout the year. Total amount of rainfall was 620.6 mm only which was 55.1 % of long period rainfall average (1127.3 mm) for the station. Total annual rainfall was "deficient" for 2018 also with departure of -44.9 % over the normal rainfall and similar kind of situation was also observed during four monsoon months from June to September with -38.3 % of rainfall departure over normal, receiv-

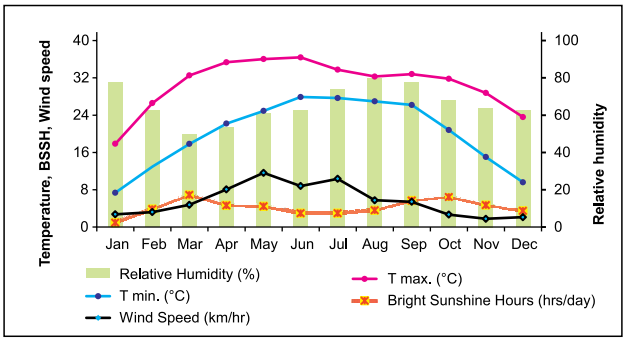


Fig. 3.1. Mean monthly variation of weather parameters during 2018

Table 3.1. Mean monthly weather data of 2018 at ICAR-RCER, Patna

Month	Mean temperature (°C)				Mean relative tumidity (%)	Mean bright sun-shine (hrs/ day)	Total rainfall (mm)		Total rainy days (Nos.)	Total pan evapora-tion (mm)	Mean wind speed (km/ hr)
	Max	Nor-mal	Min	Normal			Ob-served	Normal			
Jan	17.9	23.0	7.4	9.3	77.5	1.0	0.0	20.4	0	22.8	2.7
Feb	26.6	26.1	13.0	11.6	62.7	3.9	0.0	11.1	0	69.8	3.2
Mar	32.5	32.4	17.8	16.4	49.4	6.9	0.4	11.4	0	119.9	4.8
Apr	35.4	37.4	22.2	22.1	53.4	4.7	10.9	9.0	1	120.0	8.1
May	36.0	38.4	24.9	25.1	60.7	4.5	20.7	35.6	4	195.4	11.6
Jun	36.4	36.7	27.9	26.7	62.3	3.0	46.0	141.1	3	175.4	8.8
Jul	33.8	32.9	27.7	26.1	73.5	3.0	241.6	319.2	8	144.2	10.3
Aug	32.3	32.5	27.0	26.1	79.6	3.6	183.2	279	10	139.7	5.8
Sep	32.8	32.2	26.2	25.3	77.4	5.7	116.7	212.6	7	115.2	5.4
Oct	31.8	31.7	20.8	21.6	67.9	6.5	0.0	72.3	0	145.4	2.7
Nov	28.8	28.9	15.0	14.8	63.8	4.7	0.0	8.2	0	110.9	1.8
Dec	23.6	24.6	9.6	10.1	62.5	3.5	1.1	7.4	0	67.6	2.1
Annual	**30.6**	**31.4**	**20.0**	**19.6**	**65.9**	**4.2**	**620.6**	1127.3	33	1426.3	5.6

ing only 587.5 mm of rainfall. Number of rainy days in 2018 (33 days) were also lower than the last year (45 days). It rained for very less number of days during monsoon months (28 days only). A comparative analysis of total monthly rainfall, normal rainfall as a long period average (LPA) and water loss from surface as evaporation has been depicted in Fig. 3.2. Total pan evaporation in 2018 was 1426.3 mm, which was recorded minimum in January (49.1 mm) and maximum in May (195.4 mm).

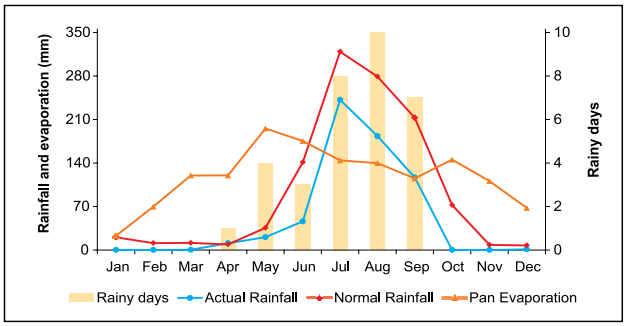


Fig. 3.2. Comparative analysis of total monthly rainfall, normal rainfall, rainy days and evaporation

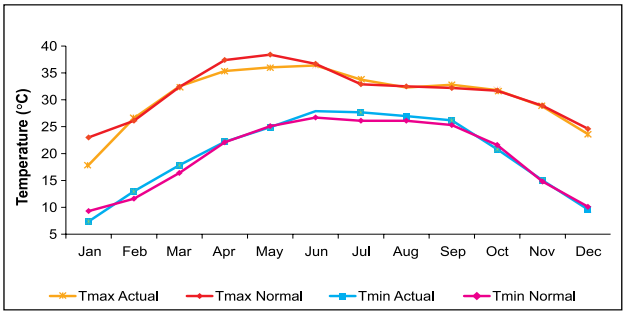


Fig. 3.3. Comparison of mean monthly maximum and minimum temperatures over the normal values

Fig. 3.3 shows the comparison of mean monthly maximum and minimum temperatures over the normal values of temperature. A dip of -5.1°C during January and a shoot of +0.9°C during July were reported for mean monthly maximum temperature over normal values. Similarly for mean monthly minimum temperature, a dip of -1.9 °C during January and a shoot of +1.6 °C during July was observed for 2018. In totality, minimum temperature remained slightly above and maximum temperature remained slightly below normal temperatures.

Extremes in weather variables for 2018 have been reported in Table 3.2, where 17th June was recorded as the hottest day of the year (41.2 °C) while

Table 3.2. Extremes of weather observed during 2018

Parameter	Date	Value
Warmest day	17th June 2018	41.2°C (Tmax)
Coldest day	30th December 2018	4.3°C (Tmin)
Most humid day	29th July 2018	97 % (RH)
Least humid day	15th April 2018	32 % (RH)
Most rainy day	28th July 2018	128.8 mm (Rainfall)
Most shiny day	17th August 2018	10 hrs 36 min (BSSH)
Most windy day	23rd July 2018	19.2 km/hr (Wind speed)

30th December was reported as the coldest day (4.3°C). July month recorded maximum amount of rainfall in a day (128.8 mm) on 28th, the highest wind speed in a day also (19.2 km/hr) on 23rd and the highest maximum humidity (97 %) on 29th but the least humidity was reported on 15th April (32 %). Maximum bright sunshine hours of 10 hrs 36 min were recorded on 17th August.

At Ranchi, the total annual rainfall for the year was 1313 mm. Although the annual rainfall receipt was close to normal (1398 mm). The summer months of April and May also received 151 and 153 mm of rainfall, respectively. The monsoon months (June to September) received 64.2% of annual rainfall. Rainfall during the months of August and September was 29 and 33% less than normal rainfall of the respective months. Comparison of monthly rainfall receipts with the monthly normal rainfall is presented in Fig. 3.4. The average monthly relative humidity (RH) ranged from 40.3% (March) to 95.7% (August). Summary of the monthly climatic parameters is presented in Table 3.3. A total of 79 rainy days were recorded during 2018, of which 53 rainy days occurred during the monsoon season. The month of July recorded

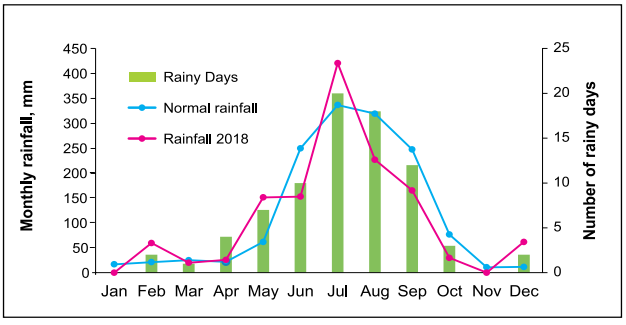


Fig. 3.4. Comparison of monthly normal rainfall with monthly rainfall

Table 3.3. Mean monthly weather parameters at ICAR-RCER, Research Centre Ranchi for 2018

Month	Total rainfall (mm)		Rainy days	Temperature (°C)		Average relative humidity (%)	Solar energy (MJ/m^2)	Wind speed, (m/s)
	Normal rainfall	Observed		Max	Min			
Jan	16.7	0.0	0	23.4	7.4	51.8	15.4	6.7
Feb	21.2	59.4	2	27.9	12.5	53.8	16.3	7.6
Mar	25	19.8	1	32.7	16.6	40.3	18.6	8.4
Apr	21.8	25.7	4	34.9	20.0	54.0	20.8	8.5
May	61.7	151.1	7	36.1	22.3	63.8	20.5	9.2
Jun	249.4	152.7	10	33.0	23.8	77.0	16.8	7.7
Jul	336.6	420.6	20	29.5	23.6	93.3	13.4	6.7
Aug	319.1	226.8	18	29.5	23.6	95.7	13.5	6.7
Sep	247.3	165.1	12	30.0	22.3	92.0	16.6	6.1
Oct	76.6	29.7	3	29.2	16.8	75.5	17.5	5.8
Nov	10.8	0.0	0	27.1	12.8	69.6	15.2	5.0
Dec	11.6	61.7	2	21.9	8.3	69.0	11.8	5.3
Annual	**1397.8**	**1312.7**	**79**	**29.6**	**17.5**	**69.7**	**16.4**	**7.0**

maximum (20) number of rainy days. Trends of the mean monthly maximum and minimum temperature at Ranchi are presented in Fig. 3.5. January was the coolest month with mean monthly minimum temperature of 7.4°C while May was the hottest month with mean maximum temperature of 36.1°C. The maximum and minimum solar energy received was during April (11.8 MJ/m^2) and December (20.8 MJ/m^2), respectively while the annual average solar energy receipts at Ranchi was 16.4 MJ/m^2. The maximum wind speed increased gradually from January to April reaching a maximum value of 9.2 m/s, thereafter it decreased till December 2018 (Fig. 3.6).

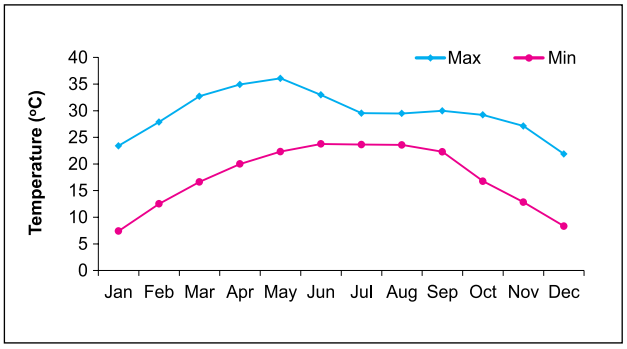


Fig. 3.5. Mean variations in monthly average minimum and maximum air temperature

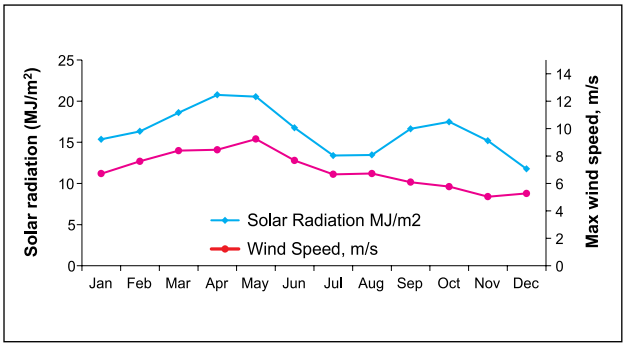


Fig. 3.6. Monthly distribution of solar radiation and maximum wind speed

4. Climate Change

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

Hybrid model for predicting the incidence of mango hoppers in South Konkan region of Maharashtra

A hybrid approach based prediction model was developed for mango hoppers incidence in South Konkan region of Maharashtra (Vengurla) which may be used as a decision supportive tool for planning real time hopper management strategies. The Autoregressive Integrated Moving Average (ARIMA) model with exogenous factors was first constructed with the data of fortnightly interval mango hopper incidence from year 1999 to 2015. The data from Jan 2011 to Dec 2011 were used to validate the model. Then the Artificial Neural Network (ANN) and Support Vector Regression (SVR) model combinations were established. Finally, the fitting and prediction accuracy of the three models was evaluated. A total of 312 observations were reported between years 1999 to 2015 at RFRS, Vengurla (Fig. 4.1 A). The residual series of autocorrelation function, partial autocorrelation and inverse autocorrelation function of model were good fit (Fig. 4.1 B, C & D).

The ARIMA (1, 1) model was selected from several plausible ARIMA models to predict mango hopper incidence in Vengurla in the next one year (Table 4.1). ANN model specification for ARIMA residuals of mango hopper incidence, shows that network has a input layer with four input nodes,

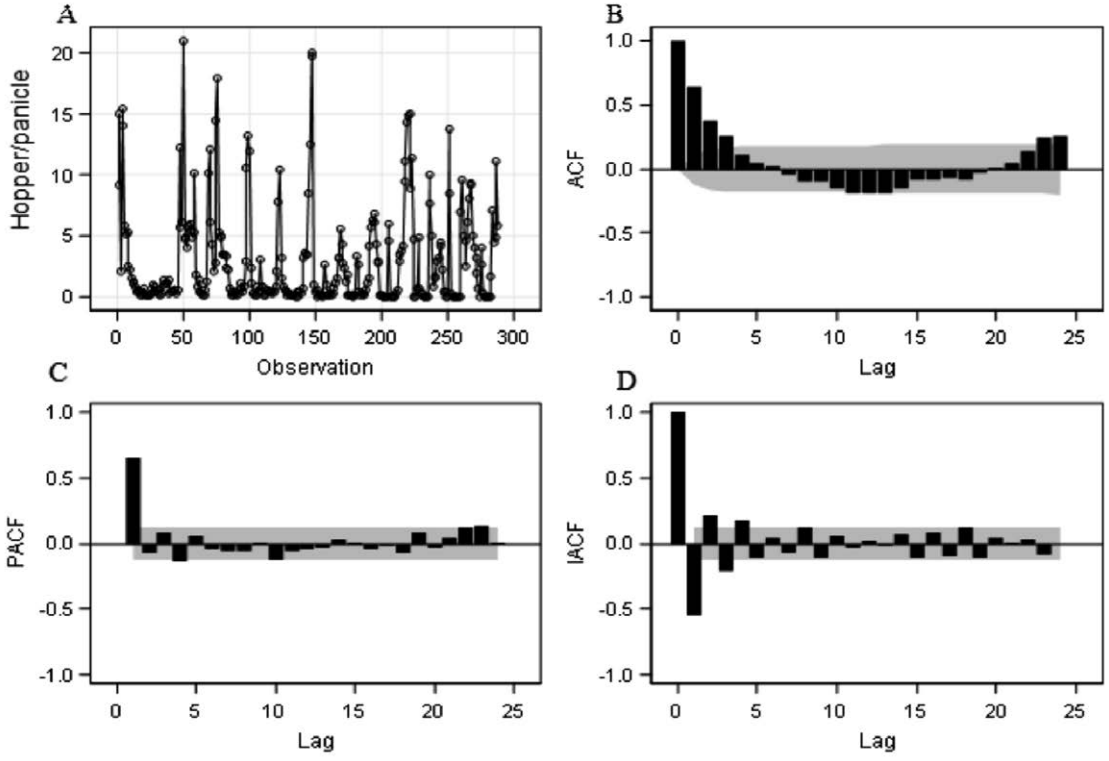


Fig. 4.1. Trend and correlation analysis of mango hopper population at RFRS, Vengurla. (A) Plot shows the trend of hopper population. (B), (C) and (D) plots show the autocorrelation function (ACF), partial autocorrelation function (PACF) and inverse autocorrelation function (IACF), respectively, time series of hopper population. Shadow indicates the 95% confidence intervals.

a single hidden layer with 15 hidden node and a output layer with one output node means (4, 15,1) for feed forward network (Table 4.2). Support vector regression (SVR) model was fitted with 233 radial support vectors (Table 4.3). Finally, Mean Absolute Percentage Error (MAPE) residuals of the ARIMAX, ARIMAX-ANN, and ARIMAX-SVM were evaluated and forecasted mango hopper population were validated with year 2011 observed mango hopper population (Table 4.4).

Table 4.1. Estimated parameters of ARIMA model (1, 1, 0) by Maximum Likelihood Estimation method for hopper population

Parameter	Estimate	Standard Error	t Value	Approx Pr > |t|	Lag
MU	3.06480	0.52454	5.84	<.0001	0
AR1,1	0.65002	0.04484	14.50	<.0001	1

Table 4.2. Parameter specification of optimum artificial neural network model

Specifics	Optimum ANN parameters
Cross validation	25 fold
Optimum lag	4
Optimum hidden node	15
Network type	(4, 15, 1)
Activation function	Linear
σ2	2.70
Total number of parameters	150

Table 4.3. Support vector regression (SVR) model specification for hopper population data series

Kernel function	Number of support vector	Cost	Gamma (γ)	Epsilon (ε)
Radial	233	1	1	0.1

Climate Change Simulating Production Potential of Rice under Changing Climate in Bihar

A field experiment was initiated during *Kharif* season 2018 to simulate the production potential of rice-wheat cropping system under changing climate scenario. Rice variety Swarna Shreya was transplanted at 3 different dates *viz.* 20th July (timely), 5th August (late) and 20th August 2018 (very late) along with 3 irrigation levels using the concept of "pani pipe" i.e. irrigating rice field when water level goes beyond certain depth in pipe from surface (Fig. 4.2). Timely transplanted paddy

Table 4.4. Predicted model performance results of ARIMAX and hybrid approach with year 2011 hopper population data

Fortnight of year	Observed hopper nos./ panicle	ARIMAX predicted hopper nos./panicle	ARIMAX-ANN predicted hopper nos./ panicle	ARIMAX-SVM predicted hopper nos./ panicle
1	16	2.30	13.42	14.43
2	20	3.33	17.57	20.46
3	21.1	3.28	3.57	3.98
4	19.8	3.11	2.14	3.98
5	8.3	3.26	3.50	2.59
6	6.3	3.19	4.56	6.00
7	2	3.03	7.33	2.60
8	1.4	3.10	6.68	2.72
9	1.1	3.01	7.49	2.66
10	0.2	2.86	0.56	0.35
11	4.6	2.85	6.96	0.94
12	2.5	3.45	1.77	3.09
13	0.3	3.02	1.63	0.85
14	0	3.70	-	-
15	0	3.28	-	-
16	0	3.28	-	-
17	0	3.59	-	-
18	0	2.77	-	-
19	2.9	3.16	4.00	3.01
20	6.4	3.51	5.80	6.23
21	8.6	3.56	6.13	2.42
22	6.1	3.52	8.31	6.48
23	7.1	3.67	8.16	5.32
24	4.7	3.06	7.48	5.29
MAPE		176.29	126.47	52.41

Fig. 4.2. View of field experiment

produced maximum yield of 5.7 t/ha which was reduced significantly for late (4.0 t/ha) and very late transplanted rice (3.4 t/ha) showing that for every 15 days' delay in sowing, grain yield may reduce by 15-30 % and may go up to 40 % under very late conditions. Crop growth duration was also shortened by nearly one week under very late sown conditions than the normal sowing (120 days). This shortened crop duration reduced the need of water to be applied in the field by irrigation, nearly 18.1 % and 35.5 % less amount of water was applied in late and very late transplanted conditions, respectively, as compared to timely transplanted rice i.e. 10.82 m^3.

Scaling up Climate Smart Agriculture through Mainstreaming Climate Smart Villages in Bihar

The project aims to improve the adaptive capacity of farmers to cope with the climate risks through interventions in targeted villages of Bihar. The project is located around Patna-Biharsharif State Highway covering both Patna and Nalanda districts of Bihar. For demonstration of climate smart technologies, two blocks namely Fatuha and Daniyawan from Patna district and three blocks viz., Nagarnausa, Chandi and Noorsarai from Nalanda district have been selected and five villages from each blocks have been selected alongside the Patna Biharsharif State Highway. Stakeholders meeting with State agriculture department officials was conducted on 19.11.2019 at ICAR-RCER Patna to sensitize them about the role of different stakeholders in the project and baseline survey was conducted in the selected villages covering 100 farmers from each village. The initiation of planned demonstration started from *Rabi* 2018 with introduction of zero tillage technology in wheat. The demonstrations were carried out in an area of around 21.5 acre covering 23 farmers in Noorsarai block of Nalanda district. During summer season 79 acre area (23 acres in Patna district and 56 acres in Nalanda district) have been covered under zero-till summer mungbean (var. Samrat and IPM 2-3) (Fig. 4.3 & 4.4).

Fig. 4.3. Zero till mungbean at farmers' fields in Chandi block, Nalanda

Fig. 4.4. Zero till mungbean at Noorsarai, Nalanda

5. Cereals

RICE

Screening and Evaluation of Drought Tolerant Rice Genotypes

Evaluation of rice genotypes for drought tolerance at reproductive stage

Drought is the most severe stress causing reduction in rice yield in rainfed as well as poorly irrigated areas. Moreover, in most rainfed regions, the probability of occurrence of reproductive-stage drought is high due to the early withdrawal of monsoon rains. Forty eight rice genotypes received from IRRI along with local varieties were evaluated during *Kharif* 2018 for drought tolerance at reproductive stage. Fifty five days old plants were subjected to drought by withholding irrigation and draining water from the field. Thereafter crop was left rainfed and there was no standing water till maturity. Non-stress irrigated experimental field was kept continuously flooded after transplanting until 25 days before harvest. Grain yield varied from 0.413 to 4.05 t/ha and 5.81 to 9.33 t/ha under stress (drought) and non-stress (irrigated) conditions, respectively. Among genotypes, IR 90257-B-577-1-1–B (4.05 t/ha), IR 95817-5-1-1-2 (4.02 t/ha), IR 107891-B-B-447-3-1 (3.75 t/ha), IR14L157 (3.51 t/ha), IR 107891-B-B-1284-2-1 (3.49 t/ha), IR14L362 (3.44 t/ha), IR 106312-50-1-1-1 (3.33 t/ha) and IR14L613(3.32 t/ha) showed significantly better drought tolerance at reproductive stage as compared to checks MTU 1010 (2.61 t/ha), IR64 (2.37 t/ha), and Sahbhagi Dhan (3.03 t/ha).

Evaluation and identification of rice genotypes for aerobic condition

Thirty two rice genotypes comprised of advanced breeding lines and released varieties were evaluated during *Kharif* 2018 under direct-seeded aerobic condition. Rice genotypes, IR84899-B-179-13-1-1-1 (5.69 t/ha), IR 88964-24-2-1-4 (5.62 t/ha), IR14L572 (5.52 t/ha), IR14L360 (5.51 t/ha), Swarna Shreya (5.43 t/ha), IR 84899-B-184-16-1-1-1 (5.42 t/ha), IR 84899-B-185-8-1-1-1(5.41 t/ha), IR 93827-29-1-1-3 (5.41 t/ha), IR 97073-26-1-1-3 (5.39 t/ha), and IR84898-B-165-9-1-1 (5.33 t/ha) were promising as compared to checks CR Dhan 201 (4.65 t/ha), CR Dhan 202 (4.70 t/ha) and Sahbhagi Dhan (4.51 t/ha).

Evaluation and identification of rice genotypes for multi-stages drought tolerance

Twenty four rice genotypes were evaluated under multi-stage drought stress and non-stress (control) conditions during *Kharif* 2018. In stress field, only one irrigation was applied immediately after sowing for proper germination. The non-stress plot was maintained by applying irrigation as and when required. Grain yield of different genotypes varied from 0.103 to 1.88 t/ha and 4.03 to 5.67 t/ha under drought and non-stress conditions, respectively. Among rice genotypes Swarna Shreya (1.88 t/ha), IR 84899-B-183-20-1-1-1(1.61 t/ha), IR84899-B-182-3-1-1-2 (1.40 t/ha), IR83929-B-B-291-2-1-1-2 (1.38 t/ha), IR84898-B-168-24-1-1-1(1.09 t/ha), IR84899-B-183-CRA-19-1 (1.05 t/ha) and IR83929-B-B-291-3-1-1 (0.99 t/ha) were identified promising for multi-stages drought tolerance as compared to Sahbhagi Dhan (0.77 t/ha).

Evaluation of rice genotypes for tolerance to multiple stresses (drought and submergence)

Nineteen rice genotypes were evaluated during *Kharif* 2018 under submergence, drought and irrigated conditions (Fig. 5.1). Under submergence experiment, the crop was completely submerged ten days after transplanting with 1.0 to 1.25 m water depth for twenty one days and thereafter water was drained out from the field. Under drought stress experiment, crop faced stress at reproductive stage. Sixty days old seedlings were subjected to drought by withholding irrigation and withdrawing water from the field. Thereafter crop was left rainfed. The control (irrigated) trial was maintained by applying irrigation as and when required. Results revealed that irrespective of the genotypes, there was significant reduction in grain yield under drought (76.5%) and submergence (82.3%) stress

Fig. 5.1. Evaluation of rice genotypes under irrigated (a), submergence (b) and drought (c) conditions.

conditions as compared to control (non-stress). Among rice genotypes, IR96322-34-223-B-1-1-1, IR 96321-327-274-B-1-1-1, IR96321-558-563-B-2-1-1, IR96321-558-209-B-6-1-1, IR96321-558-563-B-2-1-3, IR83383-B-B-129-4, IR 96321-1447-521-B-2-1-2 and IR96321-558-257-B-4-1-2 were found promising for cultivation under multiple stresses situation. Grain yield of rice genotypes varied from 0.435-3.490 t/ha, 0.00-2.078 t/ha and 5.90-8.35 t/ha under drought, submergence and control conditions, respectively (Table 5.1).

Table 5.1. Performance of promising rice genotypes under irrigated, drought and submergence conditions

Name of rice genotypes	Grain yield (t/ha)		
	Irri-gated	Drought	Sub-mergence
IR 96322-34-223-B-1-1-1	8.17	2.45	1.72
IR 96321-327-274-B-1-1-1	6.30	1.43	1.78
IR 96321-558-563-B-2-1-1	7.02	1.62	2.08
IR 96321-558-209-B-6-1-1	7.52	1.50	1.96
IR 96321-558-563-B-2-1-3	6.27	1.33	1.79
IR 96321-558-257-B-4-1-2	8.35	3.45	1.24
IR 96321-1447-521-B-2-1-2	7.12	3.40	1.58
IR83383-B-B-129-4	7.47	1.48	1.51
Swarna sub 1	7.13	0.89	1.59
Swarna	7.70	0.84	0.000
Mean	7.18	1.69	1.27
LSD (P=0.05)	0.86	0.36	0.28

Identification of drought tolerant donor lines

Sixteen donor lines of rice received from IRRI were evaluated under reproductive stage drought (RSD) and vegetative stage drought (VSD) conditions during *Kharif* 2018. Grain yield varied from 0.463 to 3.38 t/ha and 1.55 to 3.45 t/ha under RSD and VSD conditions, respectively. Under reproductive stage drought, maximum grain yield was recorded in Aus 344 (3.38 t/ha) followed by Swarna Shreya (3.33 t/ha) and Aus 301 (3.19 t/ha) whereas, under vegetative stage drought, maximum grain yield was recorded in Swarna Shreya (3.45 t/ha) followed by Aus 344 (3.42 t/ha), Sahbhagi Dhan (3.28 t/ha) and Aus 301 (3.27 t/ha). These promising donor lines can be further utilized in rice breeding programme for drought tolerance.

Participatory varietal selection

Nine rice genotypes received from IRRI were evaluated in participatory mode under transplanted and direct-seeded conditions at on-station as well as on-farm (Fig. 5.2). Among rice genotypes IR 97030-7-2-2-2 (6.71 t/ha), IR 90257-B-273-1-B B (6.29 t/ha), IR 98976-20-1-2-2 (6.20 t/ha) and DRR 44 (6.17 t/ha) performed better as compared to checks Sahbhagi Dhan (5.23 t/ha) and IR 64 (5.04 t/ha). Sixty four farmers participated in screening of rice genotypes. Genotypes were selected by the farmers on the basis of panicle length, grain quality, resistant to diseases, insect-pests and lodging.

Fig. 5.2. Participation of farmers in varietal selection

Frontline demonstration and OFT

The frontline demonstrations (FLDs) of rice variety Swarna Shreya were conducted by ICAR-RCER, Patna during *Kharif* 2018 with 80 beneficiary farmers' (including 13 women farmers) covering an area of 31.80 hectares in five districts (Gaya, Jamui, Buxar, Patna and Madhubani) of Bihar under National Food Security Mission (NFSM) programme of Government of India (Fig. 5.3). The performance of the demonstrated variety Swarna Shreya was superior compared to the check varieties. Swarna Shreya recorded an average yield of 4.46 t/ha with a maximum yield of 5.80 t/ha with yield advantage of 18.6%. The feedback of the farmers revealed that early maturity, high yielding attributes along with tolerance to drought and pest and diseases were the promising attributes of the variety. Under changing climate scenario, this varietal technology would best address the drought/water scarcity problem.

Fig. 5.3. Performance of Swarna Shreya in Lalmatia village in Jamui district.

Front line demonstration of aromatic rice variety CR Dhan 909 was conducted during *Kharif* 2018 in 20 ha area in the farmers' field in Katihar, Purnea and Madhubani districts of Bihar. The participating farmers obtained an average grain yield of 5.46 t/ha of the variety. On Farm evaluation of rice varieties Maudamani and Pratikshya was conducted at Krishi Vigyan Kendras and also in farmers fields (Table 5.2). The performance of Maudamani and Pratiksya was better than different popular varieties exhibiting 28.6% and 5.8% superiority, respectively.

Table 5.2. Performance of rice varieties Maudamani and Pratikhsya in different locations during *Kharif* 2018

Location	Grain yield (t/ha)			
	Mauda-mani	Pra-tikhya	Local check	Name of local check
KVK, Saharsa	3.42	2.37	-	-
KVK, Madhe-pura	6.72	6.00	4.77	Rajendra Mahsuri
KVK Muraul	4.80	6.90	5.55	27P31
KVK Purnea	3.60	4.37	-	-
KVK W. Cham-paran	4.40	2.00	2.48	Rajshree
KVK, Buxar	6.89	6.32	5.88	Swarna
ICAR-RCER, Patna	5.30	4.84	3.85	Swarna
Farmer's field				
Chanpatia, Motihari	7.59	6.05	3.58	Sarjoo 52
Kushar, Sheohar	4.40	-	3.30	MTU1001
Chanaur, Manigacchi, Darbhanga	8.25	-	4.68	Swarna sub1
Sukhait, Lakh-nour, Madhu-bani	4.40	3.85	2.75	Rajendra Sweta
Ghat Bhatra, Bisfi, Madhu-bani	4.40	-	4.12	Swarna
Lalganj, Pandaul, Mad-hubani	4.40	3.85	4.40	Rajendra Mahsuri
Thahar, Khajau-li, Madhubani	-	4.40	3.30	Rajshree
Rampatty, Ra-jnagar, Madhu-bani	8.25	3.30	6.87	Swarna
Mean	5.49	4.52	4.27	--

On Farm Evaluation of Rice Varieties for Semi-deep Water and Flash Flood Situations

Flash-flood tolerant rice varieties Samba Mahsuri sub1, Swarna sub1, Ranjit sub1, Ciherang sub1 and IR64 sub1 were evaluated in the farmers' field in Madhubani, Sheohar and Darbhanga districts of Bihar. Farmers obtained average grain yield of 4.64 t/ha for Samba Mahsuri sub1, 5.50 t/ha for Ranjit sub1, 5.49 t/ha for Swarna sub1, 5.50 t/ha for Ciherang sub1 and 5.81 t/ha for IR64 sub1. Samba Mahsuri sub1 was preferred over Ciherang

Fig. 5.4. Front Line Demonstration of paddy in Rawahi village in Laukahiblock (Madhubani)

sub1 and IR64 sub1 for its better grain quality and Ciherang sub1 and IR64 sub1 for early maturity. However, the actual worth of these genotypes for flood tolerance could not be demonstrated in the farmers' field due to non-occurrence of flood.

Field Days

A Field day was organized at Krishi Vigyan Kendra, Lalganj, Buxar on 26th October, 2018 to evaluate the performance of rice genotypes. Seventy seven farmers and scientific staff of IRRI, Philippines, ICAR-RCER, Patna and KVK Buxar participated in the programme (Fig. 5.5).

Field days were also organized at Mahamadpur village in Gaya district and Lalmatia village in Jamui district on 27th and 29th October, 2018, respectively with objective to record the performance of newly released aerobic rice variety Swarna Shreya at farmer's field grown under FLDs programme of NFSM, Government of India. More than 125 farmers, State Government officers and scientists participated in the progarmme. Farmers were highly impressed with the performance of the variety.

Breeder Seed Production

As per the indent of DAC, the institute produced breeder seed (13.5 quintals) of rice variety Swarna Shreya during *Kharif* 2018 (Fig. 5.6). Director, Bihar State Seed Certification Agency, representative of National Seed Corporation, Patna and scientific staff of ICAR RCER, Patna participated in monitoring of breeder seed production. Besides, nucleus seed (1 quintal) and truthfully lebelled (TL) seed (10 quintals) were also produced during *Kharif 2018*.

Fig. 5.6. Breeder seed production of rice variety Swarna Shreya

Seed Distribution

The seed of rice variety Swarna Shreya was distributed to more than 100 farmers in Jamui, Gaya, Patna, Buxar, Madhubani, Nalanda, and Dharbhanga districts of Bihar during *Kharif* 2018 (Fig. 5.7) for conducting FLD under NFSM. Besides,

Fig. 5.5. Participation of farmers and scientific staff in field day

Fig. 5.7. Seed distribution of rice variety Swarna Shreya

seeds were also distributed to the farmers of Jharkhand, Uttar Pradesh and Odisha for on-farm testing.

Maintenance and generation advancement of rice breeding materials

Seventy three advanced breeding lines and 27 released varieties of different duration were grown, purified and maintained during *Kharif* 2018 at ICAR RCER, Patna. Besides, fifty two F_4 and twenty six F_5 generation rice breeding materials along with parents were also raised. Uniform plants or lines of early and medium early duration were selected based on the plant type, panicle length, effective tiller numbers, grain features, lodging resistance and tolerance to diseases and insect pests. The F_5 and F_6 seeds have been retained for further evaluation and generation advancement.

Breeding for Submergence Tolerance in Rice

Evaluation of rice genotypes for submergence tolerance at vegetative stage

Twelve rice genotypes were evaluated for submergence tolerance along with Swarna sub1 and Ciherang sub1 as tolerant and Swarna as susceptible checks. Thirty days old seedlings were transplanted in the main field on 28th July 2018. After twelve days of transplanting, the crop was completely submerged in the field at water depth of 75.0 cm to 1.0 m for 21 days and thereafter water was completely drained out of the field. The field was completely covered with the growth of aquatic weed Hydrilla during submergence. Rice genotypes TP30193-2 and ST-26 showed above 70% survival under submergence (Table 5.3).

A set of these genotypes was also evaluated in replicated yield under normal condition to assess their agronomic values. The Table 5.3 depicts the performance of these genotypes under stress free condition. There was no significant difference in grain yield of genotypes under normal condition.

Evaluation of elite rice genotypes under rainfed shallow lowland

Eighteen elite rice genotypes selected from different crosses for the development of improved rice varieties for rainfed shallow lowland were evaluated in the second year during 2018 *Kharif* under shallow lowland along with four checks (Table 5.4).

Table 5.3. Performance of rice genotypes under normal condition

Genotypes	Days to 50% flowering	Plant height (cm)	Number of panicles/hill	Panicle length (cm)	Grain yield (t/ha)
IR11F 195	109	113	10	27.6	5.82
IR09L 342	109	129	10	27.5	5.03
IR10F 365	108	118	10	26.1	5.78
IR10L 182	105	116	11	26.0	5.78
ST -26	104	91	10	25.3	5.37
ST -3	109	122	9	24.8	4.36
TP30193-1	112	115	12	27.6	6.00
TP30193-2	110	113	12	27.7	5.32
TP30193-3	105	106	10	24.7	5.98
TP30504	104	126	11	24.3	5.12
Naveen	104	129	12	28.4	5.60
Ciherang sub1	111	88	10	23.5	5.37
LSD (P=0.05)	3	3	3	1.0	0.98

Rice genotypes RP5366-13 (7.58 t/ha) and RP5377-9 (7.10 t/ha) performed significantly better than the highest yielding check Swarna (6.81 t/ha). These genotypes have been nominated to AICRIP as RCPR67-RP5484 and RCPR67-RP5366, respectively.

Evaluation of aromatic rice genotypes under irrigated condition

Twenty traditional aromatic rice genotypes were evaluated along with seven improved aromatic rice varieties during *Kharif* 2018 under irrigated condition. The traditional aromatic rice genotypes grew very tall and lodged at the time of maturity and hence their grain yield was low as compared to improved variety like CR Dhan 909 (5.11 t/ha) and Rajendra Kasturi (4.20 t/ha). However, some traditional aromatic varieties like Champaran Basmati (4.39 t/ha), Marcha Dhan (4.36 t/ha), Lalsataria (3.97 t/ha), Sonachur (3.79 t/ha), Chandanchur (3.69 t/ha), etc., are grown by farmers due to their superior grain quality and fairly high grain yield. There is a scope to improve the yield along with plant type of these traditional varieties through breeding as the other attributes like panicle length, number of tillers/plant and total biomass production are better in these genotypes.

Table 5.4. Performance of elite rice genotypes under shallow lowland

Genotype	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Number of panicles/ hill	Harvest index (%)	Grain yield (t/ha)
RP5484-2	131	129.3	28.1	10	35.1	6.57
RP5377-3	108	124.6	24.0	8	44.9	6.33
RP5753-4	106	121.0	26.9	9	43.2	5.75
RP5753-5	105	134.8	25.0	11	43.6	4.68
RP5484-6	119	139.4	23.2	10	41.6	5.38
RP5484-7	106	97.2	24.6	11	38.2	4.79
RP5535-8	118	122.2	25.4	9	42.0	6.77
RP5377-9	130	123.4	26.7	9	40.7	**7.10**
RP5410-10	107	109.0	24.3	11	51.3	5.64
RP5504-12	108	155.9	28.6	10	34.5	4.19
RP5366-13	116	130.2	25.8	9	49.5	7.58
RP5404-14	112	125.2	26.3	10	46.9	5.88
RP5537-17	117	122.1	25.0	12	41.1	6.39
RP5366-18	110	109.7	26.6	11	39.6	5.75
RP5423-21	105	117.3	25.2	10	45.8	5.68
RP5535-22	116	122.1	24.5	10	42.6	6.65
RP5528-23	110	101.7	27.1	8	40.2	5.48
RP5366-24	115	108.5	25.6	9	39.7	5.36
Naveen	110	128.1	28.6	10	49.4	6.33
Rajendra Bhagwati	110	126.3	28.1	10	44.7	5.58
Rajendra Sweta	127	102.1	23.6	11	39.7	5.84
Swarna	131	89.9	22.8	12	41.0	6.81
LSD (P=0.05)	2	14.7	1.1	1	4.5	0.46

Evaluation of optimum plant spacing and fertilizer dose for rice variety CR Dhan 909

To ascertain the optimum spacing and dose of fertilizer application in recently released aromatic rice variety CR Dhan 909, four spacings (15cm x 20cm, 20cm x 20cm, 25cm x 20cm and 30cm x 20cm) and three doses of fertilizer application (80:40:20, 100:50:30 and 120:60:40 kg N:P:K/ha) were evaluated during *Kharif* 2018. Results revealed that the spacing of 30 cm x 20cm was better than the closer spacings and there was no significant difference among the three doses of fertilizers for grain yield. Owing to its high tillering ability, CR Dhan 909 performed better at wider spacing.

Preliminary yield trial of elite rice genotypes

Forty elite rice genotypes with mid-early to medium maturity duration, developed by selection from the BC_1 F_2 received in 2014 from IIRR, Hyderabad, were evaluated during *Kharif* 2018 in preliminary yield trial along with four checks. Based on grain yield, maturity duration and field reaction to diseases and insect pests, eleven promising genotypes (SP6, SP19, SP27, SP31, SP39, SP42, SP58, SP62, SP71, SP84 and SP85) have been selected for further evaluation.

Seed production and maintenance breeding in rice

During *Kharif* 2018, seed of improved rice variety CR Dhan 909, Pratikhya, Maudamani, Swarna sub1, Samba Mahsuri sub1, IR64 sub1 and Ciherang sub1 have been produced for conducting FLD /OFT. Twenty five improved rice varieties of lowland situation have also been maintained.

Screening of disease resistant/tolerant rice genotypes

Under irrigated conditions forty eight rice genotypes were screened against major diseases of rice under natural conditions. These genotypes were grown under normal irrigated condition. Disease incidence was scored at respective stages. Six genotypes *viz.*, IR 95817-5-1-1-2, IR 107891-B-B-1216-1-1, IR 106312-50-1-1-1, IR14L613, IR 93827-29-1-1-4 and IR14L157 were identified as tolerant to false smut; brown spot, sheath rot, sheath blight, bacterial leaf blight and leaf blast. Similarly, eighteen rice genotypes were screened for various biotic stresses under submerged trial. These genotypes faced 21 days submergence at vegetative stage. Four rice genotypes i.e., RCPR 10, IR 96322-34-223-B-1-1-1, IR 96321-558-209-B-6-1-1 and IR 96321-558-563-B-2-1-3 were found moderately resistance to brown spot and sheath rot, however, all the genotypes were free from false smut and sheath blight.

On station evaluation of rice varieties for semi-deep water situation

Eight improved semi-deep water rice varieties along with Sudha and Vaidehi as local check were evaluated under stagnant water situation during *Kharif* 2018. Out of these Savitri sub1 (5.10 t/ha), TTB404 (4.63 t/ha) and CR Dhan 401 (4.39 t/ha) produced significantly higher grain yield under

semi-deep water condition (water depth >40 cm) than the best local check Sudha (3.50 t/ha) (Table 5.5).

Table 5.5. Performance of improved semi-deep water rice varieties

Varieties	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Number of panicles/ hill	Grain yield (t/ ha)
CR Dhan 401	105	110.8	27.9	6.9	4.39
CR Dhan 500	124	151.3	22.5	6.9	3.83
CR Dhan 505	128	155.7	21.9	6.7	3.92
CR Dhan 507	129	150.8	24.1	7.2	4.01
CR Dhan 510	127	110.4	25.6	7.3	3.39
Savitri sub1	124	112.7	24.8	5.5	5.10
Varshadhan	129	149.1	23.6	7.7	3.47
TTB404	110	123.8	25.5	7.0	4.63
Sudha	113	113.4	22.8	7.1	3.50
Vaidehi	124	152.1	24.1	7.1	2.13
LSD (P=0.05)	2	2.1	1.0	2.8	0.85

Weed Management

Integrated weed management in DSR

Heavy weed infestation is a major problem in successful cultivation of direct-seeded rice (DSR). An experiment was conducted to find out weed suppressing ability of rice cultivars under different weed management practices (Fig. 5.8). Weed infestation was lower with rice cultivar 'Arize 6444' followed by Sahbhagi Dhan, while the highest weed infestation was recorded with 'BPT 5204'. Pendimethalin *fb* halosulfuron resulted in better weed control. Due to vigorous tillering in Arize 6444, weed growth was suppressed and resulted in higher grain yield (7.3 t/ha), followed by Sahbhagi Dhan (4.0 t/ha). Among different weed control

Fig. 5.8. Field view of direct seeded rice experiment

treatments, pendimethalin *fb* halosulfuron had higher weed control efficiency (72 %) over other treatments and resulted in higher yield (6.0 t/ha) followed by pendimethalin *fb* bispyribac sodium (58.5 %, 4.8 t/ha), pendimethalin *fb* tembotrion (58 %, 4.8 t/ha) and pendimethalin *fb* ethoxysulfuron (57.5 %, 4.5 t/ha), respectively.

In another experiment 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 2 DAS 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)]. ZT-DSR was sown with happy seeder on 22 June 2018. For CT-dry DSR, field was prepared properly by 2 harrowings followed by planking, and sowing was done under dry condition with happy seeder, and a light irrigation was applied to ensure proper germination. In case of CT-DSR-dust mulching), field was prepared thoroughly after irrigation and primed seeds of rice were sown in field under the moist–condition with the same machine. Rice cv. Swarna Shreya was used as test crop. Significantly higher grain yield (3.42 t/ha) was recorded under CT–DSR with low weed pressure and the lowest (0.53 t/ha) (Table 5.6). Amongst crop establishment methods, grain yields were followed the trend of CT–DSR>CT–Dry DSR>ZT–DSR. Yield trends under weed pressure also follows as low weed pressure>medium weed pressure>high weed pressure.

Table 5.6. Interaction effect of crop establishment methods and weed pressure on grain yield of direct seeded rice (t/ha)

Weed pressure	ZT-DSR	CT- dry DSR	CT-DSR	Mean
Low	1801	2495	3422	2573
Medium	1199	1504	1750	1484
High	530	667	708	635
Mean	1176	1555	1960	1564
		SEm±	LSD (P=0.05)	
Crop establishment method (E)		37	147	
Weed pressure (W)		26	80	
E×W		45	139	

Weed competitive ability of rice cultivars under transplanting

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 (post–em. at 2 DAT) followed by *(fb)* bispyribac–Na (post–em. at 2 DAS at 20 DAT) *fb* 1 HW (35 DAT), medium weed pressure (application of pretilachlor (post–em. at 2 DAT) *fb* bispyribac sodium (post–em. at 20 DAT) and high weed pressure (weedy check)] (Fig. 5.9). Twenty one days old seedlings were transplanted on 17th July 2018 with 2-3 seedlings/hill with spacing of 20 ×15 cm.

Fig. 5.9. Cropping view of rice cultivars under various weed pressure management

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 (5.25 t/ha) and Rajendra Sweta, the least (3.35 t/ha) (Table 5.7). Hybrids were more tolerant to increase in weed pressure as compared to varieties. Short duration rice hybrid Arize 6129 with low weed pressure produced the maximum grain yield (6.14 t/ha) of rice.

Table 5.7. Grain yield (t/ha) of rice cultivars as influenced by different weed pressure in irrigated transplanted condition

Cultivars	Low weed pressure	Medium weed pressure	High weed pressure	Mean
Arize 6129	6.14	5.24	4.37	5.25
Arize 6444	5.36	4.88	3.97	4.74
Arize Dhani	5.17	4.62	4.12	4.64
Swarna Shreya	5.06	4.12	2.30	3.82
Rajendra Sweta	4.26	3.95	1.84	3.35
MTU 7029	4.65	3.86	1.66	3.39
Mean	5.11	4.44	3.04	4.20
LSD (P=0.05)	Variety (V)	0.23		
	Weed pressure (W)	0.16		
	V×W	0.40		

6. Pulses

Pigeonpea

Genetic improvement for yield and biotic stress resistance in Eastern Plateau and Hill region

Sixteen genotypes identified during the previous year *viz.*, Type-7, DBGA-7-10, RCEA 14-5, IPA-203, RCEA 14-1, Pusa-9, RCEA 14-6, IC 611212, IC 611215, IC 611232, IC 611261, IC 611682, IC 611683, RCRPP-1, RCRPP-2 and RCRPP-3 were evaluated along with checks NDA-1, Bahar and Asha for various morphological, yield and yield related traits. RCEA-14-1, RCEA-14-5 and RCEA-14-6 showed cleistogamous with non-diadelphous condition of stamens and no out crossing was reported in them. IPA-203 recorded the highest yield of 6.0 t/ha followed by Type-7 (5.48 t/ha). IC 611682 was early (82.3 days to 50% flowering) and RCRPP-1 recorded highest 100 seed weight (19.77g). Statistical analysis showed that all the characters were significant for the twenty genotypes (Table 6.1). Heritability estimates were the highest for days to 50% flowering (99.13%) and 100 seed weight (86.94%) (Table 6.2). Yield (t/ha) was significantly correlated with shelling percentage.

Table 6.1. Mean performance of 10 pigeonpea genotypes for morphological and yield characters

Character	Range	C.D.	C.V.	ANOVA F test
Days to 50% flowering	82.3-179.67	4.44	1.91	HS
Plant height (m)	2.29-3.63	0.26	4.90	HS
Pod bearing length (m)	0.91-1.81	0.40	17.96	HS
Biological yield (t/ha)	37.12-79.03	12.93	12.99	HS
Yield (t/ha)	6.00-2.37	0.82	13.06	HS
No. of seeds per pod	5.40-3.50	0.47	6.69	HS
Shelling %	79.36-50.95	10.17	8.95	HS
100 seed weight (g)	7.15-19.77	1.78	9.02	HS

Table 6.2. Heritability, GCV, PCV, GA and GA as percent of mean (GAM) of 20 pigeonpea genotypes for morphological and yield characters

Character	Heritability %	GCV	PCV	GA	GAM
Days to 50% flowering	99.13	20.41	20.50	58.56	41.88
Plant height (m)	75.60	8.62	9.91	0.50	15.44
Pod bearing length (m)	32.02	12.33	21.78	0.19	14.37
Biological yield (t/ha)	70.01	19.85	23.72	20.52	34.21
Yield (t/ha)	76.68	23.67	27.03	1.63	42.70
No. of seeds per pod	66.47	9.42	11.56	0.67	15.83
Shelling %	49.16	8.81	12.56	8.71	12.71
100 seed weight (g)	86.94	23.27	24.95	5.33	44.69

[GCV: Geotypic Coefficient of variation; PCV: Phenotypic Coefficient of variation; GA: Genetic advance]

Multiplication and maintenance of faba bean varieties

Faba bean varieties Swarna Gaurav and Swarna Suraksha under rainfed as well as irrigated ecology were multiplied (178 kg) and distributed to the farmers. In addition, five faba bean promising genotypes *viz.* RCPFB01, RCPFB02, RCPFB03, RCPFB04 and RCPFB05 were also under varietal development programme.

Chickpea

Evaluation of promising genotypes for the North East plain zone

A station trial comprising 4 test entries and 6 checks was conducted under normal sown condition (during the 3rd week of November 2017) to select the promising genotypes for the North East plain zone (NEPZ) at ICAR RCER, Patna. All the test entries 'DBGC 1' (2813 kg/ha), 'DBGC 2' (2871 kg/ha), 'DBGC 3' (2782 kg/ha) and 'DBGC 4' (2851

kg/ha) with 100 seed wt of 26.7 g, 28.7 g, 21.5 g and 24.5 g, respectively showed an yield advantage over the best check 'Pusa 3043' (2455 kg/ha) by more than 13% (Table 6.3). The test entry 'DBGC 3' also recoded the highest protein content (18.9%). Another station comprising 6 entries including three checks was conducted under late sown condition (second fortnight of December) at KVK, Vaishali and KVK, Buxar. Yield of both test entries and check varieties were reduced significantly compared to those under normal sown condition at Patna. The test genotype 'DBGC 1' out-yielded the best check at Vaishali and Buxar by around 12% and 9%, respectively.

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 "resistant" against the available races of *Fusarium ciceri* at TCA, Dholi.

Evaluation of chickpea genotypes for heat stress tolerance

A station trial was conducted to assess the effects of heat stress on chickpea genotypes. All the genotypes were sown during the second week of January 2018. Drastic reduction in yield and component traits was observed. 'Pusa 3043' and 'DBGC 4' performed better than the check variety 'JG 14' (Table 6.4). Promising heat tolerant genotypes showed intermediate values for most physiological parameters such as rate of photosynthesis, leaf conductance, internal CO_2, transpiration rate, total chlorophyll, carotenoid, ascorbic acid and lipid peoxidation (T bars). These attributes conferred maximum reproductive fitness upon the better performing genotypes.

Table 6.4. Performance of promising chickpea genotypes for heat stress

Genotypes	Yield (kg/ha)	Yield/plant (g)	100-seed wt (g)
Pusa 3043	483	3.6	17.0
Pusa 1103	397	3.7	20.0
DBGC 4	381	3.7	22.7
DBGC 1	365	3.1	20.5
Pusa 547	354	2.2	19.5
JG 14 (Check)	142	2.2	18.0
LSD (P=0.05)	98	0.9	2.0

Root studies: An experiment comprising 10 chickpea 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. In control, fixed quantity of irrigation water (1000 ml) was applied in each treatment at the interval of 3 weeks after sowing. However, in one set of treatments, complete moisture stress was maintained (no irrigation water was provided). The percentage reduction in root and shoot attributes has been mentioned in Table 6.5. 'ICC 4958' recorded intermediate values for all the root attributes, whereas 'DBGC 4' and 'Pusa 372' showed least reduction for root fresh weight and root dry weight.

Breeding materials and germplasm maintained: The advance breeding lines (DBGC 1, DBGC 2, DBGC 3, DBGC 4, RCECK 15-1, RCECK 15-2,

Table 6.3. Mean performance of chickpea genotypes in station trials (2017-18)

Genotypes	Yield (kg/ha)			100-seed wt (g) Patna	Maturity duration (days) Patna	Protein* (%)
	Patna	Buxar	Vaishali			
DBGC 1	2813	1667	1510	26.7	132	18.9
DBGC 2	2871	1598	1319	28.7	133	15.2
DBGC 3	2782	1615	1041	21.5	132	15.8
DBGC 4	2851	---	---	24.5	132	15.8
Pusa 372	2421	---	---	13.2	133	18.0
Pusa 547	---	1268	1388	--	---	14.9
Pusa 1103	2442	1490	1193	22.7	132	16.8
Pusa 3042	2455	1406	1306	21.6	132	16.1
LSD (P=0.05)	300	149	153	1.6	NS	---

*Analyzed at ICAR RCER, Patna; Protein content on whole grain basis; Data of only best checks are included in the Table.

Table 6.5. Percent reduction in root and shoot attributes of chickpea genotypes

Genotypes	Root length (cm)	Root fresh wt (g/ plant)	Root dry wt (g/ plant)	Shoot fresh wt (g/plant)	Shoot dry wt (g/plant)
Pusa 256	01.04	41.49	46.23	18.36	8.16
Pusa 372	17.70	17.81	19.56	33.37	35.94
Pusa 547	0.0*	27.04	27.77	16.34	36.00
Pusa 1103	31.02	54.12	0.00	45.71	51.76
Pusa 3043	26.32	57.14	0.00	54.08	32.35
ICC 4958	36.65	52.12	37.3	41.17	18.75
DBGC 1	23.97	80.69	74.87	58.33	47.50
DBGC 2	30.47	89.52	76.92	58.01	44.00
DBGC 3	58.33	88.31	82.50	66.92	48.57
DBGC 4	39.90	14.19	12.50	55.78	4.54

*Negative estimate for which the most reasonable value is zero

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 and GNG 1581) and Kabuli (IPCK 2002-29 and Pusa 1003) chickpea varieties were grown and maintained. In addition, 20 single plant selections in each of the three F_7 bulks (received from IARI, New Delhi) was performed, and seeds were individually harvested and kept for their utilization in the forthcoming *Rabi* season.

Management of wilt complex in chickpea

Three chemical fungicides *viz*., azoxystrobin 250SC, fluopyram (17.6%) +tebuconazole (17.6%), iprovalicarb (5.5%)+propineb (25%) and three biocontrol agents *viz*., *Trichoderma asperellum*, *T. viride* and *Pseudomonas fluorescens* were selected for evaluation of their disease controlling potential against natural incidence of *Fusarium oxysporum* f. sp. *ciceri*, *Sclerotinia sclerotiorum* and *Rhizoctonia solani* in chickpea (var. Sabour Chana 1). Seed treatment of chickpea by the combination of iprovalicarb + propineb @ 2.5g/kg seed showed minimum wilt incidence (6.55%) followed by azoxystrobin @ 2.5 ml/kg (6.94%), fluopyram + tebuconazole @ 2.5 ml/kg seed (8.82%). Similarly among the bioagents, *T. asperellum* @ 10g/kg seed showed minimum wilt incidence (11.24%) followed by *T. viride* @ 10g/kg (12.38%) and *P. fluorescens* @ 5g/kg (14.79%) over control (24.59%) after 90 days of sowing. However, no infestations of *R. solani* and *S. sclerotiorum* were recorded in chickpea.

Root rot incidence in chickpea

Twelve varieties of chickpea were screened for root rot incidence under irrigated and rainfed conditions. None of the genotypes were resistant to root rot and variable degree of disease incidence could be observed. Overall, high incidence of root rot was observed under irrigated condition (41.65%) as compared to rainfed conditions (35.15%). Under irrigated condition, root rot incidence varied from 26.2 % to 54.1% while under rainfed conditions it was from 22.1% to 49.6%. Highest disease incidence was observed in ICC 4958 (52.8%) and Pusa 547 (49.6%) under irrigated and rainfed conditions, respectively (Table 6.6).

Table 6.6. Root rot incidence in chickpea

Disease reaction	Genotypes	
	Irrigated conditions	Rainfed conditions
Resistant (< 10 %)	-	-
Moderately resistant (10-30%)	DBGC 4 (29.1%) and BGD9971(26.2 %)	DBGC 4 (22.1%) and BGD9971 (26.9%)
Susceptible (> 30%)	Pusa 256, Pusa 547, Pusa 3043, Pusa 372, Pusa 1103, DBGC 1, DBGC 2, DBGC 3, GNG 1581 and ICC 4958	Pusa 256, Pusa 547, Pusa 3043, Pusa 372, Pusa 1103, DBGC 1, DBGC 2, DBGC 3, GNG 1581 and ICC 4958

Lentil

Evaluation of promising genotypes for the North East plain zone

A station trial comprising 8 treatments including 4 checks (Pusa Vaibhav, DPL 15, KLS 218 and HUL 57) was conducted under normal sown condition (3rd week of November 2017) to select the promising lentil genotypes for the North

East Plain Zone (NEPZ). None of the test entries excelled the best check 'Pusa Vaibhav' (1438 kg/ha); however, 'DBGL 135' and 'DBGL 138' showed maturity advantage by around two weeks at ICAR RCER, Patna. One other station trial comprising 6 entries including three checks (KLS 218, HUL 57 and IPL 220) was conducted under late sown condition each at KVK Vaishali and KVK Buxar. Seed yield and maturity duration of genotypes were reduced significantly compared to those under normal sown condition. The test genotype 'DBGL 135' out yielded the best check 'HUL 57' at both places and appeared as the earliest maturing genotype.

Evaluation of advance breeding lines in wilt sick nursery: Three advance breeding lines namely DBGL 62', 'DBGL 105'and 'DBGL 135' were tested for the disease reaction in the wilt sick nursery at TCA, Dholi during the year 2017-18. Test lines 'DBGL 62' and 'DBGL 105' were rated "resistant" and the remaining one line 'DBGL 135' showed moderate resistance to the wilt pathogen at TCA, Dholi.

Grass pea

Evaluation of promising genotypes for the North East plain zone

A station trial comprising 7 genotypes including 3 local checks was conducted during the second fortnight of November 2017. The test entry 'RCEGP 16-2' yielded the highest (1302 kg/ha) with 100 seed weight and maturity duration of 5.47 g and 121 days, respectively. In a separate analysis for ODAP content, a white flowered genotype 'RCEGP 16-1' (an spontaneous mutant selected from an ICARDA line 63101) recorded the lowest ODAP content (Table 6.7).

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 and pigeonpea were undertaken at ICAR RCER, Patna and KVK, Buxar. Details of quality seed produced are mentioned in the Table 6.8.

Table 6.7. Performance of grass pea genotypes in station trial (2017-18)

Genotypes	Yield (kg/ha)	100 seed wt (g)	Maturity duration (days)	ODAP content* (%)
RCEGP 16-5	1077	5.24	123	0.26
RCEGP 16-4	1140	5.43	122	0.29
RCEGP 16-3	1132	5.13	122	0.31
RCEGP 16-2	1302	5.47	121	0.30
RCEGP 16-1	--	--	--	0.13
Local-2	1152	4.64	121	--
Local-3	1083	4.60	120	0.36
Local-4	1104	4.60	120	0.36
LSD (P=0.05)	68	0.38	NS	--

*Analyzed at IIPR, Kanpur

Table 6.8. Quality seed of pulses produced during the year 2017-18

Pulse Seed Hub	Crop	Variety	Class of Seed	Quantity (t)
ICAR RCER, Patna	Lentil	HUL 57	F/S	2.5
		KLS 218	T/L	1.2
		PL 8	C/S	8.0
		IPL 220	Nucleus	0.05
	Field pea	DFP 1	F/S	2.5
	Chickpea	Pusa 3043	Nucleus	0.05
		Shubhra	T/L	0.1
	Pigeonpea	IPA 203	Nucleus	0.02
			TL	0.5
	Mungbean	Samrat	F/S	0.9
		Virat	F/S	0.7
		IPM 02-3	F/S, T/L	2.0
		IPM 02-14	T/L	1.0
KVK, Buxar	Chickpea	GNG 1581	F/S	35

F/S: Foundation seed; C/S: Certified seed; T/L: Truthfully labelled seed

7 Fruits

Evaluation of Tamarind Germplasm

Twelve tamarind genotypes conserved at the field gene bank of the institute were evaluated for their performance based on fruit quality characters (Table 7.1). Average fruit weight ranged between 14.75g (ICAR RCER TS 2/2) to 41.35g (ICAR RCER TS 3/1). Pulp content ranged between 28.63% (ICAR RCER TS 2/2) to 59.20% (ICAR RCER TS 3/1). The genotype ICAR RCER TS 3/1 recorded the minimum seed per cent (22.68%). The maximum TSS (62.40°B) was recorded in case of 4/1. Hence, based on overall performance the tamarind genotype ICAR RCER TS 3/1, (Fruit weight – 41.35g, pulp % - 59.20%, seed % 22.68%- TSS 49.20°B) was found to be the most promising during the year.

Evaluation of Jackfruit Genotypes for Table Purpose based on Fruit Traits

A wide range of variability in fruit traits has been noticed among the selected 28 genotypes. The fruit weight ranged from 3.8 to 18.00 kg with standard deviation 3.69 and coefficient of variation 44.52. The maximum fruit weight was recorded in genotype ICAR-RCER JS 3/8 and minimum in ICAR-RCER JS 1/8. Fruit pulp per cent is the important parameter to determine the value of genotypes. It ranged from 2.54–60.04 %. The highest fruit pulp per cent was measured in ICAR-RCER JS 6/3 followed by ICAR-RCER JS 3/8, 7/7 and 10/3and lowest in ICAR-RCER JS 6/1 (53.72%) with standard deviation 13.34 and coefficient of variation 35.58 %. Based on overall performance, the genotypes ICARRCER JS 6/3, 3/8, 7/7 and 10/3 were found to be the most promising (Fig. 7.1).

Fig. 7.1. Promising jackfruit collections ICARRCER JS 6/3

Table 7.1. Performance of tamarind germplasm

Germplasm (ICAR-RCER TS)	Average fruit weight (g)	Average no. of seeds	Pulp %	Shell %	Seed %	TSS (°B)	Titratable acidity (%)	Total sugar (%)
2/1	16.51	6.20	45.22	23.62	31.16	56.60	4.17	29.41
2/2	14.75	6.00	28.63	35.60	35.77	47.40	4.40	31.25
2/3	22.79	7.60	47.00	19.75	33.25	53.60	6.98	35.71
3/1	**41.35**	8.40	**59.20**	**18.12**	**22.68**	49.20	5.91	33.33
3/2	18.38	7.60	43.26	22.38	34.36	53.80	4.15	27.78
4/1	21.67	8.40	45.00	19.73	35.28	**62.40**	4.05	31.25
4/3	21.24	9.00	51.73	19.56	28.71	53.40	4.33	33.33
5/1	18.53	9.00	40.60	22.44	36.97	44.60	5.88	33.33
5/3	22.89	9.20	46.32	20.17	33.51	60.20	5.61	31.25
7/1	20.00	8.00	42.94	28.06	29.00	41.20	6.78	29.41
7/2	19.28	9.00	40.14	23.98	35.88	51.20	6.47	31.25
8/2	21.10	7.60	45.80	24.28	29.92	61.00	6.07	33.33

Evaluation of Sapota Varieties under Jharkhand Conditions

A total of eleven varieties conserved in the field gene bank were evaluated for fruit quality. The maximum fruit weight was recorded in case of CO-2 (101.60g). The highest pulp % was recorded in Murabba (93.82%). The lowest seed per cent was recorded in Murabba (1.30%). The minimum numbers of seeds were found in the Murabba (1.5) (Fig. 7.2). The maximum TSS was recorded in case of Bhuripatti (34.30°B). Hence, based on fruit quality, the sapota variety Murabba was found most promising during the year.

Fig. 7.2. Spota genotype Murabba

Standardization of Basin Enrichment under High-density Orchards of Bael, Sapota and Guava

Estimation of cumulative nutrient content which has been recycled into the plant basin during the last five years indicated maximum values with Tephrosia (nitrogen- 4.17 t/ha, phosphorus- 0.23 t/ha and potassium -1.50 t/ha). The poor regeneration of shoots from the fifth year old Tephrosia plants indicated the need for resowing of Tephrosia seeds at fifth year.

The significant effects of the treatments on basin enrichment were recorded on organic carbon (%) in the soil at both 0-15 cm and 15-30 cm depths. At 0-15 cm soil depth, all the treatments had resulted in significantly higher soil organic carbon content (ranging from 0.56± 0.05 % to 0.79± 0.08 %) over that of control (0.44± 0.06 %), whereas at 15-30 cm soil depth, soil incorporation of Tephrosia biomass resulted in significantly higher organic carbon (0.71± 0.16 %) over control (0.37± 0.07 %). The increase in the soil available phosphorus content at 0-15 cm depth, was maximum in case of mulching of Tephrosia (21.38± 1.23 kg/ha) and Vegetable soybean (21.13± 1.19 kg/ha).

In the litter decomposition studies, the nutrient-wise release pattern among the different biomass yielding plants under different treatments of mulching were compared. The percentage of total phosphorus and potassium contents released initially was found much faster in case of Tephrosia followed by Subabul, rice bean and vegetable soybean, but in the later stage the released rate became faster in case of Subabul than the other case (Fig. 7.3 & 7.4). On the other hand, when the nutrient-wise release pattern among the different biomass yielding plants under different treatments of soil incorporation were compared, then the percentage of total phosphorus and potassium content released initially was found significantly much faster in case of both Tephrosia and Subabul, followed by rice bean and vegetable soybean, but later the released rate was comparatively higher in case of Subabul (Fig. 7.5). In all the cases, the litter decomposition process took maximum period upto eight months to complete.

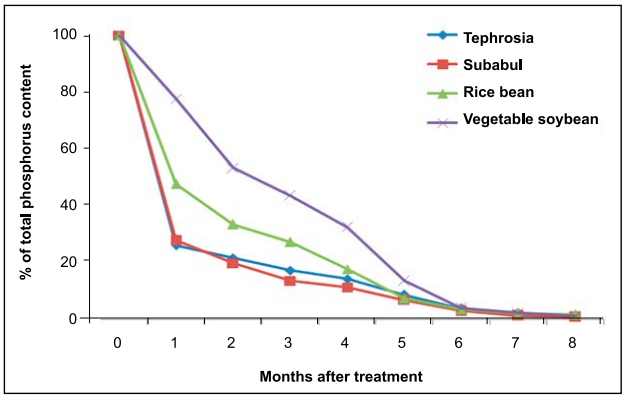


Fig. 7.3. Phosphorus release pattern under different treatments of mulching

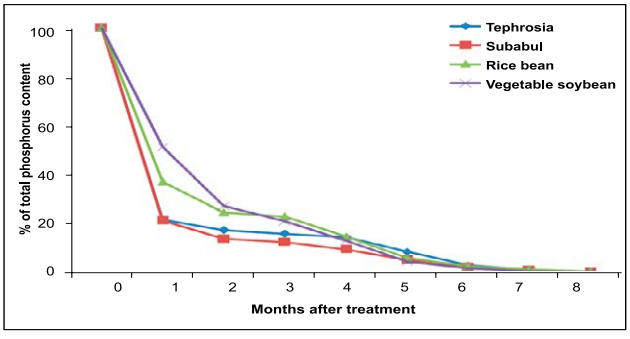


Fig. 7.4. Phosphorus release pattern under different treatments of soil incorporation

Fig. 7.5. Mulching of Tephrosia biomass

Fruit flies (Tephritidae: Diptera) Diversity and their Host Plant Determination from Eastern region of India

Thirty three varieties/genotypes of pointed gourd, *Trichosanthes dioica* were screened in search of resistance source against melon fruit fly, *Zeugodacus cucurbitae* under field conditions. Results indicated significant variations among tested varieties/genotypes in levels of fruit infestation and maggot density per fruit. None of varieties/ genotypes were observed to be free from *Z. cucurbitae* (Fig. 7.6 & 7.7). The minimum infestation was recorded in HAP-88 (6.36%) followed by HAP-65 (8.12%) genotypes with 1.0 and 0.9 maggots per fruit, respectively which were designated as resistant source against melon fruit fly, *Zeugodacus cucurbitae* infestation. Susceptible genotypes were recorded as HAPH-1 (55.01% fruit infestation) followed by HAP-74 (53.33% fruit infestation) with 4.7 maggots per fruit. Model relationship was established between fruit fly infestation and allelochemical (phenol and tannin) and antixenotic (length of pubescence and rind hardness) fruit traits in pointed gourd varieties/ genotypes to test the validity of hypothesis for highly influencing factor. Regression analysis indicated that phenols as independent factor was the most influencing factor of pointed gourd infestation on the basis of R^2 as the test criterion. Results also revealed that phenol, tannin, length of pubescence and rind hardness accounts for 82, 35, 34 and 32% variability inhibiting fruit fly infestation, respectively.

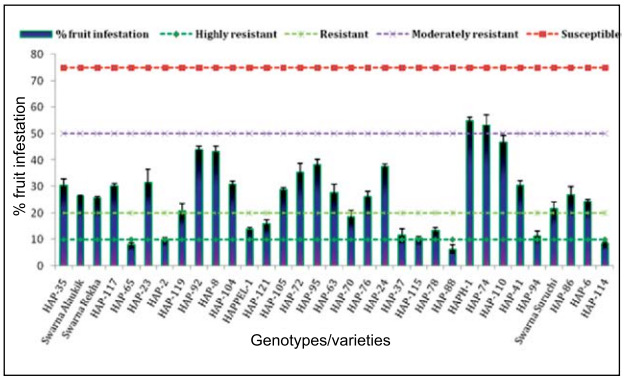


Fig. 7.6. Melon fruit fly, *Z. cucurbitae* infestation against different varieties/ genotypes of pointed gourd, *T. dioica*

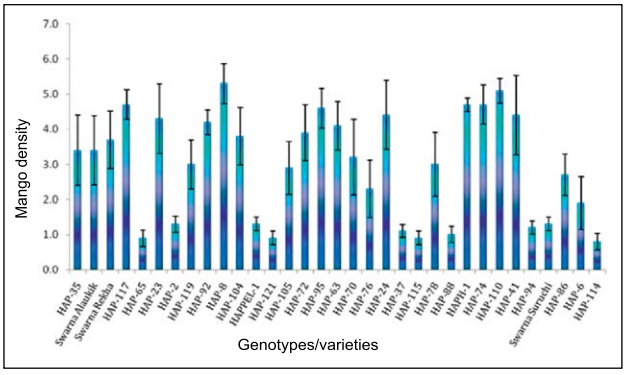


Fig. 7.7. Maggot density of fruit fly, *Z. cucurbitae* in the different varieties/ genotypes of pointed gourd, *T. dioica*

8. Vegetables

Tomato

Five promising crosses of tomato (bacterial wilt and nematode resistant) were evaluated for yield characters. HAT-296 x HAT-311, Swarna Lalima x HAT-311 and HAT-296x HAT-310 were promising in terms of yield, quality and resistance to bacterial wilt and root knot nematode (Fig. 8.1-8.3 and Table 8.1).

Table 8.1. Evaluation of bacterial wilt and nematode resistant crosses of tomato

Crosses	No. of fruits/ plant	Yield/ plant (kg)	Yield (t/ha)	Percent plant survival against wilt (%)	Resistance to root knot nematode
HAT-296 x HAT-310	27.91	1.73	43.17	82.5	Resistant
Swarna Lalima x HAT-311	36.21	2.17	51.38	80.0	Resistant
HAT-296 x HAT-302	28.70	1.89	43.65	75.0	Susceptible
Swarna Lalima x HAT-310	27.91	1.98	44.42	78.0	Resistant
HAT-296 x HAT-311	31.24	2.09	52.37	80.0	Resistant
CV %	31.40	38.80	38.50		

Garden pea

Under Initial Evaluation Trial (IET) of early season garden pea, seven numbers of entries were tested. The entries 2018/PEVAR-5 (24.59 t/ha) and 2018/PEVAR-7 (23.71 t/ha) were found promising in respect of marketable green pod yield whereas under Advance Varietal Trial (AVT)-I, the entries 2017/PEVAR-3 (24.91 t/ha) and 2017/PEVAR-6 (24.65 t/ha t/) and under AVT-II of early season garden pea, the entries 2016/PEVAR-6 (21.22 t/ha) and 2016/PEVAR-2 (20.42 t/ha) were found promising. Among the mid season entries, 2018/PMVAR-1 (21.84 t/ha) and 2018/PMVAR-7 (19.39 t/ha) under IET, 2017/PMVAR-5 (17.97 t/ha) and 2017/PMVAR-4 (17.35 t/ha) under AVT-I and 2016/PMVAR-5 (22.52 t/ha) and 2016/PMVAR-4 (20.67 t/ha) under AVT-II were found promising in respect of marketable green pod yield. Among edible pod type, the entries 2018/PEDVAR-1 (39.72 t/ha) and 2017/PEDVAR-4 (23.96 t/ha) were found promising under IET.

Cowpea

Under AVT-II of bush type cowpea, out of five entries tested, 2016/COPBVAR-5 (21.70 t/ha) and 2016/COPBVAR-4 (18.97 t/ha) were found promising in respect of marketable green pod yield.

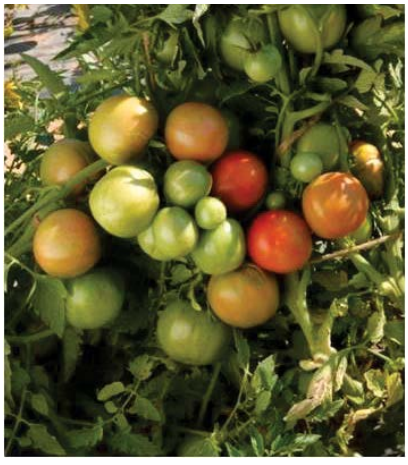


Fig. 8.1. Swarna Lalima x HAT-311

Fig. 8.2. HAT-296 x HAT-310

Fig. 8.3. HAT-296 X HAT-311

French bean

Under AVT-II of bush type french bean, the entries 2016/FBBVAR-3 (12.75 t/ha) and 2016/FBBVAR-2 (12.42 t/ha) were found promising for marketable green pod yield whereas under AVT-I of pole type french bean, the entry 2016/FBPVAR-7 (19.25 t/ha) was found promising.

Dolichos bean

Under IET of bush type, the entries 2018/DOLBVAR-2 (24.22 t/ha) and 2016/DOLBVAR-4 (18.32 t/ha), under AVT-II of Bush type, the entries 2016/DOLBVAR-5 (30.14 t/ha) and 2016/DOLBVAR-6 (27.00 t/ha) and under AVT-I of Bush type, the entries 2017/DOLBVAR-5 (31.17 t/ha) and 2017/DOLBVAR-2 (30.45 t/ha) were found promising for marketable green pod yield. In case of Pole type Dolichos bean, under IET, the entries 2018/DOLPVAR-7 (35.66 t/ha) and 2018/DOLPVAR-6 (24.83 t/ha), under AVT-I, the entry 2017/DOLPVAR-1 (25.13 t/ha) and under AVT-II, the entries 2018/DOLPVAR-12 (45.54 t/ha) and 2018/DOLPVAR-4 (31.57 t/ha) were found promising in respect of marketable fresh pod yield.

Nucleus Seed Production of Released and pre-Released Varieties of Leafy, Underutilized and Legume Vegetables

Nucleus seeds of released varieties of garden pea Swarna Amar (11 kg) and Swarna Mukti (13 kg), snow pea Swarna Tripti (53 kg), bush type French bean Swarna Priya (10 kg), pole type French bean Swarna Lata (3 kg), pole type vegetable cowpea Swarna Sweta (1.5 kg), Swarna Harita (3 kg) and Swarna Suphala (3 kg), bush type vegetable cowpea Swarna Mukut (2.5 kg), pole type photosensitive lablab/dolichos bean Swarna Utkrisht (2 kg), pole type photo-insensitive lablab bean Swarna Rituvar (2 kg), vegetable soybean Swarna Vasundhara (58 kg), pole type lima bean Swarna Poshan (10 kg), vegetable Faba/winter bean Swarna Safal (19 kg) and leaf amaranth Swarna Raktim (3.76 kg) were produced for maintenance. Nucleus seeds of pre-released varieties of vegetable cowpea HACP-3 (3 kg), HACP-24 (1.5 kg), HACP-30 (2.5 kg), HACP-56 (2 kg), HACP-57 (2 kg) and HACP-65 (1 kg), early peas HAEP-1 (12 kg) and HAEP-2 (12 kg), bush type pencil bean HAFB-212 (10 kg), pole type photo-insensitive lablab/dolichos bean HADB-32 (25 kg) and HADB-119 (1.5 kg), leaf amaranth HAMTH-13 (11.75 kg) and HAMTH-21 (3.4 kg), faba bean HAVFB-37 (18 kg), basmatic vegetable soybean AGS-458 (63 kg) and pole type french bean HAPB-5 (2 kg) were produced for maintenance and demonstration trials.

Maintenance of germplasm lines of leguminous, under-utilized and leafy vegetables

Germplasm lines of garden pea (78), bush type french bean (36), pole type french bean (32), cowpea (29), lablab/dolichos bean (26), vegetable soybean (31), winged bean (11), sword bean (2), velvet bean (3), cluster bean (1), jack bean (1), lima bean (2), mung bean (9), rice bean (2), black gram (26), horse gram (22), lai sag (7), chinese cabbage (1), palak (2), fenugreek (2), coriander (2), bathua (3), faba bean (28), vegetable pigeonpea (7) and yam bean (2) were maintained.

Nutritional Characterization and Value Addition of Potential Underutilized Leafy Vegetables

Survey was conducted to collect underutilized leafy vegetables from West Bengal, Odisha and Jharkhand. A total of thirty-four underutilized vegetables including leaves, flower bud, flower, stolon, young shoot and edible fern commonly consumed by the tribals were collected and identified from local haats and farmers fields of Darjeeling and Jalpaiguri district of West Bengal, Keonjhar, Cuttack and Khorda districts of Odisha, Ranchi and Latehar district of Jharkhand. The anti-oxidative properties (total phenols, total flavonoids content and antioxidant activity) and nutritive properties (macro-mineral content and micro-mineral content) of these thirty-four underutilized vegetables were estimated. The ranges of bioactive compound and nutritional properties of leafy vegetables are given in Table 8.2 & 8.3. The leafy vegetables *Celosia argentea, Leucas plukenetii, Bacopa monnieri* (West Bengal collection), *Leucas aspera* (cultivated) and *Bacopa monnieri* (Jharkhand collection) recorded highest antioxidant properties whereas, *Alternanthera sessilis* and *Celosia argentea* recorded highest mineral content. The study indicates that the leafy vegetables collected from the three states possess high nutritional properties. These underutilized, locally available, easily accessible, inexpensive leafy vegetables may be used as potential source of unconventional foods.

Table 8.2. Bioactive compounds and antioxidant activity of underutilized leafy vegetables

Bioactive compounds and antioxidant activity	Range	Leafy vegetables having high content
Total phenol content (mg-GAE/ 100g FW)	36.72-844.93	*Leucas plukenetii, Celosia argentea, Bacopa monnieri* (West Bengal collection), *Leucas aspera* (cultivated), *Bacopa monnieri* (Jharkhand collection)
Total flavonoids content (mg CE/100g FW)	15.15-561.97	*Celosia argentea, Bacopa monnieri* (Jharkhand collection), *Leucas plukenetii, Bacopa monnieri* (West Bengal collection), *Leucas aspera* (cultivated)
FRAP (µ mol TE/g FW)	1.17-74.79	*Leucas aspera* (cultivated), *Celosia argentea, Tridax procumbens, Bacopa monnieri* (Jharkhand collection), *Vangueria spinosus*
CUPRAC (µ mol TE/g FW)	4.33-101.93	*Celosia argentea, Leucas plukenetii, Bacopa monnieri* (Jharkhand collection), *Leucas aspera* (cultivated), *Bacopa monnieri* (West Bengal collection)
DPPH (µ mol TE/g FW)	0.42-47.20	*Celosia argentea, Vangueria spinosus, Leucas plukenetii, Bacopa monnieri* (West Bengal collection), *Tridax procumbens*
ABTS (µmol TE/g FW)	5.74-83.11	*Bacopa monnieri* (West Bengal collection), *Leucas plukenetii, Tridax procumbens, Celosia argentea, Commelina benghalensis*

GAE- Gallic acid equivalent; CE-Catechin equivalent; FRAP-Ferric reducing antioxidant power; CUPRAC-Cupric reducing antioxidant capacity; DPPH- 2,2-diphenyl-1-picrylhydrazyl; ABTS- 2,2-azino-di-(3-ethylbenzothialozinesulphonic acid); TE- Trolox Equivalent; FW-Fresh weight

Table 8.3. Mineral content of underutilized leafy vegetables

Mineral content	Range (mg/100g DW)	Leafy vegetables having high content
Potassium	1.58-6.09	*Cucurbita moschata* flower, *Celosia argentea, Diplazium esculentum, Alternanthera sessilis, Typhonium trilobatum*
Sodium	0.01- 1.28	*Enhydra fluctuans, Bacopa monnieri* (West Bengal collection), *Alternanthera sessilis, Bacopa monnieri* (Jharkhand collection)
Phosphorus	0.10- 1.09	*Cucurbita moschata* flower, *Diplazium esculentum, Momordica charantia, Lagenaria siceraria, Bambusa bambos* (shoots)
Sulphur	0.08-0.82	*Hygrophila auriculata, Brassica oleracea* var. *botrytis*, *Enhydra fluctuans, Bacopa monnieri* (West Bengal collection), *Alternanthera sessilis*
Calcium	0.74-7.54	Tridax procumbens, Hygrophila auriculata, Andrographis paniculata, Celosia argentea
Magnesium	1.42-5.54	Basella alba, Alternanthera sessilis, Commelina benghalensis, Typhonium trilobatum, Andrographis paniculata
Zinc	1.97-18.60	*Corchorus olitorius, Hygrophila auriculata, Lagenaria siceraria, Enhydra fluctuans, Bambusa bambos* (shoots)
Manganese	1.90-96.00	*Bacopa monnieri* (Jharkhand collection), *Celosia argentea, Corchorus olitorius, Lathyrus sativus, Alternanthera sessilis*

DW-Dry weight

9. Mushroom

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

Under AICRP on Mushroom, four types of naturally grown wild edible mushrooms were identified and collected from Saal forest and Termitariums in the local forest around Ranchi, Jharkhand. Among the wild edible mushroom, Tecnus (*Termitomyces* species) and *Rugda* are widely collected by the villagers while *Rasulla* species and *Amanita* species are collected to a lesser extent. These wild edible mushrooms play an important role in promotion of rural livelihood. These were collected by the villagers during July to August and sold at a premium price @ Rs. 600-800/kg in the local market (Fig. 9.1).

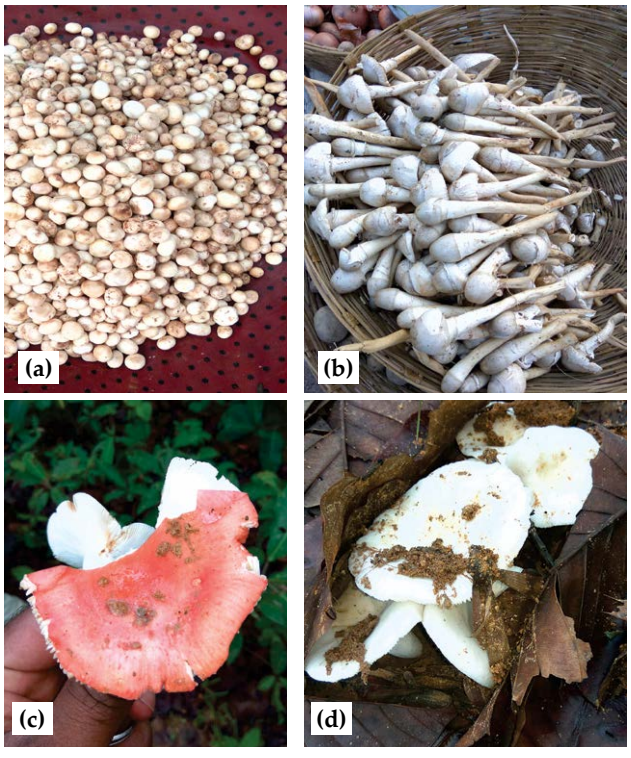


Fig. 9.1. Wild edible mushroom collected from the local market and neighboring forest of Ranchi (a) *Rugda*, (b) *Termitomyces* species, (c) *Rasulla* species and (d) wild edible mushroom *in situ.*

Advance varietal trial-1 of High Yielding Varieties/strains of Oyster Mushroom (*Pleurotus* spp)

An advance varietal trial of ten high yielding strains of *Pleurotus* species (PL-18-01 to PL-18-10) was conducted during October, 2018 to January, 2019. Among the evaluated strains of *Pleurotus* species, the highest biological efficiency was recorded in PL-18-07 (80.5%) followed by PL-18-05 (75%), PL-18-01 (74.75%) while the lowest was recorded in PL-18-09 (61.5%). The highest weight of sporophore was recorded in PL-18-03 (7.81 g) followed by PL-18-05 (7.75g) while the longest was recorded in PL-18-9 (6.51g). (Table 9.1 & Fig. 9.2).

Table 9.1. Biological efficiency of *Pleurotus* species under Ranchi condition

Strains of *Pleurotus* species	Yield parameters			
	Average yield (g)/kg substrate	BE (%)	Avg no. of sporophore/ kg substrate	Wt. of sporophore (g)
PL-18-01	747	74.75	100.25	7.46
PL-18-02	630	63.00	82.25	7.66
PL-18-03	670	67.00	85.75	7.81
PL-18-04	677	67.75	87.75	7.72
PL-18-05	750	75.00	96.75	7.75
PL-18-06	645	64.50	85.00	7.59
PL-18-07	805	80.50	108.25	7.44
PL-18-08	637	63.75	88.75	7.18
PL-18-09	615	61.50	94.50	6.51
PL-18-10	635	63.50	93.00	6.83

BE : Biological efficiency

PL-18-01 PL-18-04 PL-18-05 PL-18-07

Fig. 9.2. Biological efficiency of the four strains of *Pleurotus* species under advance varietal trials at Ranchi

10. Makhana

Evaluation of Makhana Germplasm

Ten germplasm of makhana (*Euryale ferox* Salisb) were evaluated based on yield and morphological characters. The number of fruit per plant varied from 7.22 (Manipur-9) to 13.20 (Superior Selection-1) and flowering period was about 42 days. However, peak pollination was observed between 60-70 days after transplanting. The weather of August and September was ideal for pollination and fruit set. The temperature and humidity of this period were 29-31°C and 79-81%, respectively. The number of seeds/plant varied from 82.4 in Manipur-2 to 102.00 in each of Selection -27 and Superior Selection-1. It was found that Manipur-9 recorded the minimum harvestable yield (1.8 t/ha) while Superior Selection-1 registered the maximum yield (4.9 t/ha). Superior Selection-1 was identified as early maturing promising high yielding makhana cultivar for the wet land ecosystem of North Bihar and produced the highest number of average mature fruits (12.21) (Fig. 10.1).

Evaluation of different genotypes of water chestnut

Water chestnut is a wonderful aquatic rooted floating annual herb and is valuable as fresh nut crop in wetland ecosystem of North Bihar. In the present study, the physico-chemical properties of water chestnut germplasm collected from M.P., U.P and Bihar were evaluated. The significant variations were observed in TSS (7.0-9.5°B), reducing sugar (1.89-2.96%), and total sugar (3.25-4.61%). The sugar/acid ratio among the various cultivars ranged from 44.21 (Lucknow Green) to 55.54 (Red Spineless). The maximum acidity (0.083%), reducing sugars (2.96%), non-reducing sugars (1.69%), total sugars (4.61%), sugar/acid ratio (55.54) was recorded in Red Spineless germplasm. The maximum TSS (9.5°Brix) was found in Red Spineless germplasm which were procured from M.P. followed by Green Spineless germplasm (9.0°B) from the same state. The statistically similar sugar/acid ratio was observed in both Red Spineless (55.54) and Green Spineless (54.13) germplasm. The Green Spineless exhibited the maximum yield of 12.00 t/ha followed by Red Spineless (9.50 t/ha). Red Spineless was also found to have the highest TSS of 9.6°B (Fig. 10.2-10.3 & Table 10.1).

Fig. 10.1. Superior Selection -1: No. of fruits 13-16/plant, Seeds/fruit > 100

Fig. 10.2. Red spineless water chestnut

Fig. 10.3. Green spineless water chestnut

Table 10.1. Physico-chemical characteristics of water chestnut germplasm-2018

Water chestnut germplasm	TSS (°B)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Non-reducing sugar (%)	Sugar acid ratio	Yield (t/ha)
Balia Red	7.5	0.070	1.97	3.25	1.28	46.43	4.25
Bihar Red Large	7.5	0.070	2.04	3.45	1.41	49.29	7.12
Bihar Red Small	8.0	0.087	2.64	4.06	1.42	46.67	7.50
Green Spine	7.0	0.066	1.89	3.25	1.36	49.24	4.76
Green Spineless	9.0	0.080	2.71	4.33	1.62	54.13	12.00
Lucknow Green	7.5	0.076	1.94	3.36	1.42	44.21	4.47
Orange Spineless	8.8	0.083	2.41	4.10	1.69	49.40	9.00
Red Spineless	9.6	0.083	2.96	4.61	1.65	55.54	9.50
LSD (p=0.05)	0.51	NS	0.11	0.25	NS	3.84	1.38

Production and Value Chain Analysis of Makhana in North Bihar

Makhana mandi of Purnea and Katihar are major trading centre of North Bihar which supplies popped Makhana to various parts of the country. The wholesalers also stock lava in their godown and sell it at different times of the year as per market demand and its price. This helps in maximizing their profit. Data on production system of Makhana was collected from farmers through interview schedule, group discussion and personal observation method. It was observed that unlike pond system of cultivation in Darbhanga and Madhubani, Makhana is mostly cultivated in low lying fields in both Purnea and Katihar district. It was found that more than half of the respondent farmers grow Makhana on an area higher than 5 acres of land. Nearly one fourth of total respondents took land on lease for growing Makhana. The annual lease rate varied from Rs. 7,000/- to Rs 17,000/- per acre, with average rate of Rs 13,222/- per acre. Unlike group farming of Makhana in ponds of Darbhanga and Madhubani, here it was grown by individual farmer in their field as a major crop. Maize, paddy, wheat, mustard, toria and banana were other important crops of selected region. In recent years Makhana has become primary source of income to these farmers as nearly 50% of them reported it to be the major source of income.

Fig. 10.4. Production of makhana under field condition in Purnea and Katihar

Analysis of socio-economic characteristics revealed that majority (71.05 %) of the makhana growers belonged to Above Poverty Line (APL) category. The average size of households involved in makhana cultivation was 3 to 4 members. It was observed that nearly two third of the farmers had matriculation and above qualification while rest were non-matric. The average annual income of Makhana farmers was worked out to be Rs 93,300/-. The average yield of makhana in Purnea district (2.25 t/ha) was higher than that of Katihar (1.96 t/ha). Nearly 20% respondents reported a yield of more than 2.5 t/ha makhana seed from their field.

Cost of Makhana Cultivation under field System in Selected Districts

Cost of cultivation of makhana was estimated in both Purnea and Katihar district. Component wise pooled data were analyzed using simple descriptive statistics. The operational cost of makhana cultivation was Rs 1,03,500/ha under field condition. Among different cost components, harvesting contributed maximum to the extent of 45.66 % of total cost. Harvesting of Makhana is carried out manually by the skilled labour who collects seeds from water logged field. Moreover, it was observed that each field is harvested thrice since all the seeds cannot be collected in one go from muddy field. The cost of irrigation was the

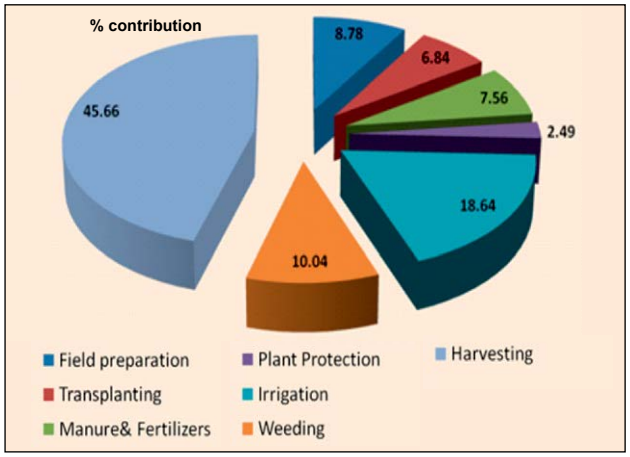


Fig. 10.5. Per cent contribution of different components in cost of cultivation in Purnea and Katihar

second highest contributing component accounting to 18.64% of total cost. Makhana is an aquatic crop which requires 1-1.5 ft standing water throughout its crop period. Therefore, maintaining water in fields is a costly affair especially during summer season. Labour cost for field preparation, transplanting and weeding also contributed to nearly one fourth of total cost of cultivation. The cost of plant protection and manures and fertilizer contribute lowest in total cost.

Makhana Processing as a Business Enterprise

Harda in Purnea is a major hub of processing of Makhana seed into popped *lava*. Hundreds of families from Darbhanga and Madhubani district specialized in manual processing migrate to Purnea and Katihar during last week of June to 1st week of July and stay there till December. They take rooms on rental basis and start processing work because harvesting of Makhana seeds starts during July-August. These processors give annual average rent of Rs. 12,200/- for their work place. Nearly 6-7 member family which includes children also do this business of processing after purchasing of seeds from local Makhana growers. During survey it was observed that purchase price of *Gudi* (Makhana seed) ranged from Rs. 7500to Rs. 8000/ per quintal during 2017 which increased to Rs. 12000-13500 per quintal in 2018. Thus there was wide fluctuation in market price of *gudi* which also results in price fluctuation of popped lava. The processing cost involved rent, transport cost of seed from field to rental place, cost of fuel and labour cost.

Fig. 10.6. View of Makhana processing centre in Purnia

11. Medicinal and Aromatic Plants

Performance Evaluation of Medicinal-Aromatic Plants in Eastern Indo-Gangetic Plains

Thirty seven medicinal and aromatic plant species were collected from various part of the country. Among them twenty nine plant species were collected from ICAR-Directorate of Medicinal Aromatic Plants Research, Anand, Gujarat. Rest five and three plant species were collected from Patna (Bihar) and Howrah (West Bengal), respectively. All plants belong to clade angiosperm with six from monocots and thirty one from dicot plants. The crops belong to fifteen family and eleven order. The family with higher number of species are Lamicaceae. All the collected plants are maintained in a herbal garden at ICAR-RCER, Patna (Fig. 11.1).

Adaptability studies of collected medicinal and aromatic plants: All the collected plants were established at the institute for their adaptability study. Seeds of neel (*Indigofera tinctoria*), senna (*Cassia angustifolia*) and holi basil (*Ocimum sanctum*) failed to germinate. Seeds of palmarosa (*Cymbopogon martini*), germinated, but could not survive under field condition. Un-rooted cutting of guggal (*Commiphora wightii*) failed to generate root. High field survival was observed in most of the perennial and some of the annual plant species. The most severe insect species was termite which destroy entire un-cutting of guggal and samudrabel. Termite also harmed the growth of basil and lemon grass. Other important insect species observed were aphid and beetle. Some of the observed disease were root rot (safed musli), collar rot and blight.

Evaluation of kalmegh (*Andrographis paniculata*) germplasm for growth, yield and andrographolid content: Seven germplasm including variety and line of Kalmegh were collected from ICAR-DMAPR, Anand, Gujarat. Total biomass varied from 32g to 87 g with the highest value obtained from Anand Kalmegh (Fig. 11.2). Total number of branches varied between 18 to 38. Hight of the plant varied between 44 cm to 89 cm. Herbage yield varied between 45 g to 93 g. Andropholoids content were evaluated using chromatographic method which varied 0.09 g to 2.22g /100g dry weight basis. Generally andropholide content in leaves was higher (0.77 g to 2.22g/100g dwb) than stem (0.09g to0.28g/100g dwb). Germplasm with high andrographolide content are Anand Kalmegh and IC-415019.

Fig. 11.2. Kalmegh

Fig. 11.1. Medicinal plants at herbal garden of ICAR-RECR, Patna

12. Farming System Research

Development of Location Specific Integrated Farming System Modules for Small and Marginal Farmers' of Bihar

Resource recycling is one of the important activities through which resource use efficiency could be increased in Integrated Farming System. Priorities should be given to those components whose by-product can be recycled within the system or can be reused as input for another component to increase input use efficiency, income and sustainability. Studies on nutrient recycling under two-acre IFS model (crops+ fish/duck+ livestock) revealed that 13.8 t of cow dung from two cows, 11.3 t of vegetable wastes from an area of 1000m^2 and 1.21 t of duck dropping from 35 ducks were produced during 2018-19 and upon recycling of these wastes into the systems, 71.5 kg nitrogen, 46.5 kg phosphorus and 57.4 kg potash were added into the soil (Table 12.1).

Likewise, studies on resource recycling under one acre IFS model comprising of crops + goat + poultry as main components while mushroom and vermicomposting as supplementary components had a total production of 2.5 t of goat manure, 6.62 t of vegetable wastes, 1.78 t of poultry droppings and 4.64 t of rice/maize/lentil straws which were recycled within the system and added 57.5 kg nitrogen, 35.5 kg phosphorus and 45.0 kg potash in the soil (Fig. 12.1 & Table 12.2).

Fig. 12.1. One acre IFS model

A study on soil fertility build up was carried out for different integrations using different organic manures obtained as wastes from different components of farming systems and chemical fertilizers in combination for six years continuously (2011-18). The per cent increase from initial value (N 216.5) in case of nitrogen in different combinations varied from 8.36 to 18.98, in case of phosphorus (9.56 to 30.15), in case of potassium (8.52 to 12.63) while percent increase in organic carbon content was reported to be (-3.39 to 11.86) at the end of April, 2018. Further, it was observed that in the fields where only crops were grown and no organic manure was added, organic carbon was depleting while in the plots where poultry manure was added in combination with chemical fertilizers there was no change in the organic

Table 12.1. Nutrient recycling pattern under two-acre IFS model (Crops + fish + livestock)

Farm waste	Quantity produced (t)	Production/ use pattern (t)	Nutrient gain (kg)	Total nutrient gain from recycling (kg)	Saving (Rs.)	Fertilizer equivalent (kg)
Cow dung (2 cows)	13.5	7.2 (FYM- 3.1) 2.5 (VC: 1.3) 4.0- Pond treat.	N-23.5 P- 10.2 K-15.3	N=71.5 P=46.5 K=57.4	Total: Rs.3784/-	155 kg urea 290 kg SSP 96 kg MOP
Veg. waste	12.2	7.2 (VC-1.6) 5.5 As fodder	N- 24.6 P- 21.1 K- 27.7			
Duck drop (35 nos.)	1.17	As fish feed/silt	N- 23.4 P- 15.2 K- 14.4			

VC: vermicompost, FYM: Farm Yard Manure, SSP: Single Super Phasphate, MOP: Muriate of Potash

Table 12.2. Nutrient recycling pattern under one-acre IFS model (crop + goat + poultry)

Farm waste	Quantity produced (t)	Production/use pattern (t)	Nutrient gain (kg)	Total nutrient gain upon recycling	Saving due to resource recycling (Rs.)	Fertilizer saving (kg)
Goat droppings (20 + 1 nos.)	2.49	1.85 (GM- 1.42) 0.64 (VC- 0.17)	N- 29.0 P- 10.8 K- 18.6	N- 57.5 P- 35.5 K- 45.0	2430	125.0 kg urea 222.0 kg SSP 75.0 kg MOP
Veg. waste	7.22	2.22 (VC- 0.38) 5.0- As fodder	N- 11.2 P- 10.2 K- 14.8			
Poultry manure (700 nos. of birds)	1.61	Used in crops	N- 17.3 P- 14.5 K- 11.6			
RWMML Straw	4.64	0.44 – mushroom shed 0.16- hut 4.28- sold				

RWMML: Rice-wheat-maize-mung-lentil , GM : Green manure

carbon status of the soil. Percent increase in case of nitrogen, phosphorus, potassium and organic carbon was found maximum with crop + fish + poultry + dairy, crop + fish + goat, crop + fish + goat and crop + fish + poultry + dairy integration, respectively (Table 12.3).

Development of Location Specific Integrated Farming System Models For Rainfed Ecosystem of Eastern Plateau and Hill Region

A 0.75 acre IFS model (crop + horti + dairy) was developed in which livestock (2 cows+ 3 calves), fruits (guava and badhal) were integrated with cereals, pulses and oilseeds. During the year 2018-19, the total fruit yield was 485 kg which is sufficient for fulfilling the daily dietary requirement of 11.07 persons. The total milk production was 1040.25 lit. from two cows which is sufficient for the 14.25 persons. So, the milk and fruit production were in surplus in the IFS. The cereals, pulses and oilseeds obtained from IFS were 250.83 kg, 33.4 kg and 16.35 kg, respectively which is sufficient for fulfilling the daily dietary requirement of 1.32, 1.83 and 1 person respectively (Table 12.4). Vegetable production from bathua (*Chenopodium* spp.), mustard, tuber crops and badhal (*Artocarpus lakoocha*) flowers is sufficient for fulfilling the daily dietary requirement of 3.61 persons. The total FYM production was 9.49 t/year and cow urine production was 3464.37 litres/year from two cows and three calves. A total of 2 kg seeds of Tephrosia was produced and total fuel wood produced from the system was 212.3 kg. The total fodder production was 4.01 t/year.

Table 12.3. Available soil nitrogen, phosphorus, exchangeable K (Kg/ha) and organic carbon (%) during 2011- 2018 under different integrations

Farming Systems	Initial 2011 (kg/ha)	2017-18 (kg/ha)				% increase			
		N	P	K	OC	N	P	K	OC
Crop only	N 216.5	237.5	32.3	255	0.57	9.70	18.75	12.58	-3.39
Cr+ Veg (50%)	P 27.2	234.6	29.8	245.8	0.65	8.36	9.56	8.52	10.17
Cr + F+ P (50%)		240.2	30.5	246.4	0.59	10 .95	12.13	8.79	0.00
Cr+ F+ Duck (50%)	K 226.5	245.6	30.5	246.7	0.61	13.44	12.13	8.92	3.39
Cr + F+ Goat (50%)		253.4	35.4	255.1	0.62	17.04	30.15	12.63	5.08
Cr+F+Dairy (50%)	OC	252.3	34.7	251.4	0.66	16.54	27.57	10.99	11.86
Cr+F+P+Dairy	0.59 (%)	257.6	34.6	254.7	0.64	18.98	27.21	12.45	8.47
Cr+Mushroom+Goat		254.6	32.5	248.6	0.63	17.60	19.49	9.76	6.78

Note: Cr = crops, F= fish, p= poultry, and data in parenthesis denotes percent of NPK provided through organic sources

Table 12.4. Production from different components of IFS

Components		Crops	Area in IFS (m^2)	Yield in IFS (kg)	No. of persons can fulfill the daily dietary requirement
Fruits Badhal		Guava	250	440	11.07
		1 tree	45		
Dairy		Milk	2 cow	1040.25	14.25
Pulses	*Kharif*	Ricebean	250	20	1.83
		Arhar (20 plants)	40	2	
	Rabi	Chickpea	250	9.4	
		Lentil	180	2	
Cereals	*Kharif*	Rice	648	134.82	1.32
		Ragi	150	76	
		Maize	250	40	
Oilseeds	*Rabi*	Linseed	85	1.6	1.00
		Mustard	350	14.75	
Vegetables Mustard Tubers Badhal flowers		Bathua	620	197.6	3.61
		350	50		
		80	92		
		1 tree	56		

Income from actual plan of land allocated in different components of IFS model of 0.75 acre at ICAR-RC, Ranchi was Rs. 1,00,792 and from optimized plan was Rs. 1,03,448. Optimization could improve income by only by Rs. 2,656 but could satisfy the pulse and oilseed requirement of the family. Tabular data shows that 0.75 acre is not sufficient to meet paddy requirement as production was less by 396 kg calculated as family (2+2) requirement but the model is able to produce sufficient milk required for a family (2+2).

Development of Climate Resilient Farming System Models for Livelihood Improvement

Integration of multiple enterprises and multiple components of agricultural system such as crops, horticulture, livestock, fisheries, agro-forestry and alternate income generation such as backyard poultry, duck rearing, mushroom cultivation, vermi-compost etc provides an opportunity to meet out the major challenges in agriculture sector in perspective of climate change. Therefore, a project entitled "development of climate resilient farming system models for livelihood improvement" is being implemented in four adopted villages of East Champaran district of Bihar with the aim to reduce the poverty in the area by improving productivity, profitability and sustainability of smallholder agriculture. Following developmental activities and demonstration works were carried out during 2018-19 under this project.

Water harvesting through reshaping and bunding of existing water bodies and by excavation of new ponds

The East Champaran district receives an average annual rainfall of 1241.6 mm. But, in last 5 years the rainfall pattern of districts has changed, leading to irregular or uneven supply of canal water, decline in groundwater level and decrease in amount of rainfall. The economy of the district mainly depends upon agriculture. To fulfill the water requirements of agriculture, there is need of supplemental irrigation in the form of conjunctive use to meet crop water requirements. This project aims at evaluating the efficacy of conjunctive use of pond and ground water resources in imparting climate resilience to the agriculture in the region. Two new ponds were excavated/ constructed one each in Chandrahiya and Khairimal villages and three old ponds (two in Jasauli Patti and one in Chintamanpur villages) were renovated and reshaped in the year 2017 for storage of water for irrigation purpose as well as for fish production. One new pond was also excavated/ constructed in Chandrahiya village for fish production in the year 2018 (Fig. 12.2). These ponds are being used for fish production and also to provide supplemental irrigation to vegetables crops in the events of dry spells or delayed monsoon.

Fig. 12.2. Water storage pond and installation of borewell

A bore well (8"/6") with 3 HP submersible pump was commissioned in Chandrahiya village to provide timely irrigation to field crops as well as to supplement the water for fish farming in a newly constructed pond (54 x 35 x 1.25 m). It covers about 2 ha (approx) command area for irrigation in crops besides supplementing water in ponds during scarcity.

Fish farming for improving fish production and livelihood support

Advance fingerlings of six cultivable fish species namely, *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 10,000 fingerlings/ha. In the current polyculture system, the stocking was done based on the adaptation to the ecological niches of different fish species such 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. The total area covered as fish ponds was about 0.72 ha which includes six number of fish ponds at 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. The analysis of water quality (2018-19) revealed that the pH, temperature, dissolved oxygen and conductivity levels were within the optimum range. The average pH, dissolved oxygen and temperature of pond waters was 8.09, 6.67 ppm and 25.91°C, respectively. The analysis indicated that the water parameter remained favorable throughout the culture period, however, during the months of December 2018 and January 2019, water temperature was recorded as low as 8.0°C on some days that can be tolerated by most of the cultivable native carp species. The growth (average body weight) analysis indicated that grass carp and silver carp were the fastest growing species whereas rohu and mrigal slowest growing among all the cultivated six fish species in all the villages. After the culture period of about seven months, the range of average growth of six cultivated fish species was estimated to be as 311.5 to 478.5 g of catla, 309.8 to 465.6 g of rohu, 269.6 to 384.5 g of mrigal, 505.7 to 805.5 g of silver carp, 518.9 to 815.5 g of grass carp and 321.5 to 458.5 g of common carp.

Integration of agroforestry for multiple production system

During the second year, there was severe mortality and damage of different perennial plants due to grazing of animals, mainly by blue bull (Neelgai). The performances of the surviving plants was found to be satisfactory. Measurement of plant growth of different perennial trees under different agroforestry systems varied during the second year of plantation. Among the different timber species, there was maximum increase in plant height (111.86 ± 20.13%) in case of Teak (*Tectona grandis)* while minimum increase (58.42 ± 9.61%) in Siris (*Albizia procera*) over the previous year. In case of trunk girth, teak showed maximum increase (83.14 ± 15.17%) while siris showed minimum increase (47.73 ± 8.59%).

Introduction of improved varieties in major crops and its production technologies

Quality seeds of high yielding varieties of potato (Kufri Sinduri), wheat (HD-2967 and HD-2733), lentil (KLS 218), sugarcane (CO-018 and CO-0238) and green gram (IPM 2-3) were distributed among the farmers in the adopted villages of the project site for improving crop productivity and income level of the farming community.

Farmers who adopted better package of practice and seed of potato obtained average yield of 13.39 t/ha which was 24.6% higher than the yield obtained by farmer cultivating local variety of potato. In wheat quality seed of HD 2733 and HD 2967 were provided to selected beneficiaries in all four villages. There was 27% increase in wheat yield due to adoption of improved varieties of wheat over local varieties. Similarly in lentil, on an average 38.63% higher seed yield was obtained with the adoption of new varieties (1.58 t/ha) as compared to local varieties (0.97 t/ha).

During *Kharif* 2018 two varieties of paddy seed *viz*., CR Dhan 909 and Swarna Shreya were distributed among the farmers, which was sown in about 32 acres land. Farmers recorded 35.98% higher grain yield than the local varieties. During spring 2018-19 two varieties of sugarcane *viz*., Co 0118 (21.9 t) and Co 0238 (105.6 t) were distributed among 5 and 26 beneficiaries farmers, planted in 2.6 and 13.8 h area, respectively. The mean productivity of Co 0118 and Co 0238 was 69.33 and 70.69 t/h, respectively which are higher in comparison to average yield of Bihar (67.9 t/h).

The productivity of Co 0118 was best in Chintamanpur (73.8 t/ha) whereas Co 0238 performed the best in Chandrahiya (79.9 t/h). Yields obtained, clearly indicates that providing quality seeds with improved management practices and technical backstopping can significantly increase the yield.

During *zaid* 2018, mean productivity of moong (2.06 t/ha) was recorded in Jasaulipatti village where 3-4 pickings was made by the farmers in this village and the crop was grown under irrigated conditions fetching net income of Rs.78,877/- per ha. In the other three villages moong was raised under rainfed conditions and only one picking was resulted into very low yields of 2.9, 2.7 and 1.7 q/ha in Khairimal, Chandrahiya and Chintamanpur, respectively.

Evaluation and Optimization of Integrated Farming System

Data were collected from different Integrated Farming System models developed at ICAR-RCER, Patna, Ranchi and farmer's field at two villages *viz.* Anantpur and Yashwantpur at Chandi block in Nalanda district. Optimization of income from various IFS models according to land allocation in different components of IFS has been done for already developed IFS models at ICAR-RCER, Patna (1 acre and 2 acre), ICAR RC, Ranchi (0.75 acre). Dietary requirement of a family of size (2+2) and observed production from 0.75 acre land at ICAR RCER RC, Ranchi (Table 12.5) and actual and optimized plan of land allocation in different components of IFS and two farmer's field of 3 acre at two villages *viz.* Anantpur and Yashwantpur at Chandi block in Nalanda district of Bihar (Table 12.6 & 12.7). Development of information system of IFS is in progress. Some databases and graphic user interfaces (GUIs) have been developed using MS ACCESS, SQL and dotNET. This system has been developed for integrated farming system (IFS) for al all types of land *viz.* lowland, midland and upland.

Cereal crop includes rice, wheat and maize. Horticulture crop includes mango, banana, guava, vegetables. In fish component, rohu and katla are being cultivated in a pond. Mushroom spawn, honey and two cows are present in this IFS model of Smt. Anita Kumari at Anantpur village, Chandi, Nalanda as actual plan but these components area and number has been optimized/ changed for increasing the income of farmer. Income from actual plan of land allocation among different

Table 12.5. Observed production from 0.75 acre model at ICAR-RCER RC, Ranchi

Components		Crops	Area in IFS (m^2)	Yield in IFS (kg)	Productivity level (t/ha)
Fruits		Guava (Nov. to Feb.)	250	238.9	9.56
Papaya		32	77.7	24.28	
Dairy		Milk	2 cow	1676.4 lit.	838.2 lit/cow
Pulses	*Kharif*	Black gram	187	3.00	0.16
		Hoursegram	520	10.00	0.19
		Arhar	90	6.75	0.75
	Rabi	Chickpea	60	3.15	0.52
		Lentil	60	1.34	0.22
Cereals	*Kharif*	Rice	144	7.37	5.12
		Ragi	560	55	0.98
	Rabi	Oats	190	6.5	0.34
Oilseeds	*Rabi*	Linseed	54	4.9	0.91
		Mustard	54	6.42	1.19

Table 12.6. Optimized land allocation among components of 3 acre IFS model and income of Smt. Anita Kumari at Anantpur village, Chandi, Nalanda

Components	Area (acre)	Income (Rs.)	Optimized area (acre)	Optimized income (Rs.)
Cereal crop	2	36000	1.5	28500
Horticulture crop	0.35	44550	0.35	44550
Mushroom	0.05	300000	0.05	300000
Cow	0.1	57600	0.2	80350
Honey	0.1	72000	0.2	94210
Fish	0.4	12000	0.7	21220
Total	3	5,22,150	3	568830

Table 12.7. Cost of cultivation and income from 3 Acre IFS model of Sri Samrendra Kumar at Yashvantpur, Chandi, Nalanda Optimized

Components	Area (Acre)	Income (Rs.)	Optimized area (Acre)	Income (Rs.)
Cereal crop	1.0	44500	0.6	32350
Horticulture crop	0.6	74550	0.8	92450
Fish	1.0	330000	1.2	364650
Cow	0.2	114600	0.2	114600
Poultry	0.2	96400	0.2	96400
Total	3.0	660050	3.0	700450

components of IFS is Rs.5,22,150 but when the land allocation is optimized according to different components of IFS, total income is Rs. 568830. So income of farmer is increased with Rs.46,680 after optimization of land resources.

Structure and Functioning of Agroforestry Systems in the Middle IGP

In order to understand the structure and functioning of agroforestry systems in the middle IGP, studies were initiated by selecting different regions of the IGP on the basis of physical topography and forest cover area. A total of 10 sites have been selected in the state of Bihar. The first site covering flood plain areas of the East Champaran District has been completed after carrying out the preliminary survey and site selection. In this district, survey was conducted in 5 villages and 30 farmers. Data analyzed revealed two major agroforestry systems in the district - *viz.*, Agri-horticultural system (Agricultural crops + mango/litchi) and Agri-silvicultural system (Agricultural crops + Teak; Agricultural crops (sugarcane) + Semal) are widely practiced by farmers (Table 12.8).

Table 12.8. Major agroforestry systems practiced and yield patterns of agricultural crops at different sites

System	Combinations	Yields
Agri-horticultural system	Agricultural crops (rice, maize) + mango	Rice- 1.7 t/ha, Maize- 3.4 t/ha
Agri-horticultural system	Agricultural crops (rice, maize) + mango	Maize- 6.37 t/ha Rice- 2.97 t/ha
Agri-silvicultural system	Agricultural crop (rice) + Teak	Rice- 2.97 t/ha
Agri-silvicultural system	Agricultural crop (rice) + Teak	Rice- 3.4 t/ha
Agri-silvicultural system	Sugarcane + Semal	Sugarcane- 63.75 t/ha
Agri-silvicultural system	Agricultural crops (sugarcane) + Semal	Sugarcane- 75.0 t/ha
Agri-silvicultural system	Agricultural crops (sugarcane) + Semal	Rice- 1.27 t/ha Maize- 4.25 t/ha Sugarcane- 59.5 t/ha

Soil samples were collected at five depths (0-15, 15-30, 30-45, 45-60 and 60-90 cm) using power auger during December 2018. Soil MBC showed variation amongst agroforestry systems studied (Table 12.9**)**. The semal + sugarcane produced the maximum MBC (126.71 µg/g) followed by teak + agricultural crops system (107.22 µg/g). Upper soil depth (0-15 cm) had higher MBC than the lower depths. On an average, the soil MBC was higher under agroforestry system than the control plot.

Table 12.9. Soil Microbial Biomass (µg/g) under different agroforestry systems

Agroforestry systems	Control				
	0-15	15-30	30-45	45-60	60-90
Sugarcane	95.44	48.59	22.24	18.67	11.71
Seasonal crops	94.01	85.72	43.95	28.82	18.01
Seasonal crops	103.85	44.29	26.98	7.77	5.27
Agroforestry systems	System				
	0-15	15-30	30-45	45-60	60-90
Semal + Sugarcane	126.71	57.49	27.38	14.06	13.42
Mango + seasonal crops	84.29	61.44	52.59	21.37	6.93
Teak + seasonal crops	107.22	81.37	27.06	20.02	7.75

Fig. 12.3. Agricultural crops (chilli) + Teak based AFS

Fig 12.4. Agricultural crops (Maize, Beans) + Mango (AHS) based AFS

13. Crop Diversification

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

A long-term study was initiated at the ICAR–RCER Patna, keeping 10 cropping systems *viz.* transplanted rice (TPR)–wheat–mungbean (Farmers practices), direct seeded rice (DSR)–wheat (ZT)–mungbean (ZT), soybean–maize (ZT), DSR–mustard–urdbean, foxtail millet–lentil–fallow, pearl millet–chickpea–fallow, finger millet–*toria* (ZT)–fallow, sorghum (grain)–chickpea (ZT)–fallow, maize (cob)–pigeonpea and sorghum (fodder)–mustard (ZT)–urdbean (ZT) during the rainy season of 2016 on clay loamy soil. Significantly the highest system annual productivity (SREY) was recorded with maize cob–pigeonpea (21.21 t/ha) followed by sorghum fodder–mustard–urdbean (15.36 t/ha) and soybean–maize (14.89 t/ha). Among the millet–based systems, sorghum (grain)–chickpea (ZT)–fallow system (12.05 t/ha) had the higher system productivity and the lowest with finger millet–*toria*–fallow (5.94 t/ha) (Table 13.1). From the findings of three years study, it may be concluded that rice and wheat may be diversified with soybean, maize for cob/fodder, fodder sorghum and millets like jowar/bajra during *Kharif* and winter maize, *Rabi* pigeonpea and mustard in winter.

Fig. 13.1. Field view of experiment

Table 13.1. System productivity as influenced by diverse cropping systems (2018–19)

Cropping system	REY (t/ha)		SREY (t/ha)
	Kharif	*Rabi*	
TPR–wheat–mungbean (FP)	4.59	5.04	9.63
DSR-wheat (ZT)-mungbean (ZT)	4.99	5.25	10.24
Soybean–maize (ZT)	4.06	10.83	14.89
DSR–mustard (ZT)–urdbean (ZT)	4.89	6.94	11.83
Foxtailmillet–lentil(ZT)–fallow	2.37	5.34	7.72
Pearlmillet–chickpea (ZT)–fallow	4.22	6.57	10.79
Fingermillet–toria (ZT)–fallow	2.62	3.33	5.94
Jowar (grain)–chickpea (ZT)–fallow	5.53	6.52	12.05
Maize (green cob)–pigeonpea (ZT)	12.10	9.11	21.21
Sorghum (fodder)–mustard (ZT)–urdbean (ZT)	9.14	6.22	15.36
LSD (P=0.05)	0.47	0.53	0.98

*REY: Rice equivalent yield, SREY: System rice equivalent yield, Farmers practices, ZT: zero tillage, FP: farmers practices , TPR: Transplanted rice

Diversification of Rainfed Upland Rice System in Eastern Plateau and Hill Region

Under rainfed upland conditions of Eastern Plateau and Hill region, an experiment on diversification of direct sown upland rice was conducted with ten treatments during *Kharif* 2018. The treatments were T_1 (sole crop of rice cv. BVD-109), T_2 (sole crop of finger millet cv. BBM-10), T_3 (sole crop of blackgram cv. Uttara), T_4 (sole crop of horse gram cv. Birsa Kulthi-1), T_5 (sole crop of pigeonpea cv. UPAS-120), T_6 (sole crop of vegetable cowpea cv. Swarna Mukut), T_7 (rice + black gram in area ratio of 1:1), T_8 (rice + horse gram in area ratio of 1:1), T_9 (finger millet + black gram in area ratio of 1:1) and T_{10} (finger millet + horse gram in area ratio of 1:1). The sole crop of vegetable cowpea recorded the maximum rice equivalent yield of 19.12 t/ha followed by that of pigeonpea (12.02 t/

ha), blackgram (9.46 t/ha), horsegram (8.91t/ha) and finger millet 5.39 t/ha). The rice equivalent yield of blackgram and horsegram was at par with each other. Among the combination treatments, T_{10} : 8.21 t/ha, T_9: 7.64 t/ha and T_7: 6.71 t/ha were at par with each other followed by T8: 6.47 t/ha in respect of rice equivalent yield. The sole crop of rice recorded yield 1.47 t/ha only. So, diversification of rainfed upland rice system with vegetable, pulses and millets would be more profitable in Eastern Plateau and Hill Region.

Fig. 13.2. Crop diversification in rainfed uplands in Eastern Plateau and Hill Region

Rehabilitation of Coal Mine Affected Areas through Agroforestry Interventions

Under this project, a model of Agri-horti-silvi-pastural system was established in the year 2015 in a farmer's field of Phusri village, near Charhi, Mandu, Ramgarh, Jharkhand which is a coal mine affected area. The model comprise of different fruit species like *Aegle marmelos, Artocarpus heterophyllus, Citrus limon, Mangifera indica, Psidium guajava* and *Punica granatum,* timber species like *Dalbergia latifolia, Swietenia mahogany* and *Tectona grandis* and multipurpose trees (MPTs) like *Melia azedarach and Pongamia pinnata.* Among all MPTs, the establishment rate was 100% after gap filling during 2nd year of plantation. The maximum plant height (3.69 m) and Plant spread was recorded in *M. azedarach* compared to other MPTs. In case of fruit crops, maximum mortality was recorded in *C. limon* (12.36%) followed by *P. guajava* (7.34%). The maximum plant height (2.14 m) and plant spread was recorded in the *A. marmelos* (Table 13.2). The species like perennial grasses, *M. azedarach* and *Tephrosia candida* produced 515 kg green fodder. As intercrops, farmers could receive approximately Rs. 30000/- from rainy season crops (like tomato, chilli and cucurbits) and Rs. 15000/- from winter crops (like mustard, groundnut, chickpea, arhar, cabbage, cauliflower and potato). The vegetable intake of family (4 members) increased by 30% due to vegetable cultivation in the system.

Table 13.2. Plant growth parameters of MPTs and fruits crops planted at coal mine affected area

Crops	Plant height (m)	Trunk diameter (cm)	Plant spread (N-S) (m)	Plant spread (E-W) (m)
MPTs				
Pongamia pinnata	3.16±0.07	18.67±3.51	3.02±0.93	2.98±0.93
Tectona grandis	3.25±0.59	15.50±5.22	0.53±0.13	0.50±0.15
Swietenia mahogany	2.06±0.46	12.33±2.89	1.26±0.39	1.25±0.43
Melia azeda-rach	3.69±0.71	18.00±2.65	1.26±0.30	1.26±0.34
Dalbergia latifolia	2.41±1.00	10.17±5.75	1.21±0.79	1.20±0.76
Fruits				
Citrus limon	1.54±0.41	9.67±1.44	1.48±0.34	1.51±0.34
Artocarpus heterophyllus	1.71±1.21	21.25±0.35	1.50±0.11	1.52±0.10
Mangifera indica	1.92±0.29	18.67±1.76	1.63±0.16	1.68±0.16
Psidium guajava	1.44±0.32	10.00±3.77	1.48±0.34	1.50±0.34
Aegle marme-los	2.14±0.29	19.00±7.00	1.78±0.24	1.82±0.23
Punica grana-tum	1.36±0.22	8.00±1.73	1.25±0.52	1.28±0.51

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

A project was undertaken to develop multitier system for rainfed uplands of Eastern Plateau and Hills. The intercrop (ragi) yield was monitored under four-year-old multitier cropping system for rainfed uplands. The highest yield was recorded under no filler+mango+mahogany whereas; the highest ragi yield was recorded under aonla+mango+mahogany system. The per cent PAR availability was more in no filler+ mango +mahogany multitier system followed by aonla+mango+mahogany system. The perennial components were planted in the year 2014-15 and up to 2018-19 the highest per cent increment in

Bearing in mango

Bearing on pomegranate

Tephrosia at boundary

Growth of Bakaine

Fig. 13.3. Field view of plantation in coalmine affected area

plant height (421.76%) was recorded in mahogany followed by in mango (411.54%). Among the different filler crops, the highest per cent increment in plant height (401.23%) and stem girth (616.45%) was recorded in peach.

Production Potential of Potato and Indian Mustard under Different Organic Mulches and Irrigation Levels

An experiment was conducted to compare the performance of organic mulches and water levels on potato and mustard sole and their intercropping system. The treatments consisted of five different organic mulches, in main plots *viz.*, farm yard manure, weed waste, farm compost, paddy straw and unmulched as control. Each main plots were divided into three cropping systems as sub-plots *viz.*, sole potato, sole mustard and potato+ mustard. Further each sub-plots were subdivided to allocate three levels of irrigation *viz.*, IW/CPE=0.70, IW/CPE=0.80 and IW/CPE= 1.00. Potato variety Kufri Lalima, Mustard variety Hybrid 5222 were used as test crops.

There was no significant difference on tuber yield of potato due to various organic mulches applied. However, the highest potato tuber yield of 24.1 t/ha was obtained by paddy straw followed by farm compost (21.5 t/ha). Potato tuber yield of 19.9 t/ha and potato tuber equivalent yield of 21.0 t/ha was recorded under sole cropping of potato and mustard, respectively. The tuber yield of potato in intercropping of potato with mustard (2:1) was reduced to the extent of 19.0 t/ha. There was significant yield improvement under at 0.8 to 1.0 IW/CPE over 0.7 IW/CPE ratio, However, there was no significant improvement in potato tuber yield due to increasing water levels from 0.8 to 1.0 IW/CPE. The highest water productivity (WP) of 26.8 kg/m^3 was recorded at 0.8 IW/CPE while it was only 24.0 kg/m^3 in 1.0 IW/CPE ratio. The lowest WP (12.13 kg/m^3) was recorded under 0.7 IW/CPE.

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

An experiment was initiated during 2018 to improve the yield and water productivity of rice-vegetable pea-summer maize system. Results revealed that water management practices and field pea genotypes had significant effect on yield and water productivity. Among pea genotypes 'Harbhajan' recorded the maximum yield (8.73 t/ha) and water productivity (8.12 kg/m^3). Irrigation at IW/CPE ratio at 0.4 recorded the lower pea yield but maximum water productivity (9.92 kg/m^3). Maximum pea yield (9.78 t/ha) was obtained with IW/CPE rate of 0.60 (Table 13.3).

Table 13.3. Interaction effects of genotypes and water management on Green pea yield (t/ha)

Treatments	W_1 (IW: CPE = 0.4)	W_2 (IW: CPE = 0.6)	W_3 (IW: CPE = 0.8)	W_4 (IW: CPE = 1.0)	Mean
V_1Annapurna	7.55	9.03	7.68	7.90	7.82
V_2Haribhajan	8.00	10.63	8.33	9.70	8.73
V_3 SPL-VS 10	7.10	10.44	8.93	9.13	8.15
Mean	6.59	9.78	8.31	8.24	
LSD (P=0.05) = V-0.63, I-0.57, VxI-0.85					

Improving Rice-Lentil-Mung Bean System Productivity through Water Management

The project started in *Rabi* 2016-17. In this experiment two level of land management i.e. Conventional tillage (CT) and Zero tillage (ZT), along with 4 water management levels (irrigation at IW: CPE) were tested in cropping system mode. During *Kharif*, rice was grown under puddled system (TP) and its productivity ranged from 4.18 to 4.38 t/ha. In *Rabi* season, lentil was attacked by soil born fungal pathogen *Rhizoctonia solani* causing root rot and crop was severly damaged. Data pertaining to root rot disease was collected twice, i.e. 17-01-2019 & 27-02-2019 and presented in Table 13.4. It was noticed that ZT plots were less affected as compared to CT plot. *Rhizoctonia solani* fungus multiplied very fast under favourable moisture regime. During summer season, mungbean under ZT plot produced significantly higher seed yield (1.15 t/ha) than CT (0.88 t/ha). In case of water management, the highest mungbean seed yield (1.27 t/ha) (Table 13.4) was recorded with IW: CPE=0.4 (W2).

Fig. 13.4. Field view of experiment

Table 13.4. Yield attributes and yields of mungbean influenced by land and water management treatments

Treatments	Biological yield (t/ha)	Grain yield (t/ha)	HI	WP (kg/m^3)	Root rot incidence (%)	
					17-01-2019	27-02-2019
Land management						
ZT	3.85	1.15	0.30	1.05	7.5	69.6
CT	3.68	0.88	0.24	0.99	13.3	83.3
LSD (P=0.05)	NS	0.21	0.04	NS	3.1	11.7
Water management						
W_1 Rainfed	2.85	0.46	0.16	0.76	10.2	68.3
W_2 IW: CPE = 0.4	3.80	1.27	0.33	1.60	10.6	70.6
W_3 IW: CPE = 0.6	4.23	1.22	0.29	0.98	11.8	66.3
W_4 IW: CPE = 0.8	4.18	1.12	0.27	0.76	13.7	70.6
LSD (P = 0.05)	1.11	0.19	0.04	0.25	4.3	12.4

Diversification of Rice-Wheat Cropping System with Vegetables

An experiment was initiated during *Kharif* 2017 to identify the most suitable diversified rice based cropping system for silty clay loam soil at ICAR-RCER, Patna. The treatments were : two (medium and long) duration of rice variety and six cropping systems where rice-wheat-greengram

was treated as control. Rice variety Swarna Shreya attained maturity in 120 days while variety Swarna (MTU 7029) took 26 more days than Swarna Shreya. During *Rabi* wheat was diversified with vegetables like potato, tomato, cauliflower, broccoli and garden pea. Results revealed that yield of Swarna (6.304 t/ha) was significantly higher than Swarna shreya (4.356 t/ha) but yield of *rabi* and summer crop were significantly lower than those grown after Swarna Shreya (Table 13.5).

Table 13.5. Effect of rice varieties and cropping system on yield and rice equivalent yield (t/ha)

Treatments	Rice (t/ha)	*Rabi* (t/ha)	Greengram (t/ha)	REY of *Rabi* crop (t/ha)	REY of greengram (t/ha)	System REY (t/ha)
Rice variety						
Swarna Shreya (medium duration)	4.36	24.07	1.012	14.45	3.00	21.81
Swarna (long duration)	6.30	7.97	0.713	4.93	2.11	13.35
LSD (P=0.05)	0.19	5.88	NS	3.74	NS	2.69
Cropping system						
R-W-GG	5.32	3.32	0.482	3.72	1.43	10.46
R-P-GG	5.28	23.94	0.375	15.44	1.11	21.84
R-T-GG	5.35	19.74	1.090	7.64	3.23	16.23
R-CF-GG	5.33	28.16	0.843	18.16	2.50	25.99
R-Br-GG	5.38	17.88	1.333	11.20	3.96	20.54
R-GP-GG	5.32	13.06	1.050	1.97	3.12	10.41
LSD (P=0.05)	NS	3.85	0.231	2.40	0.68	2.46

The system productivity of rice-cauliflower-greengram (25.995 t/ha) was significantly superior over other cropping systems followed by rice-potato-greengram (21.837 t/ha) and rice-broccoli-greengram (20.54 t/ha). Interaction effect of rice varieties and cropping system on system productivity was found significant (Table 13.6). Cauliflower and broccoli grown after Swarna Shreya (medium duration rice variety) provided an opportunity to take short span crop before sowing of greengram. Hence, onion and spinach were sown after cauliflower and broccoli, respectively which further enhanced the productivity of respective cropping system. Consequently the yield of rice-cauliflower-greengram and rice-broccoli-greengram with medium duration rice was significantly higher than that grown with long duration rice. No significant difference was found on system productivity of rice-wheat-greengram system with medium and long duration rice variety (Swarna) but for other cropping systems significant differences were observed due to duration of rice varieties.

Table 13.6. Interaction effect of rice varieties and cropping system on system productivity in terms of REY (t/ha)

Var/C. sys	R-W-GG	R-P-GG	R-T-GG	R-CF-GG	R-Br-GG	R-GP-GG	Mean
Swarna Shreya	10.21	25.34	17.26	38.42*	28.13*	11.49	21.81
Swarna	10.72	18.34	15.19	13.57	12.95	9.34	13.35
Mean	10.46	21.84	16.23	25.99	20.54	10.41	

*include yield of onion and spinach after cauliflower and broccoli, respectively

LSD for variety (V): 2.68; LSD for cropping system (CS): 2.456; LSD (CS) at same level of V:4.01, LSD(V) at the same level of CS: 3.92

14. Carbon Sequestration and Nutrient Dynamics

Evaluation of Different Production Systems for Carbon Sequestration Potential

Dry biomass production and carbon sequestration potential of mango orchards were evaluated in eastern Plateau & Hill region. The mango plants in the age group of 2 to 10 year old were uprooted and the dry biomass of different parts of mango plants corresponding to different collar diameter was measured. The whole tree was separated into root, bole, branch and leaf and the biomass of different plant parts was measured. The measured data were fitted to various growth models namely Linear, Allometric, Logistic, Gompertz, Richard's, Negative exponential, Monomolecular, Mitcherlich and Weibull to find out the parameter estimates of different model and to validate the best fitted model for estimation of dry biomass and carbon stock. Among the models, Gompertz was found best suited for prediction of biomass and carbon stock in mango orchards. The predicted total biomass of mango planted at 5 × 5 m spacing (planting density 400 trees per ha) varied from 0.53 to 10.5 Mg/ha among the 2-10 year old orchard and accounted for 84.3 to 87.26% by above ground biomass (Bole, Branch and Leaf). The bole biomass varied from 0.20 to 4.15 Mg/ha with share of 37.5 to 39.3% of total biomass. The predicted biomass of branch varied from 0.16 to 3.19 Mg/ha, which accounted for average 30% of total biomass; Similarly, the leaf biomass ranged from 0.09 to 1.86 Mg/ha. The predicted root biomass of mango in the prevailing low fertile acidic soils was 0.08-1.34 Mg/ha and accounted for average 13.5% of total biomass (Table 14.1).

The carbon content of different parts of mango plant was measured and the average carbon content in different components of mango tree was 46.5, 44.6, 44.8 and 44.4% in leaf, branch, bole and root, respectively. The highest predicted total biomass carbon in 10 year old mango orchard with average collar diameter of 14.33 cm was 3.87 Mg/ha. The highest carbon mitigation potential of 10-year old mango orchard was 3.0 Mg/ha with a corresponding carbon dioxide mitigation of 11.04 Mg/ha in eastern plateau and hill region of India (Table 14.2).

Table 14.1. Componentwise biomass estimates (Mg/ha) in *Mangifera indica*.

Age (Years)	Average collar diameter (cm)	Predicted biomass of different tree components							MAI (Mg/ha/yr)
		Branch	Bole	Leaf	Root	Above ground (AGB)	Below ground (BGB)	Total biomass (AGB+BGB)	
2	1.83 ±0.19	0.16± 0.02 (29.83)	0.20±0.03 (37.58)	0.09±0.01 (17.10)	0.08 ±0.01 (15.48)	0.45 ±0.06 (84.28)	0.08 ±0.01 (15.72)	0.53 ±0.07	0.26 ±0.03
4	4.96±0.38	0.88±0.12 (29.70)	1.16±0.16 (39.40)	0.52±0.07 (17.52)	0.39 ±0.05 (13.38)	2.55 ±0.35 (86.60)	0.39 ±0.05 (13.40)	2.95 ±0.400	0.74±0.10
6	8.00±0.28	1.87±0.08 (29.87)	2.49±0.12 (39.65)	1.11±0.05 (17.64)	0.81 ±0.04 (12.84)	5.47 ±0.26 (87.16)	0.81 ±0.03 (12.84)	6.30 ±0.30	1.05±0.05
8	10.92±0.33	2.67±0.07 (30.07)	3.51±0.09 (39.53)	1.57±0.04 (17.68)	1.13±0.03 (12.73)	7.73 ±0.20 (87.26)	1.13±0.03 (12.74)	8.88 ±0.23	1.11±0.03
10	14.33±0.99	3.19±0.10 (30.23)	4.15±0.12 (39.33)	1.86±0.05 (17.69)	1.34 ±0.04 (12.75)	9.17 ±0.27 (87.21)	1.34 ±0.04 (12.79)	10.50 ±0.31	1.05±0.03

Values in parenthesis indicates % allocation in different tree components; ± values indicate std. error; MAI, Mean annual increment

Table 14.2. Component wise carbon stock estimates (Mg/ha) in *Mangifera indica*.

Age (years)	Average collar diameter (cm)	Stored carbon				Emitted carbon	Mitigated carbon (Mg/ha)	CO_2 Stored (Mg/ha)
		Branch	Bole	Root	Total	Leaf		
2	1.83 ± 0.19	0.07 ± 0.01	0.09 ± 0.01	0.04 ± 0.004	0.20 ± 0.03	0.04± 0.01	0.15 ± 0.020	0.57 ± 0.07
4	4.96 ± 0.38	0.39 ± 0.05	0.52± 0.07	0.17 ± 0.02	1.08 ± 0.15	0.24 ± 0.03	0.85 ± 0.113	3.11 ± 0.41
6	8.00 ± 0.28	0.84 ± 0.04	1.11 ± 0.05	0.36 ± 0.02	2.31 ± 0.11	0.51 ± 0.02	1.79 ± 0.08	6.58 ± 0.31
8	10.92 ± 0.33	1.19 ± 0.03	1.57 ± 0.04	0.50 ± 0.01	3.26 ± 0.09	0.73 ± 0.02	2.53 ± 0.06	9.30 ± 0.25
10	14.33 ± 0.99	1.42 ± 0.04	1.86 ± 0.05	0.60 ± 0.02	3.87 ± 0.12	0.87 ± 0.03	3.00 ± 0.09	11.04 ± 0.33

Assessment of Total Soil Organic Carbon and Oxidisable Organic Carbon in different Tree Production Systems

The investigation was undertaken to evaluate the dynamics of total soil organic carbon in 8 year old plantations of ber, kusum and Palas in eastern plateau and hill region. The highest C_{tot} (total soil organic carbon) in 0-0.60 m depth was 56.7 Mg/ha in Palas plantations which was 38.9 % higher over control (Fig. 14.1). Similarly, the ber and kusum plantations recorded significantly higher C_{tot} (29.4 and 15.7 % higher over control, respectively). The oxidizable organic carbon (C_{oc}) varied from 30.58 to 42.62 Mg C/ha soil among the different tree plantations under study. The relative preponderance of C_{oc} under different plantations was in the following order: Palas > ber > kusum > control. This increase in C_{oc} in different plantations was due to significant increases in carbon input with leaf litter of tree system. Both total soil organic carbon and oxidizable organic carbon were highest in the surface soil and gradually decreased with increasing soil depth.

The very labile carbon fraction (C $frac_1$) was the highest (20.20 Mg C/ha) in the rhizosphere soils of Palas throughout the depth of soil profile (0-0.60 m). The C $frac_1$ in ber and kusum plantations were at par. The Palas, ber and kusum plantations registered 67.7, 31.9 and 20.5% increase in total C $frac_1$ over control, respectively. The labile carbon fraction (C $frac_2$) (0-0.60 m) was significantly higher in Palas and ber plantations over control, but when compared between them, found non-significant. The highest C $frac_2$ was in ber plantations (13.89 Mg C/ha). The C $frac_2$ in kusum was at par with control. The less labile carbon fraction, C $frac_3$ (0-0.60 m) was highest of Palas plantations (10.15 Mg C/ha). The C $frac_3$ in ber and kusum were at par with control. Similarly the highest non-labile carbon fraction, C $frac_4$ (0-0.60 m) was recorded in Palas plantations (14.06 Mg/ha) and was significantly higher over kusum plantations and control (Table 14.3-14.4).

Soil microbial biomass carbon (SMBC) in different lac-host tree plantations

The SMBC in the surface soils (0-0.30m) of Palas plantations was highest (296.9 µg/g) and was significantly higher over kusum plantations and control. The SMBC of ber and Palas plantations were at par (Fig. 14.2).

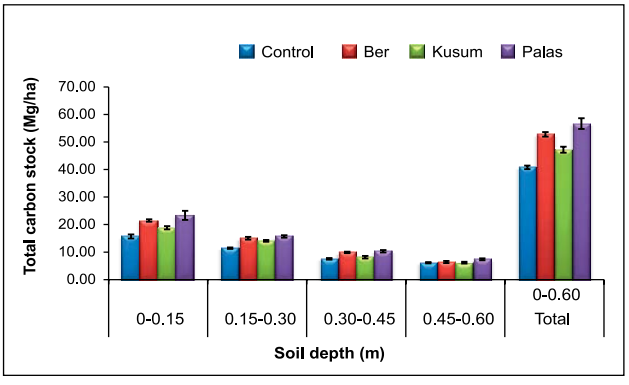


Fig. 14.1. Total soil organic carbon in soils in different layers (m) of 8 year old Lac host tree species

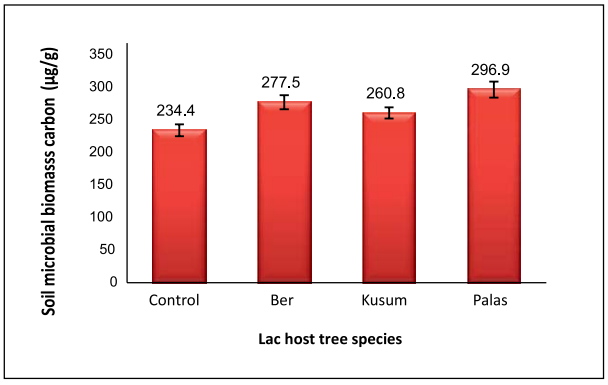


Fig. 14.2. Soil microbial biomass carbon in surface soil (0-30cm) of lac host tree plantations

Table 14.3. Very labile and labile organic C fractions (Mg/ha soil) in soils in different layers (m) of 8 year old lac-host tree plantations at Namkum.

Plantations	Soil organic carbon fraction (Mg C/ha soil)									
	Very labile pool (C*frac*-1)					Labile pool (C*frac*-2)				
	0-0.15	0.15-0.30	0.30-0.45	0.45-0.60	Total 0-0.60	0- 0.15	0.15-0.30	0.30-0.45	0.45-0.60	Total 0-0.60
Control	5.86	3.65	1.61	0.93	12.04	3.21	2.70	2.46	2.01	10.38
Ber	7.21	5.19	2.39	1.10	15.89	5.45	3.51	2.83	2.10	13.89
Kusum	6.62	5.01	1.89	1.00	14.51	4.03	3.19	2.42	1.84	11.48
Palas	9.29	5.49	3.35	2.07	20.20	4.36	3.51	2.43	1.96	12.26
LSD (p≤0.05)	1.81	0.83	0.69	0.54	2.64	1.24	NS	NS	NS	1.78

Table 14.4. Less labile and non-labile organic C fractions (Mg/ha soil) in soils in different layers (m) of 8 year old lac-host tree plantations at Namkum.

Plantations	Soil organic carbon fraction(Mg C/ha soil)									
	Less labile pool (C*frac*-3)					Non-labile pool (C*frac*-4)				
	0-0.15	0.15-0.30	0.30-0.45	0.45-0.60	Total 0-0.60	0-0.15	0.15-0.30	0.30-0.45	0.45-0.60	Total 0-0.60
Control	2.71	2.25	1.61	1.66	8.24	3.89	2.82	1.88	1.53	10.11
Ber	3.47	2.59	2.22	1.62	9.90	5.34	3.73	2.45	1.59	13.10
Kusum	3.48	2.54	1.81	1.80	9.64	4.69	3.34	2.02	1.53	11.58
Palas	3.89	2.78	1.95	1.52	10.15	5.79	3.89	2.56	1.83	14.06
LSD (p≤0.05)	0.84	NS	NS	NS	1.83	1.07	0.87	0.44	NS	2.28

Distribution of native and applied carbon in lac-host tree species

The soil organic carbon allocated to native and applied carbon throughout the soil profile depth of 0-60 cm varied among different lac-host plantations. In ber plantations, the allocation of SOC to applied carbon was higher than native carbon up to 0-45 cm soil depth. At lower depth below 45 cm, the allocation of SOC to native carbon exceeded the applied carbon. In ber plantations, the applied carbon constituted the contributions from leaf litter decomposition and stabilized into SOC in 0-45 cm soil depth. In Kusum plantations, the allocations of SOC to applied carbon was higher than native carbon up to 0-30 cm soil depth, which confirms the stabilization of leaf litter carbon to SOC in 0-30 cm soil depth. The allocation to native carbon was higher below 30 cm soil depth in Kusum plantations. In Palas plantations, the applied carbon through leaf litter being stabilized in 0-60 cm soil depth. However, higher proportion of SOC from applied carbon stabilized in 0-15 cm soil depth and thereafter, the SOC from native carbon was higher over applied carbon.

Soil organic carbon stock in agroforestry tree species in eastern Plateau and Hill region of India

The different agroforestry plantations namely Arjun, Gamhar and Teak showed significantly higher total SOC over control (no plantations) throughout the depth of soil profile (Table 14.5). The total SOC when compared among the plantations showed non-significant difference. The total SOC in surface soil at 0-15 cm depth was highest in Arjun plantations (26.78 Mg/ha) followed by teak (24.73 Mg/ha). The highest total SOC was 64.17 Mg/ha in teak plantations in 0-0.60 m soil depth and was 36.8% higher than control. Similarly, Arjun and ber plantations had 29.6 and 22.8% higher in total SOC over control, respectively. The highest oxidisable organic carbon (OOC) in the surface soil at 0-15cm depth was 20.13 Mg/ha in Arjun plantations and was 37.4% higher than the control. However, the highest OOC in the entire soil depth of 0-0.60 m was 48.21 Mg/ha in teak plantations and was followed by Arjun plantations (45.7 Mg/ha).

The very labile carbon fractions (*Cfrac*-1) under different agroforestry plantations were significantly

Table 14.5. Total and oxidisable organic carbon in soils of different layers (m) in 8 year old agroforestry plantations

Agroforestry species	Soil organic carbon (Mg C/ha soil)									
	Total soil organic carbon (C_{tot})					Oxidizable organic carbon (C_{oc})				
	0-0.15	0.15-0.30	0.30-0.45	0.45-0.60	Total 0-0.60	0-0.15	0.15-0.30	0.30-0.45	0.45-0.60	Total 0-0.60
Control	19.48	12.43	8.77	6.20	46.88	14.65	9.32	6.60	4.67	35.24
Arjun	26.78	14.89	11.08	8.05	60.79	20.13	11.19	8.32	6.05	45.70
Gamhar	21.94	14.75	12.23	8.65	57.57	16.49	11.09	9.20	6.34	43.13
Teak	24.73	16.21	13.20	10.02	64.17	18.59	12.17	9.92	7.52	48.21
Mean	23.23	14.57	11.32	8.23		17.47	10.95	8.51	6.15	
LSD (P≤0.05)	2.56	1.98	1.85	1.02	5.04	2.81	1.83	1.12	0.97	4.48

higher over control. The highest *Cfrac-1* in the surface soil at 0-0.15 m was 9.16 Mg C/ha in Arjun plantations. The *Cfrac-1* in the entire soil depth of 0-0.60 m was highest (18.31 Mg C/ha) in Arjun plantations and was followed by teak plantations (15.38 Mg C/ha). The labile carbon fractions (*Cfrac-2*) in the surface soil at 0-0.15 m were the highest of 9.71 Mg C/ha in Gamhar plantations. Further, the entire soil depth of 0-0.60 m registered highest *Cfrac-2* of 28.98 Mg C/ha in Gamhar plantations and was followed by teak plantations (20.37 Mg C/ha).

The soil microbial biomass carbon (SMBC) in Arjun and Teak plantations was significantly higher than control (no plantations). The SMBC was the highest (423.4 µg/g) in teak plantations in the surface soils at 0-30 cm depth (Fig. 14.3). 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 unfavorable environment.

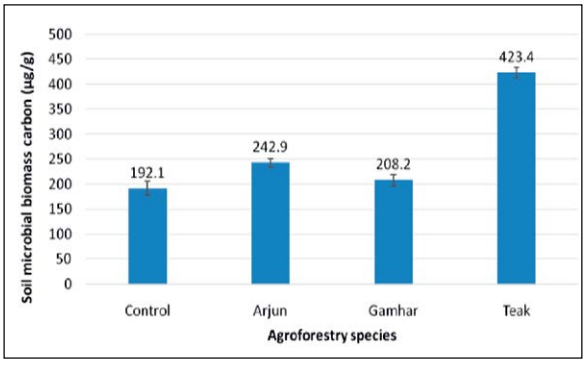


Fig. 14.3. Soil microbial biomass carbon in surface soil (0-30cm) of agroforestry plantations

Distributions of native and applied carbon in agroforestry plantations

The soil organic carbon distributed throughout the soil profile depth of 0-0.6 m in all the agroforestry plantations was categorized into native and applied carbon. The native carbon corresponds to the total SOC content in the control plot, while the applied carbon represents the stabilized carbon in different plantations resulting from leaf litter additions. In Arjun plantations, the SOC distributed as applied carbon was stabilized throughout the soil profile depth of 0-0.6 m. However, the percentage share of applied C (52.4%) was higher than native C (41.5%) in surface soil at 0-0.15 m and thereafter, the percentage share of native carbon was higher than applied carbon up to 0.6 m. In Gamhar plantations, the applied C% was lower than native C% in surface soil at 0-0.3 m depth. However, the applied C% was higher than native C% in subsurface soil at 0.30-0.60 m in Gamhar plantations. The highest native C % was 32.4% at 0.3-0.45 m soil depth in Gamhar plantations. Similarly, the applied C% was lower than native C% in surface soil, while the applied C% was higher than native C% in subsurface soil in Teak plantations. The highest native C% in Teak plantations was 30.3% at 0-0.15 m soil depth.

15. Water Quality and Productivity

Evaluation of Vegetable Cropping Sequences under Drip Irrigation with Mulching in Eastern Plateau and Hill Region

The experiment was conducted with three treatments comprising of drip irrigation (DI), drip irrigation with bicolor polythene mulch (DIM) and furrow irrigation (FI) (Fig. 15.1). The response of crops *viz.* cabbage, cauliflower and broccoli in *Rabi*; okra, cowpea and french bean in *Zaid* and tomato, vegetable soybean and capsicum in *Kharif* was evaluated in terms of yield, water productivity and economic water productivity.

During the *Rabi* season the DIM resulted in significantly the highest curd yields of 31.17, 27.07 and 13.01 t/ha for cabbage, cauliflower and broccoli, respectively with respective water productivities of 9.6, 6.8 and 3.2 kg/m^3. During subsequent summer season cowpea, okra and capsicum were planted on the same beds without disturbing mulch and drip while fields were prepared in furrow irrigation. In case of the summer crop, the DIM resulted in significantly highest fruit yield of 6.33, 6.6 and 3.33 t/ha for okra, cowpea and french bean, respectively. The highest yield of 6.88, 6.94 and 3.26 t/ha was observed under drip irrigation with mulch with respective economic water productivity of 29.8, 31.0 and 29.1 Rs/m^3 for *Kharif* crops of tomato, vegetable soybean and capsicum. Thus the drip system in conjunction with polyethylene bicolour silver black mulch technology was found effective for commercial cultivation of vegetables under different seasons in Eastern Plateau & Hill region.

Fig. 15.1. Field view of cabbage-cauliflower-broccoli during *Rabi* season

Seasonal water balance of irrigation methods for cabbage

The seasonal water balance of furrow and drip irrigation methods was assessed under field conditions. Soil moisture balance was worked out daily using root zone soil water balance equation. The analysis revealed that, deep percolation loss of 139.3 and 30.4 mm (Table 15.1**)** was observed under furrow and drip irrigation systems, respectively, which was about 42.2 and 11.2% of the total seasonal water applied to the crop. This study highlights the need for precise irrigation scheduling under furrow irrigation systems to reduce the deep percolation loses. Lower deep percolation losses under drip system provided optimal soil moisture conditions in the root zone of the crops leading to higher crop yields.

Table 15.1. Water balance parameters of cabbage

Water balance parameter	Furrow	Drip
Irrigation, mm	330	272
Crop ET, mm	156.1	202.5
Seasonal soil water gain, mm	38.2	38.7
Duration of plant available water, days	78	78
Deep percolation, mm	139.3	30.4
Percolation loss, %	42.2	11.2

Assessment of Runoff and Soil Loss from different Production Systems

Soil loss from vegetable planting systems

Plastic mulching is an important agricultural practice gaining popularity due to its potential in improving crop productivity and reducing labour usage. Vegetable cultivation in plateau region of India utilizes different planting methods involving raised beds and different kinds of mulches.

A study was carried out to assess the runoff and soil loss under different planting methods *viz.* raised bed + polythene mulch, raised bed + straw mulch, check basin system of irrigation and grass cover as control. Water from demarcated plots was collected in the plastic drums of 200 litre capacity installed at the lower corner of the plots. Water samples were collected for each rainfall event during monsoon season and were analysed for the sediment content using calibrated turbidity meter. Analysis revealed that the raised bed system of planting with polythene mulch resulted in higher production of runoff (13.8% of rainfall) and soil loss (235.5 kg/ha) as compared to the other planting systems (Table 15.2). The basin method of cultivation recorded lowest percentage runoff (9.4%) and soil loss (47.5 kg/ha).The soil loss from these plots was well below the permissible limits mainly because of leveled plots and establishment of grass cover in the empty space between crop rows with the progress of cropping season. Although, the soil loss was on lower side, we found that plastic mulch substantially accelerated runoff generation and soil erosion from the experimental plots. The results obtained in this study have practical implications for soil and water conservation in vegetable cultivation systems.

Table 15.2. Runoff depth and runoff as percent of total rainfall from different planting systems

Parameter	Raised bed + polythene mulch	Raised bed + straw mulch	Basin irrigation	Grass cover
Crop	Chilli	Elephant foot yam	Paddy	No crop
Runoff depth, mm	52.4	45.0	35.6	40.4
% of Rainfall	13.8	11.8	9.4	10.6
Soil loss, kg/ha	235.5	62.3	47.5	48.6

Runoff and soil loss from orchard systems

Runoff and soil loss assessments were made from four major fruit crops (mango, litchi, guava and jackfruit) of Eastern Plateau and Hill Region of India. Plots were demarcated using bunds of 25 cm height and runoff was collected using a plastic drums of 200 litre capacity installed at the lower corner of each plot. Runoff production from selected fruit orchards was comparatively less as compared to that observed from vegetable production systems. Runoff percentage varied from 0.8% (litchi) to 4.8% (Guava) (Table 15.3). The thick layer (3 cm) of decomposed leaf litter on the soil surface offered resistance to the movement of water increasing the infiltration opportunity time, consequently reducing the amount of runoff from the experimental plots. The soil loss from orchards was recorded at 31.7, 11.2, 16.3, 33.3 and 19.2 kg/ha from the orchards of litchi+guava, litchi, mango, guava and jackfruit, respectively. Presence of good cover of leaf litter reduced the soil loss from litchi orchards while the higher proportion of the exposed soil surface and lack of proper grass cover increased the soil loss from guava orchards. The results of this study will assist in bench marking of runoff generation from the orchard dominated hydrological response units (HRUs) of a watershed.

Table 15.3. Runoff and soil loss from different orchards

Parameter	Litchi+ Guava	Litchi	Mango	Guava	Jackfruit
Rainfall	746.3	746.3	746.3	746.3	746.3
Runoff, mm	17.1	6.1	9.8	35.9	15.6
% of rainfall	2.3	0.8	1.3	4.8	2.1
Soil loss, kg/ha	31.72	11.20	16.28	33.34	19.21

Rainfall interception loss in fruit plants

A study was conducted to assess the stemflow and throughfall from four major fruit tree species (mango, litchi, guava and jackfruit) of Eastern Plateau and Hill Region (Fig. 15.2 & 15.3). To measure stemflow volumes, 5 plants were randomly selected from the blocks of the four fruit species. Trees were fitted with stemflow collecting collars (50 mm wide and 40 mm deep) and pipe connections were made to collect the stemflow in cans of 20 litre capacity. For the measurement of throughfall, four collectors were placed under each of the selected tree in a systematic pattern. Results showed that stemflow percentages varied from 0.45% (jackfruit) to 2.32% (guava) (Table 15.4). The differences in total stemflow and throughfall among the monitored tree species were significant ($P \leq 0.05$). Seasonal throughfall varied from 378.8 mm for jackfruit to 440.7 mm for guava corresponding to 79.3% and 92.4% of the gross rainfall. Mango and litchi transmitted about 9.3 and 11.7% less throughfall as compared to guava. Total rainfall interception loss ranged from 6.5% of gross rainfall for guava to 21.3% for Jackfruit. Given its higher proportions (6.5-21.3%), the interception loss from fruit trees needs to be accounted in the water balance of watersheds having larger areas under orchards.

Fig. 15.2. Arrangement for measurement of stemflow

Fig. 15.3. Arrangement for measurement of throughfall

Table 15.4. Summary of total rainfall, throughfall, stemflow and interception for selected fruit tree species

Parameter measured	Mango	Litchi	Guava	Jackfruit
Stemflow				
Rainfall (mm)	645.3	645.3	645.3	645.3
Stem flow (mm)	7.19b*	5.22c	15.00a	2.91d
Percent stem flow	1.11	0.81	2.32	0.45
Throughfall*				
Rainfall (mm)	477.0	477.0	477.0	477.0
Throughfall (mm)	399.7b*	389.0b	440.7a	378.1c
Percent throughfall	83.8	81.5	92.4	79.3
Interception loss (mm)†	72.4	80.4	27.9	91.6
Interception loss (%)	16.8	18.7	6.5	21.3

*Stem flow and throughfall figures separated by different letters are significantly different (LSD, P≤0.05).

Predictive Models for Stem Flow and through Fall Assessment

Partitioning of rainfall into stem flow and through fall by plant canopies affects water replenishment to soil root system and runoff generation processes. Inclusion of stemflow and through fall processes in rainfall-runoff modeling necessitates reliable prediction models for these two parameters. Keeping in view greater influence of rainfall on stem flow and through fall, rainfall based predictive models were developed for estimation of stem flow and through fall from the fruit trees. Different models *viz.* Linear, Allometric, Logistic, Exponential, Mitcherlich and Weibull were fitted to derive the relationship between stem flow/through fall and rainfall. The best performing stem flow and through fall prediction models were selected on the basis of higher R^2 and lowest AIC values. The functional form and parameter estimates for the best performing models for each tree species along with other related statistics fitted on the estimation datasets are presented in Table 15.5. The non-linear models namely Weibull, Logistic, Allometric and Exponential fitted well for stem flow prediction in mango (R^2=0.77), litchi (R^2=0.82), guava (R^2=0.74) and jackfruit (R^2=0.81), respectively. In case of through fall, Weibull (R^2=0.99) and Allometric (R^2=0.94) models fitted well for Mango and litchi trees while linear models fitted well (R^2> 0.98) for guava and jackfruits. The higher value of adjusted R^2 (> 0.74) clearly implies that the fitted models were efficient and that these can be included in runoff models at a larger scale of a watershed.

Impact of changed cropping intensity on groundwater table in Madhubani

With increased water availability of solar pumping systems and intensification of rural electrification, access to irrigation water has increased in the eastern Gangetic Plains. It was demonstrated that with increased water availability the cropping intensity can be increased from present level of 130% to 240%. These changes in cropping patterns, if occurred on wider scale, are likely to impact the groundwater tables within the district. To assess the impacts of such changed cropping patterns, a study was conducted to simulate the groundwater table behaviour in Madhubani district under different cropping intensities using MODFLOW aquifer simulation model. After setting the aquifer properties and boundary conditions, the spatially distributed recharge rate was inputted to MODFLOW for calibration. The MDFLOW was calibrated using the observed data of tubewells located in the study area (Fig. 15.4).

Table 15.5. Parameter estimates for the best fitted candidate function for stemflow

Tree species	Best fitting model	Functional form of model	Parameter estimates			Adjusted R^2	RMSE	AIC
			a	b	c			
Stemflow								
Mango	Weibull	$Y = [a - b \times \exp(- c \times X)] + \varepsilon$	0.521	0.542	-0.032	0.774	0.065	-74.47
Litchi	Logistic	$Y = a/1 + \exp(c - b \times X) + \varepsilon$	0.247	2.910	-0.219	0.819	0.040	-121.7
Guava	Allometric	$Y = a \times X^b + \varepsilon$	0.045	0.765	--	0.743	0.132	-5.55
Jackfruit	Exponential	$Y = a \times [1 - \exp(-b \times X)] + \varepsilon$	0.420	-0.012	--	0.812	0.025	-168.6
Throughfall								
Mango	Weibull	$Y = [a - b \times \exp(- c \times X)] + \varepsilon$	-213.278	211.674	0.0041	0.993	1.078	178.3
Litchi	Allometric	$Y = a \times X^b + \varepsilon$	0.462	1.193	--	0.943	3.087	281.1
Guava	Linear	$Y = a + b \times X + \varepsilon$	-1.221	1.004	--	0.987	1.459	207.6
Jackfruit	Linear	$Y = a + b \times X + \varepsilon$	-1.691	0.904	--	0.980	1.683	220.0

Y: Dependent growth variable; X: Independent growth variable; a, b and c are parameter estimates and ε is the additive error term

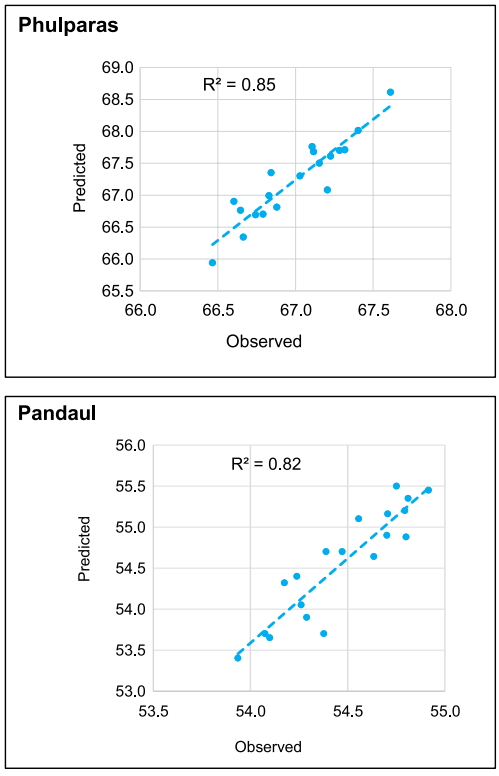


Fig. 15.4. Comparison of observed and predicted water tables (meter above mean sea level) for Phulparas and Pandaul blocks of Madhubani district.

The calibrated and validate model was used to simulate the water table behaviour under changed cropping intensity scenarios of 140%, 160% and 180% (Table 15.6). The irrigation water requirement for each of the selected cropping sequences was estimated using Penman-Montieth Method. Simulation results indicated that, by the end of monsoon season of year 2025, the average water tables will decline at a rate of 0.32 and 0.53 m per year under 160% and 180% cropping intensity scenarios, respectively. The spatial distribution maps (Fig. 15.5) of water table (below ground level) indicated that with increasing cropping intensity the area having water tables in the range of 6-8 m and below 8 m level will increase significantly, specifically in the northern and central parts of Madhubani.

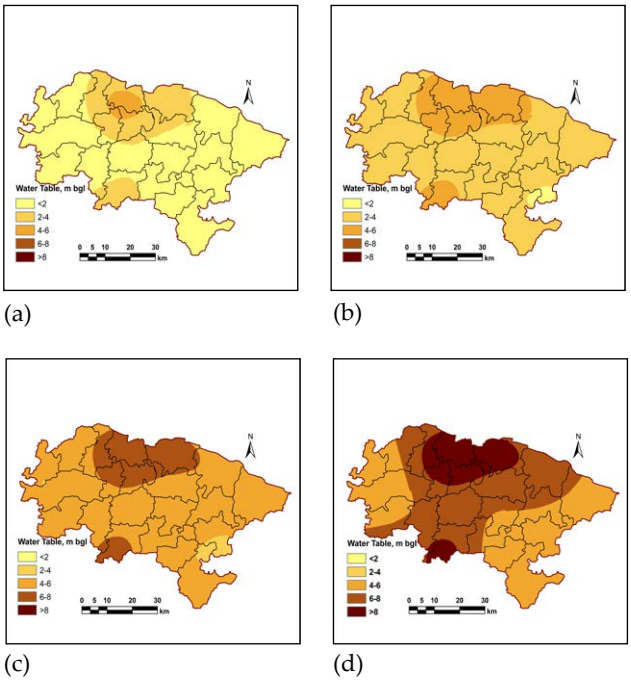


Fig.15.5. Spatial distribution of simulated groundwater levels under (a) present (b) 140 % cropping intensity, (c) 160% cropping intensity and (d) 180% cropping intensity scenarios

Table 15.6. Scenario wise percentage increase in cropped areas during three cropping seasons

Cropped area in *Rabi* and summer	Cropping intensity, %	*Kharif* area %	*Rabi* area %	Summer area %
Scenario-I (present)	130	100	30	0
Scenario-II	140	100	20	20
Scenario-III	160	100	30	30
Scenario-IV	180	100	40	40

Development of Resistive Type Soil Moisture Sensor Assembly for Measuring Soil Moisture in Light Soil

A study was taken to develop and calibrate a resistive soil moisture sensor for determining volumetric water content in a soil mass of 5 cm depth (Fig 15.6). A soil mass constitutes of different soluble mineral which enables soil to conduct electric current flow. When there is more water in soil, current flow through soil experiences less resistance and vice versa. This creates a voltage difference between the ends of two electrodes when inserted into the soil mass. Here, the voltage difference between to ends of the resistive soil moisture probe is detected with the help of a LM393 chip inbuilt in this soil moisture sensor module. Analog reading of this output voltage in 0 to 1023 scale measured by this soil moisture sensor module is read with the help of micro controller of Arduino Uno device. Water content for dry and saturated soil is measured using a capacitance type soil moisture sensor (Fieldscout from Spectrum Technologies, Inc., USA). The analog output of voltages against the water contents for dry and saturated soil is used to calibrate and map the water content of soil using the resistive soil moisture sensor. At the end, water content measured in soil using the resistive soil moisture sensor is displayed in a LCD unit for displaying the water content. Soil collected from the farm of ICAR RCER Patna showed water content in dry and saturated conditions 3.9 and 49.6%, respectively measured with the capacitance type soil moisture sensor. An analog voltage for this soil in dry and saturate condition is recorded to be 987 and 254. Analog voltages and water contents of dry and saturated soil is used to map the water content in wet conditions of the soil. Result showed the resistive type soil moisture sensor measures moisture content of soil with 98% accuracy. However, such resistive type soil moisture sensor is suitable for light sandy soil where its probe can be inserted easily. Also it can measure soil moisture content up to a depth of 5 cm only.

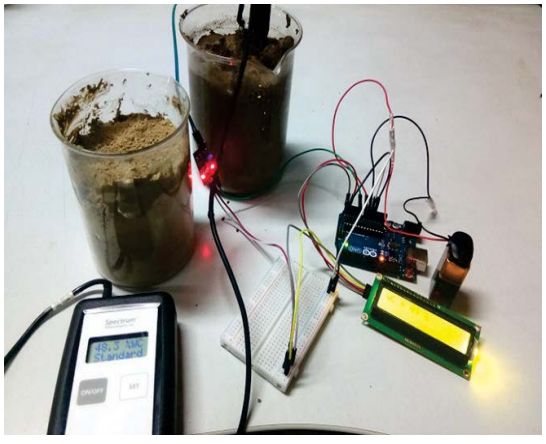


Fig. 15.6. Testing of resistive type soil moisture sensor for saturated soil

Development of Bio-Drainage in Participatory Mode under Waterlogged Areas

Due to effect of climate change phenomenon, the extent of water logging in the bio-drainage site has been showing decreasing trend which also shows scope for intervention like intercropping and goat rearing.

The survival of *Mangifera indica* as on 20.02.2019 is 83.33%, *Anthocephalus cadamba* is 86.66%, *Syzigium cumini* is 86.66% and *Terminalia arjuna* is 100%. *Anthocephalus cadamba* attained the maximum height (4.0 m) and diameter at breast heigh (dbh) (8.92 cm) followed by *Syzigium cumini* height (3.0 m) and collar diameter (7.32 cm). The number of secondary branches of *Terminalia arjuna, Anthocephalus cadamba, Syzigium cumini* and *Mangifera indica* were 23, 12.6, 14.75 and 6 respectively. The mean photosynthetic rate (μmol/m^2/s) of trees (3.5 year old) was higher under control as compared to trees planted in area where water logging prevailed earlier. The highest Pn rate was recorded in Jamum (12.8) followed by Arjun (12.5), while lowest Pn rate was recorded in Kadam (8.4) followed by mango (8.6) in trees planted in water logged area. Transpiration rate (mmol (H_2O)/m^2/s) was also high under control condition. The rate of transpiration was maximum in Arjun (2.7) followed by Jamun (1.9), while the transpiration rate was lowest in Kadam (1.3) followed by in Mango (1.8) in water logged area. On the same piece of land before intervention, perennial ikri grass (*Saccharum* sp.)

was being grown profusely every year with their seed dispersal naturally and farmers used this grass for thatching purposes and earned Rs. 10,000/ha/yr. The interspaces of newly planted trees were utilized by growing suitable crops throughout the year to sustain the farmer's income. Maize+moong intercropping during summer, lentil and mustard during winter and pigeon pea during rainy season were grown and fetched a net profit of Rs. 11,500/ha, Rs. 13,100/ha and Rs. 5,000/ha, respectively. In addition of this activity, the system also was able to accommodate goat rearing (5 numbers) and helped in providing regular income and employment to the poor goat keepers with B:C ratio of 2.5. The gross cost/goat was Rs. 2,500/-.

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

Bharatpura Sub-distributary irrigates three villages, *viz.* Bharatpura (345 ha), Pansuhi (355 ha), Sihi (309 ha). This area received an annual rainfall of 578.3 mm in 2018. During first 6 months of the year it received only 36.6 mm rainfall and created water stress to *Kharif* crops in absence of canal water supply.

Survey of irrigation sources, agricultural practices, consequences of water stress on main crops of the region and socio-economic status was carried out. It was found that crop production faced severe moisture stress during this period as there was no release of water into canal since *Kharif* season 2018 to *Rabi* 2018. Therefore, it was suggested that canal command should be substantiated with tube well command along with ex-situ water storage in ponds. The farmers were advised to use laflate tube/flexible plastic pipe in place of earthen channel for increasing water use efficiency by reducing water delivery losses.

Fig. 15.7. CCA map of Bharatpura sub-distributary

One pond of size 25m × 20m × 2m was constructed and treated with 5 kg of $CaCO_2$, 100 kg of cow dung, 1 kg Alum. The farmers used diesel pump which took 4 hr. to fill 1' water @ Rs. 100/hr from distance of 200' by flexible plastic pipe. Jasur variety fish production recorded 4.6 tons/ha in 115 days. Feed costed Rs.1680/bag of 35 kg and about 4 bags were used for feeding in 115 days. Two pond was constructed on participatory mode (size: 60 m x 20 m x 2.5 m) are currently being practiced for multiple/conjunctive use of water, which are being used for fish production and water storage.

Integrated Water, Nutrient and Weed Management under SRI

Water, nutrient and weed management are major concerns in SRI. Therefore, an experiment was conducted to evaluate the integrated effect of water, nutrient and weed management practices on *Kharif* rice (Arize gold 6444) under SRI (Table 15.7). Maximum grain yield (5.85 t/ha) was recorded in WA1 which was significantly higher than that of WA2 (5.38 t/ha). Saturation all throughout crop duration and T1-(STBR + 5t FYM /ha + Green manure+ Biofertilizer) + WM (SRI weeder 3 times) treatment combination can be recommended for better productivity.

Enhancing Water Productivity through Irrigation Scheduling in System of Wheat Intensification

System of wheat intensification (SWI) aimed at increasing the yield of wheat, where all agronomic principles are put into practices to provide high wheat yield per drop of water and per kg of agricultural inputs like fertilizer, seed etc. Irrigation through micro-irrigation is very much suited to the concept of SWI because in this system inundation of water is not required; rather saturation of soil is needed during most of the crop growth periods. Moreover, water productivity (WP) is significantly enhanced over surface method of irrigation under new establishment methods of SWI. Wheat variety HD 2967 was used for sowing in the tilled field of at 25×25 cm by placing two seeds at 2.0 to 2.5 cm depth. The irrigation through micro sprinkler yielded significantly the highest (4.08 t/ha) than all the treatments except the treatment where 7 irrigations were given. However, the highest water productivity (2.87 kg/m^3) was measured for the treatment in which 3 irrigations were applied.

Table 15.7. Growth, yield attributes and grain yield of rice in SRI

Treatment	Root volume at 60 DAT (cm^3)	LAI at 60 DAT	Panicle/ m^2	Grains/ panicle	1000-grain weight (g)	Grain yield (t/ha)
Main plot						
WA1-Saturation throughout crop period	37.1	1.51	335	97	24	5.85
WA2-Saturation till PI followed by 1″ standing water till dough stage	35.0	1.42	329	96	23	5.38
LSD (P=0.05)	NS	NS	NS	NS	NS	0.47
Sub-plot						
T1-STBR+5 t FYM/ha+ Green manure + bio fertilizer + conoweeder 3 times	41.2	1.67	366	98	25	6.01
T2-STBR++5 t. FYM/ha+ Green manure + bio fertilizer + conoweeder 2 times	39.0	1.59	355	96	24	5.25
T3-100% RFD+5 t. FYM/ha + Green manure + bio fertilizer + conoweeder 3 times	40.0	1.30	312	97	25	5.93
T4-100% RFD+5 t. FYM/ha + Green manure + bio fertilizer + conoweeder 2 times	31.5	1.10	306	97	23	5.35
LSD (P=0.05)	7.3	0.14	19	NS	NS	0.37

16. Conservation Agriculture

Effect of Crop Establishment Methods and Foliar Nutrition on Productivity of Lentil in Rice-Fallow System

A field experiment was conducted on clay loam soil (23.3% sand, 39.6% silt, 37.4% clay) during the *Rabi* season of 2018–19 to evaluate the effect of crop establishment methods and foliar nutrition on productivity of lentil in rice–fallow system. Treatments consisted of three crop establishment (*utera*, ZT and CT) in main–plot and six foliar nutrition [(control (N1), seed priming+2% urea (N2), seed priming+2% DAP (N3), seed priming+0.5% KNO_3 (N4), seed priming+spray of 0.5% of 19:19:19 NPK (N5) and seed priming+microbial treatment +2% urea at branching+2% DAP at flowering+0.5% KNO_3 at pod formation stages)] in sub–plot. Results revealed that conventional tillage (2.42 t/ha) being on a par with *utera* (2.33 t/ha) ptoduced the maximum seed yield. The lowest yield was produced with ZT (2.19 t/ha). The combined application of seed priming+microbial treatments+2% urea at branching+2% DAP at flowering+0.5% KNO_3 at pod formation stages had out yielded (2.82 t/ha) over rest of the treatment combinations. Hence, it may be concluded that growing of lentil under the CT/*utera* along with combined application of seed priming+microbial treatment+2% urea at branching+2% DAP at flowering+0.5% KNO_3 at pod formation stages may be a viable option to achieve higher productivity of lentil in rice–fallow system in Eastern India (Table 16.1).

Fig. 16.1. Field view of experiment

Table 16.1. Seed yield of lentil (t/ha) as influenced by crop establishment methods and foliar nutrition

Foliar nutrition	Crop establishment methods			
	Utera	ZT	CT	Mean
Control (N1)	1.75	1.73	1.83	1.77
N1+2% Urea (N2)	2.16	1.90	2.16	2.07
N1+2% DAP (N3)	2.20	2.12	2.42	2.25
N1+0.5% KNO3 (N4)	2.38	2.21	2.53	2.37
N1+0.5% (19-19-19 NPK) (N5)	2.64	2.43	2.77	2.61
N1+N2+N3+N4+ Microbes	2.87	2.74	2.84	2.82
Mean	2.33	2.19	242	232
LSD (P=0.05)	Crop establishment methods (E)			0.11
	Foliar nutrition (N)			0.07
	E×N			0.13

Evaluation of Crop Establishment Methods for Improving the Productivity of Rice-Fallows

A long-term study was initiated during rainy season of 2016 at the ICAR RCER Patna to find out the most promising rice based crop rotation in rice–fallows. Treatments 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. Results revealed that lentil, chickpea and safflower were more productive over linseed and mustard. Average productivity of winter crops was in the order

Fig. 16.2. Crop performance during the winter season in rice-fallows

of chickpea > lentil>safflower >mustard > linseed (Table 16.2). Rice productivity was the highest in PTR followed by CTDSR and the lowest in ZTDSR, irrespective of the residue management (Table 16.3). $ZTDSR_{R+}$ and ZTDSR treatments resulted in higher grain yield of all the winter crops over PTR, being higher in chickpea, lentil and safflower.

Conservation Agriculture for Up keeping Soil Quality through Zero Tillage and Residue Retention

A study was conducted to investigate the best management practices involving different tillage based crop establishment and residue retention technique which contributes to agricultural system sustainability by developing soil quality index (SQI) from Cereal System Initiative for South Asia (CSISA) experiment of institute farm, Patna, during 2015-2018. We used SQI as an instrument based on physical [macro aggregate stability (MAS), available water capacity (AWC) and soil penetration resistance (SPR)], chemical [soil organic carbon (O.C%), available N (Av. N), available P (Av. P) and available K (Av. K)] and biological [microbial biomass carbon (MBC), fluorescein diacetate (FDA) and dehydrogenase activity (DHA)] properties, because these are very useful indicators of soil's functions from agronomic productivity and soil fertility point of view. SQI for different treatments were calculated by performing principal component analysis (PCA) based on total data set (TDS) method. The indicators values were transformed into score (0-1) and integrated to get SQI. Significant correlation (P< 0.001) was observed between the calculated SQI and system rice equivalent yield (SREY). The higher SREY was 12.41 t/ha obtained at SQI value of 0.90 at 0-10 cm and 0.86 at 10-20 cm in ZTDSR-ZTW (Fig. 16.3). Therefore, crop residues (CRs) retention on the surface with zero tillage and legume inclusion is beneficial for

Table 16.2. Yields of winter crops as influenced by rice establishment methods and residues management practices

CERM	Grain yield (t/ha)						LSD	
	Chickpea	Lentil	Safflower	Linseed	Mustard	Mean		
ZTDSR	1.66ab	1.61a	1.66b	0.80b	1.11a	1.37		
$ZTDSR_{R+}$	1.84a	1.76a	1.89a	1.04a	1.13a	1.53	CERM	0.11 ($p < 0.001$)
CTDSR	1.28cd	1.14bc	0.95d	0.80b	0.95a	1.02	WC	0.02 ($p < 0.001$)
$CTDSR_{R+}$	1.46bc	1.17b	1.17c	0.86b	1.05a	1.14		
PTR	1.08d	0.91c	0.65e	0.62c	0.92a	0.83		
PTR_{R+}	1.21cd	1.05bc	0.75e	0.79b	1.14a	0.99		

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

Table 16.3. Yields of rice (t/ha) as influenced by preceding crops, establishment methods and residues management practices (CERM)

CERM	Chickpea	Lentil	Safflower	Linseed	Mustard	Mean	LSD	
ZTDSR	3.58d	3.91bc	3.35c	3.57c	3.59c	3.60	CERM	0.26 (p < 0.001)
$ZTDSR_{R+}$	3.75cd	3.64c	3.42c	3.55c	3.88bc	3.65	WC	0.06 (p < 0.001)
CTDSR	4.30bc	4.12bc	4.19b	3.97bc	3.77c	4.07		
$CTDSR_{R+}$	4.48b	4.45b	4.24b	4.34b	4.47b	4.40		
PTR	5.27a	5.48a	5.33a	4.99a	5.52a	5.32		
PTR_{R+}	5.65a	5.98a	5.85a	5.43a	5.86a	5.75		
Mean	4.50	4.60	4.40	4.31	4.51			

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

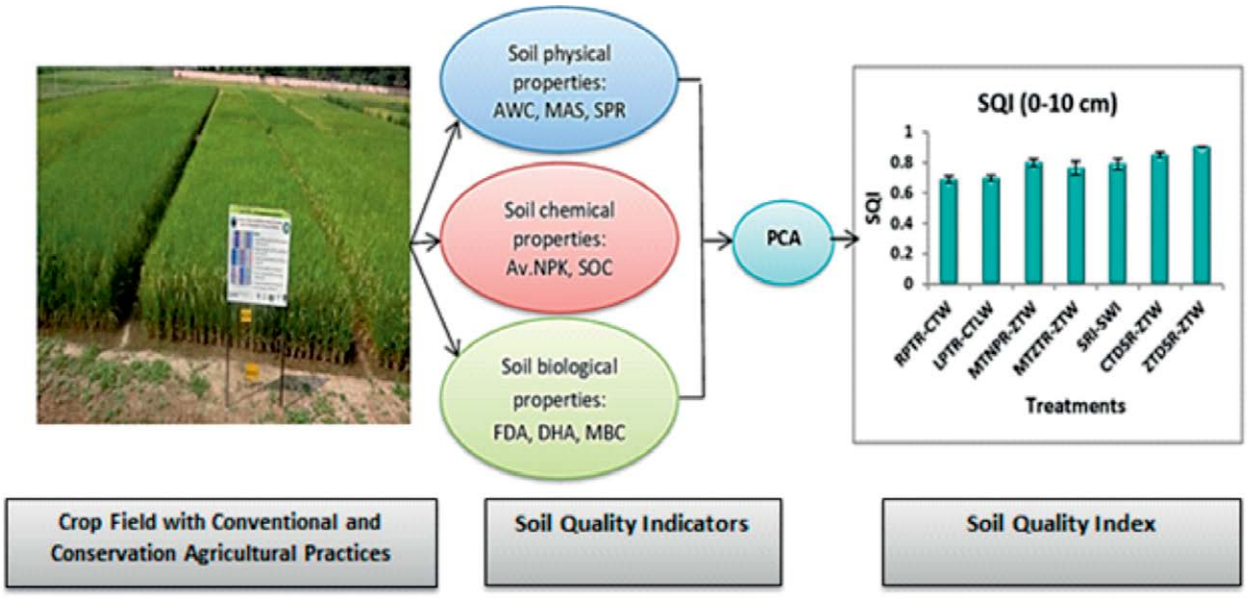


Fig. 16.3. Soil quality indicators under different tillage-based crop establishment methods

soil sustainability and productivity in rice-wheat system in EIGP of India.

Nitrogen and Carbon Mineralization Dynamics as Influenced by Crop Residue Retention in Rice-Wheat System

A laboratory study was conducted by taking soils from Cereal System Initiative for South Asia (CSISA) experiment at main campus farm, ICAR-RCER, Patna from seven different treatments to predict C and N mineralization of rice residue placed on the surface and incorporated into the soil.

The cumulative C mineralization was higher for residues placed on the soil surface (T_3, T_4, T_6 and T_7) than for residue incorporated (T_1, T_2 and T_5) into the soils. This result indicates that the incorporation of residues into the soils in our study inhibited residue decomposition, most likely by modifying the availability of oxygen to decomposer microorganisms. After 56 days of incubation, the cumulative mineral N for residue placed on the soil surface was higher than for residues incorporated into the soils (Fig. 16.4). These suggests that rice residue addition resulted in greater N immobilization when the residues were incorporated into

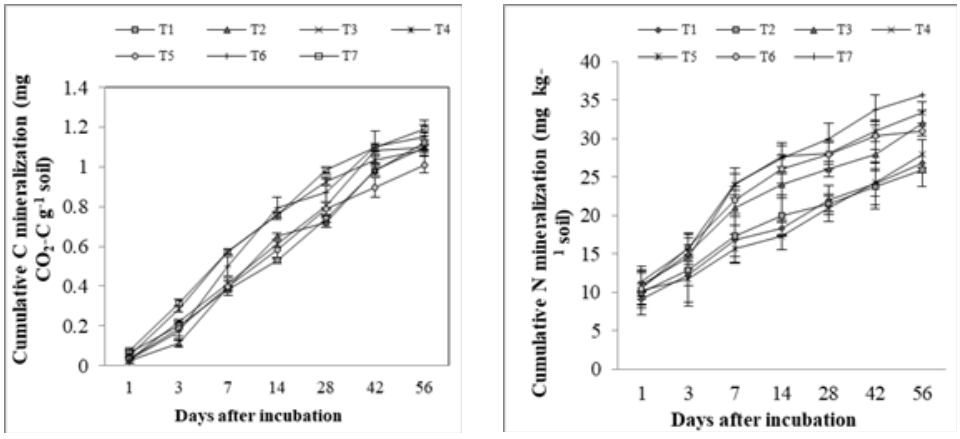


Fig. 16.4. Cumulative C and N mineralization under different treatments.

T_1: Random puddled transplanted rice- Conventional till broadcasted wheat-Zero till green gram (RPTR-CTW-ZTGG); T_2: Puddled line transplanted rice (LPTR-CTW-ZTGG); T_3: Machine transplanted non-puddled rice (MTNPR- ZTW-ZTGG); T_4: Machine transplanted zero-till rice (MTZTR-ZTW-ZTGG); T_5: System of rice intensification (SRI-SWI -ZTGG); T_6: Conventional till direct seeded rice (CTDSR-ZTW-ZTGG); T_7: Zero-till direct seeded rice (ZTDSR- ZTW-ZTGG).

the soil than when they were applied to the soil surface. Therefore, residues with less N and more C:N ratio should be incorporated into the soil not only to decrease the risk of N loss but also CO_2 emission.

Rice Mealybug (*Brevennia Rehi*): a Potential Threat to Zero-Till DSR in Rice-Mustard-Maize Rotation

Long-term experiments have been undertaken under CSISA project on conservation agriculture at ICAR RCER Patna since 2009-10. After seven years, severe infestation of the rice mealybug (*Brevennia rehi*) was observed in rice in scenario 4, i.e. ZTDSR-ZT mustard-ZT maize during *Kharif* 2017 affecting paddy fields adversely (Fig. 16.5). The rice plants were colonized between the leaf sheath and stems, forming hard waxy masses. The initial symptom was the presence of sunken patches on the plants, which showed stunted growth and peculiar depression which produced a scorched appearance in patches at later stage. Heavily infested plants did not bear panicles. It was observed that 22.56 to 28.38 per cent tillers per hill were infested. The number of mealy bugs per hill was in the range of 72-84. The severe infestation of rice mealybug was attributed to presence of grassy weeds like *Digitaria sanguinalis*, *Brachiaria repense* and *Echinochloa colona* in ZT DSR that provide alternated shelter to the mealy bugs to survive in off seasons.

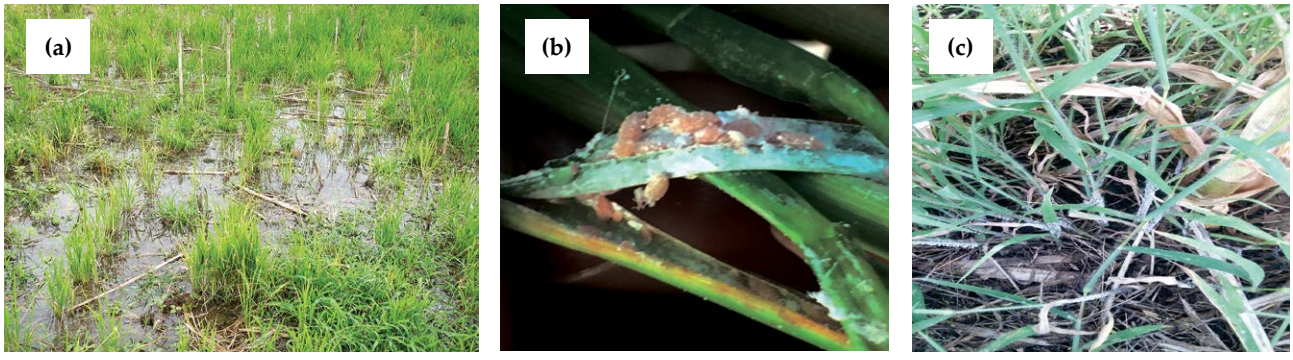


Fig. 16.5. (a) Rice mealybug infested ZTDSR field, (b) Rice mealybug in leaf sheath, (c) Grassy weed as alternate host for the pest

17. Solar Energy Application

The shallow groundwater depth, abundant solar radiation and good numbers of bright sunshine days make the solar powered groundwater pumping more viable in eastern region. But, the challenges lie in the cost of solar system and its *in situ* performance. ICAR Research Complex for Eastern Region, Patna undertook projects to assess the performances of solar pumps of different size at different sites of Bihar. The tested solar pumps with capacity and energizing arrays were 1HP (750W)-1200Wp, 2HP (1500W) -1800Wp and 3HP (2250W)- 3000Wp.

Performance of 1HP -1200 Wp Water Pumping System

Performance curve of 1HP-1200 Wp water pumping system at different dynamic heads and prevailing solar radiation condition is shown in Fig. 17.1. The performance of this water pumping system, for dynamic head ≤ 10 m and prevailing solar radiation condition (Fig. 17.2) of 3.4-6.5 kWh/m^2/day with 3 times solar array tracking on a bright sunshine day for different months is given in Table 17.1. The water yield per day on a cloud free day ranged from 35-60 m^3/day depending on the months and fluctuations in groundwater depth. This much available water was sufficient to irrigate a cropped area of 600 -1000 m^2 per day. This solar water pumping system is quite suitable for marginal farmers having cultivable area up to 1.0 ha. The pump is suitable for flood irrigation; however, a tape type drip system could be operated successfully, as available delivery pressure head is ranging from 0.4-0.5 kg/cm^2 during mid-day.

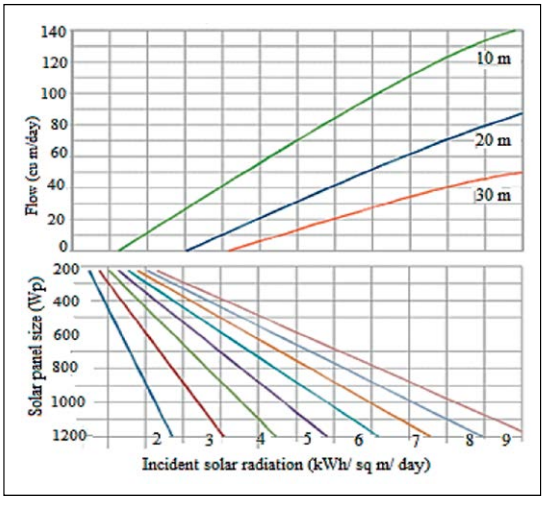


Fig. 17.1. Performance curve of 1HP-1200Wp solar water pumping system.

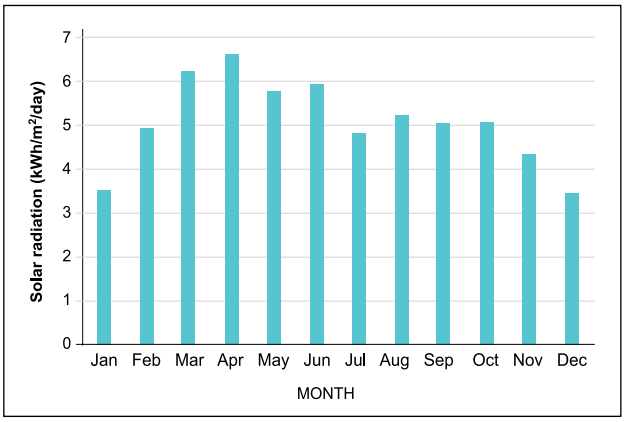


Fig. 17.2. Monthly averaged daily solar radiation in Patna district.

Table 17.1 Water output from 1HP-1200Wp solar water pumping system

Water yield (m^3) per day on a cloud free day				Irrigable area (m^2) per day on a cloud free day			
Sep-Nov	Dec-Jan	Feb	Mar-Jun	Sep-Nov	Dec-Jan	Feb	Mar-Jun
55-50	35-40	45-50	60-55	900-850	600-650	750-850	1000-900

Performance of 2HP -1800 Wp System

A 2HP-1800Wp solar water pumping system was installed at Bharatpura village of Patna district to evaluate its performance under the prevailing solar radiation condition and the available ground water depth (Fig. 17.3). The water output for dynamic head≤ 10m and the prevailing solar radiation condition 3.3-6.6 kWh/m^2/day with 3 times tracking of solar panel on a bright sunshine day, for different months, is reported in Table 17.2. The water

Fig. 17.3. 2HP-1800 Wp Solar water pumping system in Bharatpura village, Paliganj block of Patna district.

Table 17.2. Water output of 2HP-1800Wp solar Pump

Water yield (m^3) per day on a cloud free day				Irrigable area (m^2) per day on a cloud free day			
Sep-Nov	Dec-Jan	Feb	Mar-Jun	Sep-Nov	Dec-Jan	Feb	Mar-Jun
65-60	45-50	55-65	85-70	1100-1000	750-850	900-1100	1350-1150

yield on a cloud free day ranged from 45-85 m^3/day depending on the months and fluctuation in groundwater depth. This water was enough to irrigate a cropped area of 750 -1350 m^2 per day. This solar groundwater pumping system is suitable for small farmers having cultivable area of 1.0-2.0 ha. The pump can operate drip system successfully, as available pressure ranged between 0.6-0.8kg/cm^2 at the delivery head. During dry summer this pump was used to irrigate paddy nursery raised on community basis for 75 *bigha* transplantation.

Performance of 3HP-3000Wp solar water pumping system

Two solar pumps were installed in Bhagwatipur village of Madhubani district of Bihar for groundwater pumping to meet the irrigation water requirement of marginal and tenant farmers under cooperative farming arrangement during dry seasons (Fig. 17.4). This intervention promoted a new culture of sharing the benefits of solar pumps among the tenant and the marginal farmers. The mean monthly average incident solar irradiation over a day for different months in Madhubani district is 3.6-6.9 kWh/m^2/day (Fig. 17.5). With 3 times tracking of solar panel mounted on a dual axis sun tracking structure the average groundwater extraction by this solar pump per day for different months on a bright sunshine day and corresponding average irrigable area per day by

Fig. 17.4. 3HP-3000 Wp Solar groundwater pumping systems in Bhagwatipur village of Madhubani district of Bihar

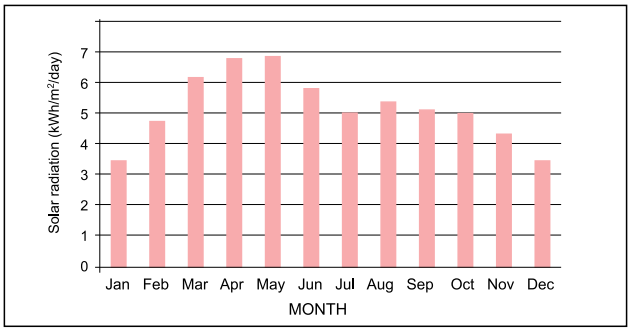


Fig. 17.5. Monthly averaged daily solar radiation in Madhubani District of Bihar.

flood method is reported in Table 17.3. The pressure availability at delivery head of this pump ranged from 1.0-1.5 kg/cm^2 between 9.00 AM to 2.00 PM (IST). Hence drip system as well as micro sprinklers were successfully operated with this system to irrigate crops for improved water application efficiency and water productivity.

Table 17.3. Water outpuat of 3HP (2250W)-1800Wp solar pump in Madhubani district of Bihar

Water yield (m^3) per day on a cloud free day				Irrigable area (m^2) per day on a cloud free day			
Sep-Nov	Dec-Jan	Feb	Mar-Jun	Sep-Nov	Dec-Jan	Feb	Mar-Jun
150-135	90-110	120-140	170-150	2350-2250	1250-1450	1650-2000	2650-2500

Similarly in East Champaran district of Bihar, a 3HP-3000 Wp solar pump was installed and tested in Chandrahiya village. This district is blessed with high incidence of solar radiation, ranging from 3.2-6.9 kWh/m^2/day (Fig. 17.6). The performance parameter of the solar pump is shown

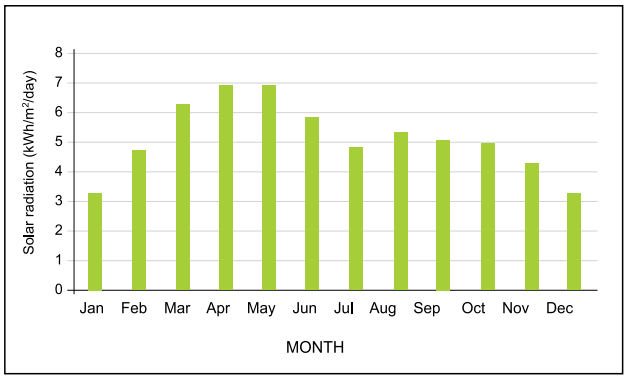


Fig. 17.6. Monthly averaged daily solar radiation in Motihari

in Table 17.4. The net abstracted groundwater of this pump ranged from 100-170 m^3/day on a bright sunshine day. The delivery pressure head availability between 9.00 AM to 2.30 PM was in the range of 1.0 to1.5 kg/cm^2. This facilitated the farmers to irrigate cropped area between 1650-2850 m^2 per day by flood method, depending upon the month and brightness of the day.

Table 17.4. Water output of 3HP (2250W)-1800Wp solar Pump in East Champaran district of Bihar

Water yield (m^3) per day on a cloud free day				Irrigable area (m^2) per day on a cloud free day			
Sep-Nov	Dec-Jan	Feb	Mar-Jun	Sep-Nov	Dec-Jan	Feb	Mar-Jun
150-130	100-110	120-140	170-155	2350-2250	1650-1850	2000-2350	2850-2550

Further a 2HP-1800 Wp submersible pump installed by a farmer himself in the village Khairimal Jamunia, Chakiya block, East Champaran district of Bihar was assessed for its performance (Fig. 17.7). The farmer installed micro sprinklers with the help of ICAR Research Complex for Eastern Region, Patna, under the project "Development of climate resilient farming system model for livelihood improvement in East Champaran and provides all the technical support. Under the prevailing solar radiation condition 3.2-6.9 kWh/m^2/day the net water output per day, on a bright sunshine day, is reported in Table 17.5. The pressure head availability between 9.00 AM to 2.30 PM was in the range from 0.8 to1.1 kg/cm^2, depending upon the month and brightness of the day. The farmer uses micro sprinklers for irrigating rice nursery, wheat and sugarcane and also developing integrated farming culture to maximize his profits (Fig. 17.8). The tentative cost of different capacity solar water pumping system excluding bore well is reported in Table 17.6.

Fig. 17.7. 2HP-1800 Wp solar system in Khairimal Jamunia, East Champaran district of Bihar.

Table 17.5. Water output of 2HP-1800Wp solar Pump Khairimal Jamunia, block Chakiya, East Champaran district of Bihar

Water yield (m^3) per day on a cloud free day				Irrigable area (m^2) per day on a cloud free day			
Sep-Nov	Dec-Jan	Feb	Mar-Jun	Sep-Nov	Dec-Jan	Feb	Mar-Jun
70-60	45-50	60-65	85-70	1150-950	750-850	900-1000	1250-1150

Fig. 17.8. Use of solar pump coupled with micro sprinkler system for pressurized irrigation

Table 17.6. Tentative cost of solar water pumping systems excluding bore well

System type	Cost (lakhs)	Tracking option
1HP (750W) -1200Wp	1.25	Manual tracking
2HP (1500W)-1800Wp	2.10	Manual tracking
3HP (2250W)-3000Wp	3.00	Manual tracking

18. Farm Machinery

Ergonomic Study on Spades of different Regions during Field Operation

An ergonomic study on five different types of spades *viz.*, Spade-1 (Tata-Bihar), Spade-2 (Eastern UP), Spade-3 (Small/JH-1), Spade-4 (Jharkhand-2) and Spade-5 (CIAE, Bhopal) have been carried out with parameters of energy expenditure, cardiac cost and heart rate during working and resting period (Table 18.1).

Table 18.1. Field evaluation and performance data of different parameters of male worker during digging a pit with spade (N=5)

Parameters	Spade -1	Spade -2	Spade -3	Spade -4	Spade -5
Output (m^3/hr)	0.890	0.954	0.732	0.742	0.732
Area Covered	0.112	0.112	0.112	0.112	0.112
ΔHR, beats/ min	38.60	34.00	37.00	38.80	42.60
Energy Expenditure, kJ/Min	8.14	7.68	7.76	8.42	8.08
Cardiac cost (beats/m^3)	317.89	274.78	439.07	476.25	528.46
Reduction in drudgery (%)	39.84	48.00	16.91	10.96	-
Increase in efficiency (%)	17.70	23.27	-	1.34	-

Fig. 18.1. Spades from different regions (Spade-1 (Tata-Bihar), Spade-2 (Eastern UP), Spade-3 (Small/ JH-1), Spade-4 (JH-2) and Spade-5 (CIAE) (from Left to right)

The highest efficiency was recorded in case of spade with a torso angle of 30-32° (Spade-2) which increases the efficiency by 23.27%, followed by spade-1 with increase by 17.70% respectively. From the comparative analysis between five different designs of spade, spade-2 was more efficient to dig a pit or to form a bund with an output of 0.954 m^3 followed by spade-1 with 0.89 m^3. The maximum drudgery reduction was found with spade 2 (48%) and least was found with spade 4 (10.96%).

Eco-energetic Analysis of Different Crops in Eastern India

The study was conducted at BISA farm, Pusa, Samastipur, North Bihar during 2018-2019. Eight crops *viz;* rice, wheat, maize, potato, lentil, mung, chickpea and mustard were taken into account to estimate input-output energy for production of various crops. Inputs used in calculation of agricultural energy were human labor, machinery, electricity, chemicals, diesel, water, fertilizers, and seeds. Energy output arises mainly from the main product and their residues. The total energy requirement from different sources of producing rice, wheat, maize, potato, lentil, mungbean, chickpea and mustard were 37081.77 MJ/ha; 25632.72 MJ/ ha; 18133.09 MJ/ ha; 38810.75 MJ/ ha; 8723.76 MJ/ ha; 5633.68 MJ/ ha; 10152.15 MJ/ ha and 21381.63 MJ/ ha, respectively.

The percentage share and component wise energy inputs (MJ/kg) in various farm operations during crop production are illustrated in Fig. 18.2.

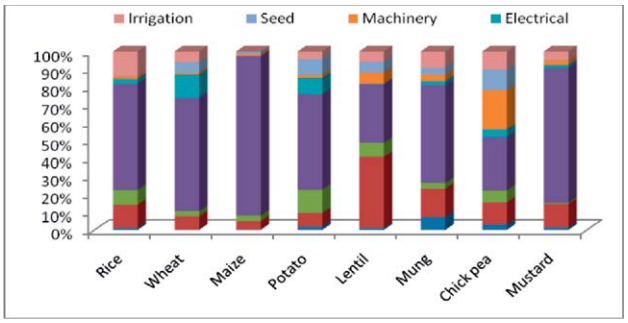


Fig. 18.2. Energy use pattern in different crops

Assessment of Traditional Tools Used in Agriculture in Jharkhand

A survey was conducted in the selected villages namely Aarabasti, Badka Chumba, Gandhonia, Govindpur and Gargali in Ramgarh district. A total 29 number of traditional tools/ implements were found during the survey as like desi plough, pickaxe, spade, hoe, yoke, leveler, sickle, khurpi, dao, axe, sabbal, knife etc., Most of the tools, which were developed and fabricated by local artisans were made from wood and iron plates, angle and solid rod. These tools and implements were economical in term of labour, money and time saving.

Ergonomic evaluation of pedal operated paddy thresher in tribal area

It has been observed from this study that with pedal operated paddy thresher the mean HR during work was 129.4 beats/min and corresponding Δ HR was 45.60 beats/min. The energy expenditure rate (EER) was found to be 11.85 kJ/min. In traditional system, i.e. by manual beating on wooden log, the mean HR was found to be 137.5 beats/ min and corresponding Δ HR was 59.10 beats/ min. During manual beating the energy expenditure was high and it was recorded as 13.14 kJ/min. According to categorization of the agricultural work pedal operated paddy thresher work can be put in the category of 'moderate' work but with the manual beating of paddy on wooden log it can be kept in higher category of moderate work.

The output capacity of the pedal thresher was 40 kg/h as against 33 kg/h in manual beating of paddy. It was observed that there was 17.50% increase in output with pedal paddy thresher. It is predicted that increase in output may be due to increase in number of strokes which resulted in more peripheral speed of the threshing drum and thus the output. The results revealed that there was a 9.80% reduction in drudgery when operating pedal operated paddy thresher as compared to manual beating on wooden block. It was also observed that there was a 26.31% increase in comfort of the operator and a 20.88% decrease in body part discomfort score (BPDS) when operating pedal paddy thresher (Fig. 18.3).

Fig. 18.3. Paddy threshing with pedal operated paddy thresher

Design and Development of Manual Makhana Grader

Grading of makhana seeds is one of the most important unit operating in makhana processing To grade the makhana seeds of various sizes, a prototype hand operated makhana grader is designed and developed with circular drum and cylindrical bars. This equipment could grade makhana seeds in five sizes *viz.*, 14 mm, 12 mm, 9 mm, 7 mm and less than 7 mm diameter. The developed prototype grader is shown in Fig. 18.4.

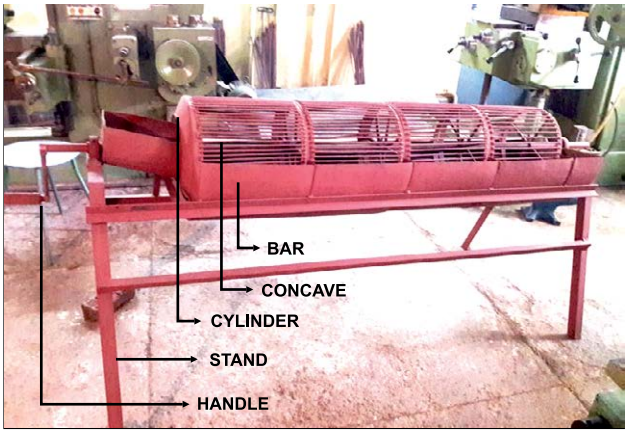


Fig. 18.4. Hand operated Makhana grader developed at ICAR RCER, Patna

19. Livestock and Fisheries

LIVESTOCK

Characterization of Lesser Known Breeds of Farm Animals in Eastern India

Eastern region of India has the largest number of livestock population with 77.58 million cattle, 19.48 million buffaloes, 52.07 million goats and 4.82 million sheep. However, the proportionate number of breeds registered are far less due to the failure to notice and proper study of the populations available with the farmers. The project attempts to address this issue in the seven Eastern states under the ambit of the Institute by making local contacts through different organizations.

There were two new population, including a type of cattle (*Medini* cattle) and a goat (*Medini* goat), noticed and studied in Mehdininagar, Garhwa and Latehar districts of Jharkhand (Fig. 19.1 and 19.2). A total of 12 villages under 5 blocks in these districts were selected to study the characteristics of new cattle and goat populations including principal and minor body measurements and body weights at 3, 6, 9 and 12 months and at 2, 4, 6 and 8 teeth stages. The cattle were small in body size and mostly grey colored in the whole body. Apart from grey coat, 9.4 per cent had dark brown shade coat color. The pooled height at withers, body length and chest girth of these adult Jharkhand cattle were found to be 95.32±0.34 cm, 82.17±0.38 cm and 127.24±0.34 cm, respectively. Further, the pooled minor body measurements including face length, horn length and tail length for both the sexes were observed to be 37.81±0.52 cm, 10.12±0.21 cm and 63.15±0.66 cm, respectively. The mean body weight, according to Shaeffer's formula was estimated to be 139.40 kg for males and 117.23 kg females. Peak milk yield ranged from 2.5 to 6.5 kg per day.

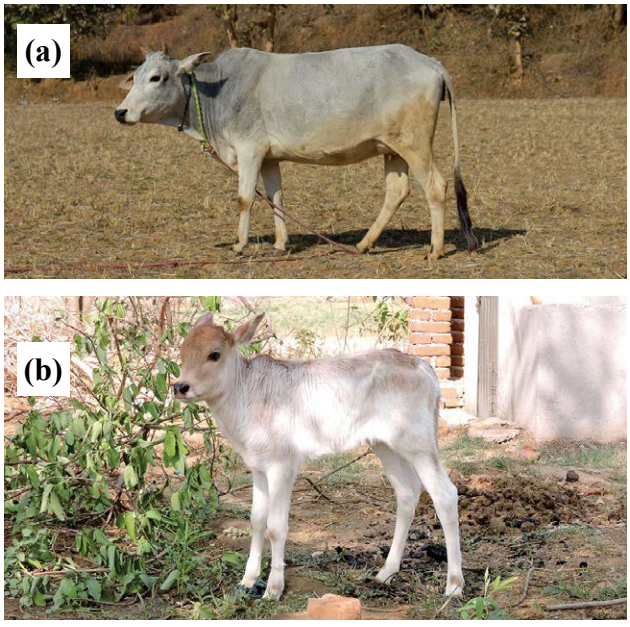


Fig. 19.1. *Medini* cow (a) and *Medini* calf (b)

The new goat population was also found in the same breeding tract of Jharkhand. The goat coat color was black, the body was slender and medium in height. These goats were distinctly different from Black Bengal breed. They were taller with slender pelvic region and there were only sparse presence white and brown coat color variants in the population. The herd size of the goats reared by the farmers ranged from 1 to 27 in the breeding tract.

The height at withers, body length and chest girth of adult Jharkhand goats were 65.12±0.36 cm, 66.28±0.38 cm and 72.45±0.30 cm, respectively. The pooled body weights of *Medni* goats of Jharkhand were 6.88±0.27 kg, 8.92±0.31 kg, 12.54±0.32 kg and 16.11±0.32 kg at respective age of 3, 6, 9 and 12 months. The age at first kidding and kidding

Fig. 19.2. *Medini* goat with kid

interval were found to be 12.32±0.76 months and 8.67±0.53 months, respectively. The average litter size of the goats was 1.26.

Network Project on Buffalo Improvement

In order to improve the herd strength, seven Murrah buffaloes along with their calves were introduced from its breeding tract (Haryana). A total of 46 artificial inseminations were carried out and 21 buffaloes were found pregnant with the conception rate of 45.7 per cent. In order to improve the conception rate, the buffaloes were regularly fed with mineral mixture and administered supplementary medication. The non-pregnant buffaloes were kept under observation from August to December months. The therapeutic and hormonal interventions were made to bring the animals cyclic. The inseminated animals were checked with the help of ultrasonography for verifying pregnancy in a period of 30 days. The mean lactation milk yield, lactation length and dry period were reported to be 2167.30±4.88 kg, 324.53±6.22 days and 90.08±5.33 days, respectively.

Fig. 19.3.Buffaloes in paddock

Management of Heat Stress in Buffalo

A 503 bp fragment spanning 5'UTR and partial coding sequence of heat shock protein 70 (HSP70) gene were amplified for Murrah and Diara buffaloes. Single strand confirmation polymorphism (SSCP) was used to study single nucleotide polymorphism. Both Murrah and Diara were found polymorphic for this fragment. Two alleles namely A and B and three genotypes namely AA, AB and BB were observed in both the breeds (Fig. 19.4). The frequencies of AA, AB and BB genotypes in Murrah and Diara buffaloes were 0.30, 0.58, 0.12 and 0.08, 0.72 and 0.20, respectively. The frequencies of alleles 'A' and 'B' in Murrah and Diara population were 0.59, 0.41 and 0.44, 0.56, respectively. Present study revealed that AB genotype was the predominant genotype in both the buffalo breeds. 'A' allele was found to be predominant allele in Murrah buffalo whereas 'B' allele was predominant in Diara buffalo.

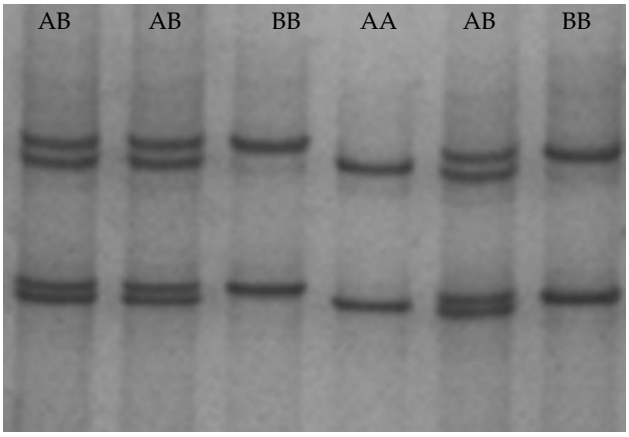


Fig. 19.4. Genotype of 503 bp fragment

Effect of zinc supplementation in summer on milk yield in Murrah buffalo

Twelve lactating Murrah buffalo (473.4± 26.3 kg body weight, 3-4 months lactation length, 2-3 parity) were selected and divided into two equal groups. Group 1 was fed standard diet whereas Group 2 was fed standard diet with supplementation of zinc sulfate @ 60 ppm/day. This study revealed that zinc supplementation has significant effect (P≤0.05) on milk yield during summer. Treatment group gave higher milk yield (6.76 ± 2.54 kg/d) than the control group (5.72 ± 1.94 kg/d).

Effect of vitamin C supplementation in summer on milk yield in Murrah buffalo

Ten lactating buffalo (452.3±45.6 kg body weight, 3-4 months lactation length, 2-3 parity) were selected and divided into two equal groups. Group 1 was fed standard diet whereas Group 2 was fed standard diet with supplementation of ascorbic acid @10 gram/animal/day. This study revealed that vitamin C supplementation had significant effect (P≤0.05) on milk yield. Treatment group yielded higher milk (6.85 ± 1.67 kg/d) than the control group (6.12 ± 1.86 kg/d).

Studies on Development of Early Pregnancy Diagnosis Method in Buffaloes

Breedable Murrah buffaloes from the Institute livestock farm were used for the study. Buffaloes exhibiting normal estrus and anestrus were identified. The anestrus buffaloes were given hormonal treatment for estrus induction. Peripheral blood samples were collected from all the buffaloes on day 0 (detection day of estrus or day of artificial insemination) displaying normal estrus or induced estrus. Subsequent collection was carried out on day 12, 15, 18 and 21. Pregnancy status of buffaloes were verified by per-rectal palpation and ultrasonongraphy. The blood samples were used for RNA extraction. Total RNA was reverse transcribed into cDNA. In order to investigate the role of two chemokines CCL8 (also known as MCP-2) and CXCL10 (also known as IP-10) in pregnancy and fetal development, quantitative PCR assay was developed for the estimation of its transcriptional abundance. GAPDH was used as endogenous control gene. The amplification products for CCL8, CXCL10 and GAPDH (endogenous control) genes yielded fragments of 399, 151 and 81 bp, respectively (Fig.19.5). Purified PCR Products were used for the generation of standard curve for all the three genes. Six scalars ten-fold serial dilutions of every PCR product was performed for amplification of genes by optimized protocol. Each sample was run in triplicate along with a no template control for every assay. Each run was completed with a melting curve analysis to confirm the specificity of amplification and lack of primers dimmers. The standards generated linear relationships with regression coefficients: r^2=0.996, 0.993 and 0.992 for CCL8, CXCL10 and GAPDH genes, respectively. The mean slopes of the log- linear regression plots, which represent the amplification efficiency, resulted to be similar. The developed assay will be further used for estimating the relative expression of cytokines CCL8 and CXCL10 in peripheral blood leucocytes of buffaloes.

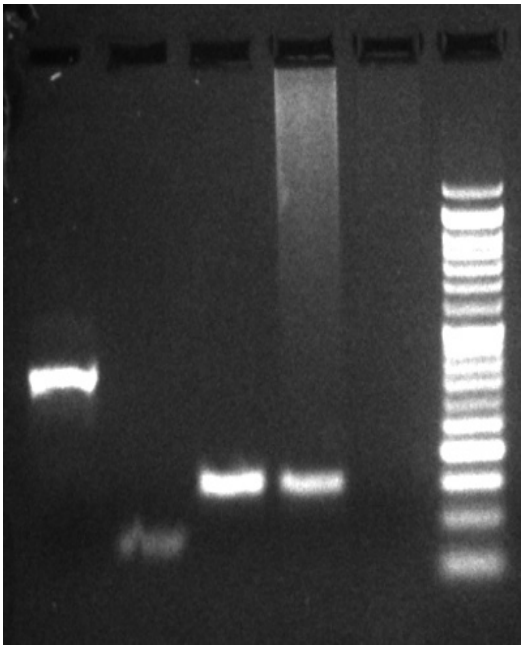


Fig. 19.5. Amplification of CCL8, CXCL10 and GAPDH gene by conventional PCR

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 Bihar in their habitat. Five districts of Bihar namely Samastipur, East Champaran, Araria, Katihar and Jamui were selected for the study based on the population density of goat. One village each was selected from these five districts. From the baseline survey, it was observed that more than 90% of goat was owned by landless and marginal farmers and share-croppers belonging to SC, ST and Muslim communities. The average herd size was 1.83 to 3.91 in different districts of Bihar. The rearing system of goat was semi intensive, mainly on crop-livestock system (54.50%) and landless production system (45.50%). During the period one capacity building programme, six vaccination and health camps and five awareness camp were conducted. Area specific mineral mixture and root slips of Hybrid Napier were also distributed.

Designing of feeder/manger to save feeding cost

Three feeding manger for goats were designed and evaluated for potential of reducing feed wastage. Findings indicated that the percentage feed wastage and cost of feed waste in head level bamboo feeder (9.38% and Rs. 72) was least followed by the elevated iron feeder (12.5% and Rs. 96) and floor level G.I tub feeder (31.25% and Rs. 300). However, the making and maintenance costs were found to be the lowest in floor level G.I feeder (Table 19.1 and Fig. 19.6).

Elevated iron feeder: Goat's head and body are angled upward; designed to mimic browsing.

Head level Bamboo feeder: Goat's head is level and parallel to the body; designed to mimic browsing.

Floor level G.I feeder: Goat's head is lowered to the ground; mimics grazing; feeder table is at hoof level.

Fig. 19.6. Goat feeding on different types of feeder

Table 19.1. Dimension and measurements of different types of feeders

Measurement	Head level Bamboo feeder (cm)	Elevated iron feeder (cm)	Floor level G.I feeder (cm)
Total length (cm)	152	280	-
Height up to concentrate feed level (cm)	17	24	17
Height up to green fodder level (cm)	50	70	17
Width of feeding trough (cm)	53	60	38
Depth of feeding trough (cm)	10	90	15

Study on high prolific goat germplasm

A study was conducted to investigate the milk production performance of Black Bengal goat and its effect on weight of kids on the basis of their litter size. Forty five goats were selected on the basis of their litter sizes from the institute goat farm. Among the different litter size, single kid showed the highest weight at birth (1.21± 0.06) followed by twins (1.11±0.05), triplets (1.07±0.03), quadruplets (1.01±0.04) and quintuplets (0.90±0.06) kg. The average milk productions up to 12 weeks of kidding of goats having 1, 2, 3, 4 and 5 litter were 0.33±0.03, 0.45±0.03, 0.54±0.05, 0.70±0.06 and 0.79±0.03 kg/day, respectively. On an average, the initial yield (kg/d), peak yield (kg/d), and total milk yield (kg) were 0.35, 0.68 and 27.84; 0.53, 0.96 and 37.84 kg; 0.64, 1.08 and 45.49; 0.81, 1.21 and 59.06 and 0.84, 1.26 and 66.35, respectively for 1, 2, 3, 4 and 5 litter size. The milk production increased in the fourth week of lactation in all types of litter size and then decreased afterwards. Total milk production was directly proportional to their litter sizes.

Fig. 19.7. Doe with her five kids

Assessing Genetic Variability in Ducks of Eastern States

Blood samples were collected from 30 desi ducks of West Bengal origin. Genomic DNA was isolated. Standardizing the protocol for isolation of mitochondrial DNA and amplification of prolactin gene in Duck is under progress. A 517 bp fragment of growth hormone gene was amplified (Fig. 19.8) and sequenced.

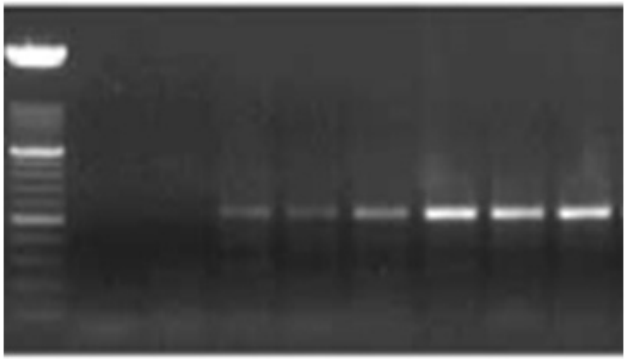


Fig. 19.8. Amplified growth hormone gene fragment in Duck

Three genotypes namely AA, AB and BB were identified in studied population. Least square analysis revealed that duck having AA genotype had comparatively more egg weight (58.45±0.12 gm) than the duck having AB (55.25±0.21 gm) and BB (53.68±0.28 gm) genotype. Hence, growth hormone gene can be used as molecular marker in future breeding programme for improving egg weight in duck.

Characterization and Evaluation of Duck Germplasm in Eastern Region

A survey was conducted in Surguja and Balrampur districts of Chhattisgarh to determine the different duck production systems and to differentiate the phenotypic characteristics of ducks. Most of the duck owners were marginal (84.51%) farmers and remaining were landless (15.49%) category households.

The annual average egg production per duck was 84.13 (range, 52 to 111). Average egg weight was 61.25 g (range, 57 to 65 g). The average flock size varied from 2-20 birds/flock. In both drake and duck, body carriage was slightly upright with horizontal shape of bill. Prominent head colour in drake was greenish black and in duck was brown. In drake dominant neck colour was brown with white ring and in duck was brown. Prominent breast and back colour was brown in drake and brown in duck. Multiple colours (ash, black and white mix) were found in wing of drake whereas brown was prominent in wings of duck. Prominent bill colour was green in drake and orange in duck. In both drake and duck prominent bean colour was black. Dominant shank colour was orange in both drake and duck. Similarly prominent eye colour in drake and duck was brown (Fig. 19.10). Mean values for all the morphometric measurements is presented in Table 19.2.

Table 19.2. Morphometric characteristics of desi ducks of Chhattisgarh

Traits	Drake (n=150)		Duck (n=376)	
	Mean	Range	Mean	Range
Body weight	1.50	1.22 to 1.8	1.31	1 to 1.45
Head diameter	2.83	2.5 to 3	2.46	2 to 3
Bill length	5.75	5.5 to 6.5	5.75	5.5 to 6.5
Neck length	12.04	11 to 13	10.79	8 to 14
Shank length	5.83	5.5 to 6.5	6.04	5 to 7
Wing length	37.33	36 to 39	36.00	35 to 38
Body length	35.25	34 to 38	35.25	34 to 38

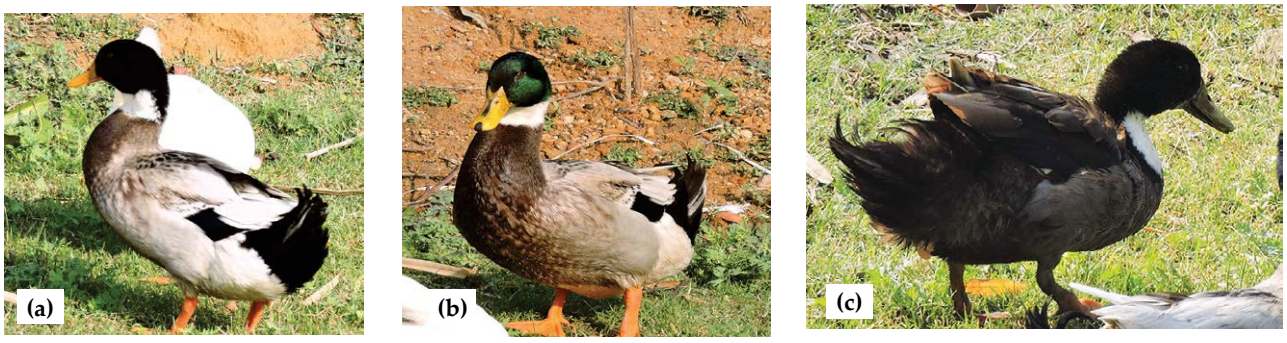
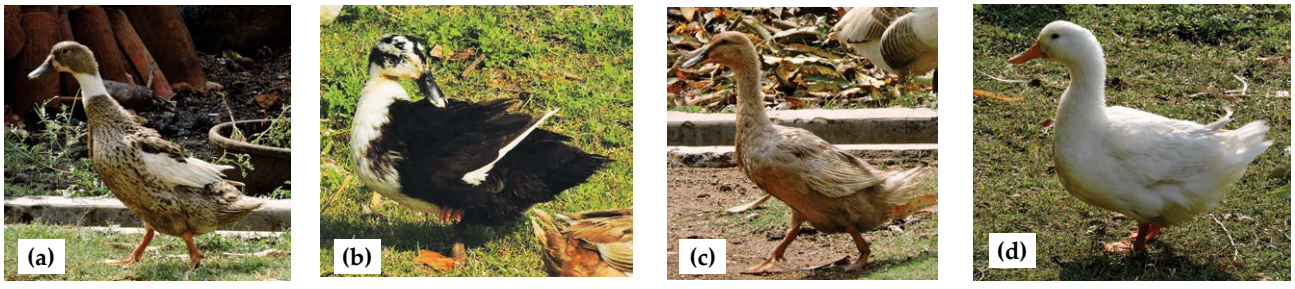


Fig. 19.9. Drake with prominent black and green head (a to c)



Spotted brown & white | Black & white | Brown | White

Fig. 19.10. Desi duck of Chhattisgarh with different plumage color (a to d)

Multiplication and Production Profiling of Improved Poultry Germplasm Under Backyard Farming System

Performance of Kadaknath, Gramapriya, and Vanaraja in Bihar was studied under backyard system of rearing at the institute's poultry farm. The overall mean body weight was significantly (P≤0.01) higher in both Grampriya and Vanaraja than Kadaknath (Table 19.3). The age at first egg in Kadaknath, Gramapriya and Vanaraja was recorded as 180, 165 and 178 days, respectively. The mean egg weight of Kadaknath, Gramapriya and Vanaraja was 42.5, 48 and 50 g, respectively. Mortality was comparatively less in Kadaknath (8%) as compared to Gramapriya (16%) and Vanaraja (20%).

Table 19.3. Body weight of Kadaknath, Grampriya and Vanaraja birds at monthly intervals under simulated backyard farming

S. No.	0 day	30 days	60 days	90 days	180 days
Kadaknath (n=50)	33.3 ± 0.44^{aA}	152.72 ± 5.03^{bA}	319.20 ± 4.87^{cA}	492.27 ± 13.85^{dA}	879.07 ± 7.94^{eA}
Gramapriya (n=50)	34.24 ± 0.34^{aA}	178.98 ± 10.31^{bB}	372.71 ± 7.43^{cB}	611.38 ± 9.20^{dB}	1209.50 ± 17.37^{eB}
Vanaraja (n=50)	34.26 ± 0.36^{aA}	185.16 ± 6.51^{bB}	378.71 ± 11.43^{c*B}	776.50 ± 16.32^{dC}	1518.10 ± 41.90^{eC}

Means bearing the different superscript in a row (small alphabet) and column (capital alphabet) differ significantly

Blood biochemical parameters of Vanaraja was analysed to assess the effect of concentrate mixture supplementation under different rearing systems. Day old Vanaraja chicks (n=150) were selected and reared for a period of 8 weeks. Birds were equally and randomly divided into three groups. Group I were kept under intensive system with supplementation of concentrate mixture as per the BIS specifications (1992) for broilers. Group II were kept under semi-intensive system with supplementation of 50% of concentrate mixture, and with small house and provision for scavenging. Group III birds were kept in backyard system where the birds were kept on scavenging only. Blood collection was done at the end of the experiment for assessment of blood biochemical parameters. The hemoglobin of the birds were found to be significantly (p<0.05) higher in group III (13.7g/dl) compared to group I (9.5 g/dl) and II (11.2 g/dl). The average levels of serum total protein (g/dl) ranged from 2.89 ±0.34 to 4.21±0.21, serum albumin (g/dl) ranged from 2.09±0.14 to 2.16±0.08 and serum globulin (g/dl) ranged from 0.80±0.12 to 2.05±0.10 in different rearing system showing the highest value in group III, followed by group II and group I birds. The average levels of serum glucose (mg/dl) in group III birds were significantly (p<0.05) lower (158.44±1.51) as compared to birds of group I (171.9181±0.41).

Molecular Epidemiology and Therapeutic Management of Bovine Theileriosis

More than 300 clinical samples (blood and lymph node aspirate) were screened for bovine theileriosis using conventional method of Giemsa staining. The presence of the organism was confirmed by the findings of piroplasms in RBCs and macroschizonts in lymphocytes commonly known as Koch's Blue Body (Fig. 19.11). Further confirmation was made by Genomic DNA isolation from these samples and specific amplification of 18s rRNA gene of *Theileria* sp. using specific primers. The purified PCR products were outsourced for sequencing. The 18s rRNA gene product sequences were confirmed for *Theileria* sp. and submitted to GenBank of NCBI (accession no. MH737680, MH737681 and MH737682). Based on these sequences, it was observed that bovine Theileriosis

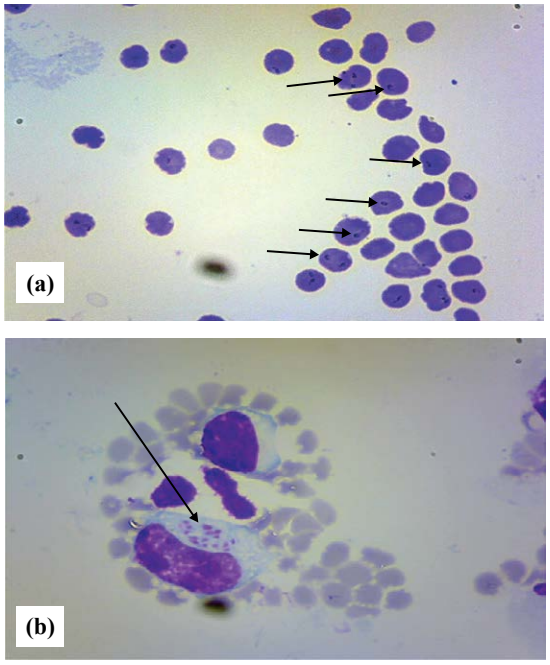


Fig.19.11. RBCs (arrow) having piroplasma (a) and KBB in lymphocyte (arrow) of *Theileria* sp (b).

in the region was due to two species of Theileria, i.e. *Theileria annulata* and *Theileria orientalis*.

It was also observed during the study that many times bovine were suffering from mixed infection of haemoprotozoa due to simultaneous infestation of different species ticks. Therefore, a multiplex PCR was attempted to diagnose the prevalent three types pathogen (*Theileria annulata*, *Anaplasma marginale* and *Babesia bigemina*) in the blood of affected cattle at a time (Fig. 19.12). The primers used in the development of the multiplex PCR were designed based on available gene sequences on NCBI.

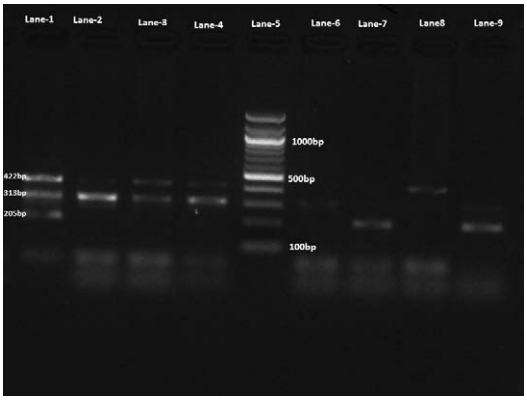


Fig. 19.12. Triplex PCR for *Theileria annulata, Babesia bigemina* and *Anaplasma marginale.*

Specific amplification of *Babesia bigemina* at 205bp, *Theileria annulata* at 313bp and *Anaplasma marginale* at 422bp using three different primers and same cyclic conditions. Lane 1 is standard positive control showing all the three amplifications, lane 2, 3, 4 positive for *Theileria annulata* and *Anaplasma marginale*, Lane 5 ladder of 100bps, Lane 6 positive for *Theileria annulata*, Lane 7 positive for *Babesia bigemina*, Lane 8 positive for *Anaplasma marginale* and Lane 9 positive for *Babesia bigemina* and *Theileria annulata*.

Epidemiological Study of Respiratory Viral Diseases in Calves

The diseases affecting cattle and buffalo calves were recorded up to the period of weaning. Out of 108 calves examined during the study period 17.57% calves were affected with respiratory diseases (Fig. 19.13). Younger calves were more susceptible to the gastrointestinal affections. Respiratory symptoms were more common in calves of more than 4 months age. Papular stomatitis (Fig. 19.14) was observed in buffalo calves in one farm where cattle and buffalo were housed together

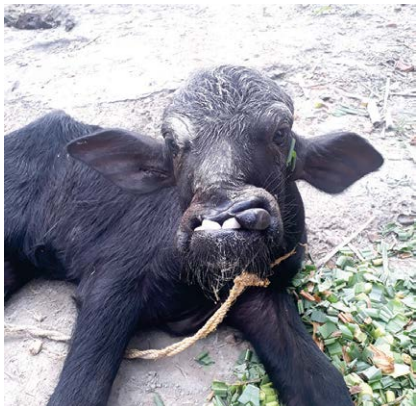


Fig. 19.13. Cleft lip and wry nose in a buffalo calf

Fig. 19.14. Papular stomatitis in a buffalo calf with bleeding tendency

but the lesions were seen only in buffalo calves. The blood sample and scrapping from oral lesions were tested for bovine papular stomatitis virus by semi-nested PCR but were found negative. Nasal swab samples were collected from calves showing signs such as nasal discharge, coughing and respiratory distress.

PCR technique was standardized for detection of bovine Corona virus using Pan- Corona primers CorFW and CorR. The nasal swabs collected from calves showing respiratory distress as well as necropsy lung samples were tested for presence of bovine Paramyxovirus and Corona virus by polymerase chain reaction but all the samples were negative.

Outreach Programme on Zoonotic Diseases

Prevalence study of Brucellosis

Epidemiological study was conducted to know the current status of Brucellosis in Bihar and Jharkhand. Serum and milk samples were collected from ten districts in four agro-climatic

zones of Bihar and two districts of Jharkhand state to study the prevalence of Brucellosis in bovine and caprine species. In Bihar, 7.30 % (n=452) of bovine serum samples was found positive by indirect ELISA (I-ELISA) test. The highest (10.05%) sero-positivity was found in agro-climatic zone III B. Pooled milk samples (n=43) collected from urban areas in Bihar were found negative by milk ring test. In caprine, 4.58% (n=262) samples were positive by RBPT but were negative by I-ELISA. In Jharkhand 65 bovine sera samples were collected from Palamu and Garhwa districts and 4.61% of samples were found sero-positive by RBPT but all were negative by I-ELISA.

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

The data collected during animal health camps conducted in the project and data available in public domain were analyzed. Economic losses due to *Peste des petits ruminants* (PPR) in goats and mastitis in cattle was calculated based on these data using suitable models. The overall prevalence of PPR in Bihar was 34.39% with range of 27.08% to 48.84% in different districts. Analysis based on group discussion, primary data recorded and secondary data retrieved from farmers indicated heavy economic losses to farmers due to PPR infection. An average loss of Rs.1283.00 per PPR affected goats was estimated. The major loss (37.35%) was due to the mortality of goats in PPR (Fig. 19.15). Overall high economic loss and mortality due to PPR in goats suggests the significance of its diagnosis, prevention and measures to eradicate the disease. Advisories to the farmers were provided for benefits of timely vaccination against PPR in goats and maintaining period of stress free environment for 3 weeks after vaccination.

Mastitis is most important limiting disease in dairy industry. Based on 10.70% prevalence of mastitis in Bihar and considering the total milch population of cattle in the State and average 7.0% fibrosis rate due to mastitis, etc., the total cost of losses from mastitis in milch cattle was estimated to be around 480.06 million which is contributed by 38% depreciation losses, 32% production losses and 30% due to treatment losses (Fig. 19.16). Farmer's friendly technology for diagnosis of subclinical mastitis using California mastitis test and benefits of dry cow blanket therapy at the end of lactation

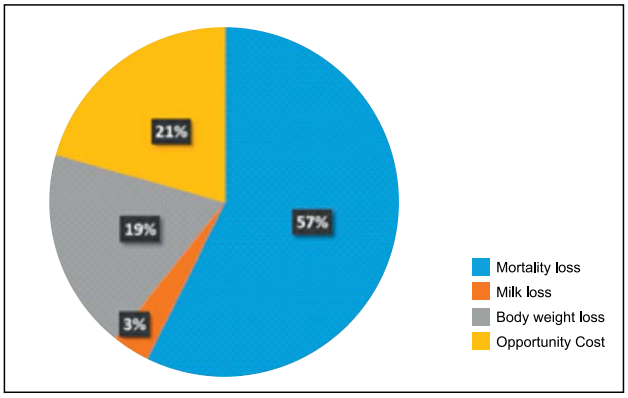


Fig. 19.15. Economics loss % of various components in untreated PPR outbreaks

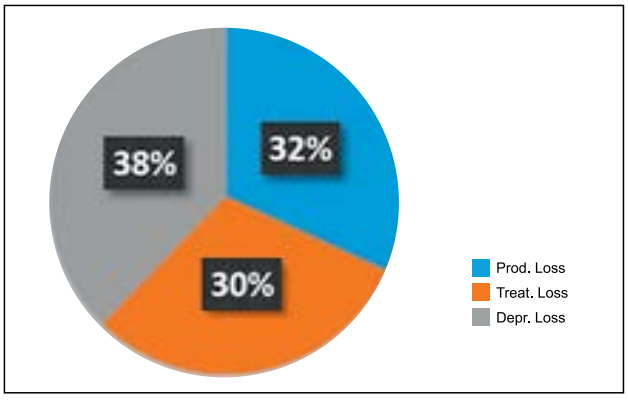


Fig. 19.16. Percent share of components responsible for losses due to mastitis

for reducing incidence of mastitis was disseminated by demonstration.

Effect of Glucosamine Supplementation on Reproductive Efficiency in Poultry

Plasma hormonal concentration (pg/ml) at 15 week (before sexual maturity) and 40 week of age (after sexual maturity) were estimated in control and treatment groups (glucosamine supplementation @ 10 mg and 20 mg/kg body weight). The plasma IGF-1 level (pg/ml) at 15 week were found to be 4709.22±214.85, 4038.06±317.10, 3322.26±513.90 and at 40 week 1651.34±297.50, 1189.93±233.44, 1420.63±131.16 in control, 10 mg group and 20 mg group of glucosamine treatment, respectively. The plasma insulin levels (pg/ml) at 15 week were found to be 148.10±33.60, 271.53±68.39, 170.20±38.42 and at 40 week of age were 306.80±43.49, 67.16± 17.99 and 93.37±18.61 in control, 10 mg group and 20 mg group of glucosamine treatment,

respectively. The plasma LH level (pg/ml) at 15 week were found to be 213.30±56.64, 332.16±59.67, 178.90±53.97 and at 40 week of age were 312.33± 87.40, 137.09±34.96 and 94.32±10.56 in control, 10 mg group and 20 mg group of glucosamine treatment, respectively. The plasma triglyceride levels 274.07±28.58, 306.06±44.69, 385.60±27.89 mg/dl, plasma cholesterol levels were 190.92±52.95, 188.16±52.18, 213.41±59.18 mg/dl in control, 10 mg group and 20 mg group at 40 week of age.

Assessing Stocking Density of Livestock under Different land use System of Fodder Production

Effect of forage crop rotation on soil nutrients status and productivity of land and water

An experiment was conducted at ICAR-RCER Patna during winter season 2018-19 in different leguminous-cereal fodder crop rotations (Oat – multi-cut sorghum-(MS); berseem-MS and annual Rye-MS) (Fig. 19.17). Significantly maximum annual fodder yield was recorded in berseem-sorghum crop rotation. Annual land productivity (t DM/ha) and nutritional productivity (protein yield t/ha) and gross energy yield (Mcal/ha) were significantly highest in berseem-sorghum crop rotation followed by annual rye-sorghum and the lowest in oat-sorghum rotation.

Significantly highest ($p<0.05$) water productivity was recorded in oat (19.15± 0.53 kg/m^3) followed by berseem (16.02±0.11 kg/m^3) and annual rye (13.64±0.23 kg/m^3). The water productivity of MS varied from 13.15 to 22.28 kg/m3 in different preceding crops. Nutritional water productivity was also found significantly ($p<0.05$) highest in berseem (0.37±0.01 kg CP/m3) and lowest in oat (0.26±0.01 kg CP/m^3). However, for multicut sorghum it was significantly ($p<0.05$) highest when preceding crops were berseem (0.30±0.01 kg CP/m^3) and annual rye (0.28±0.02 kg CP/m^3) but was observed significantly ($P<0.05$) lowest when preceding crop was oat (0.19±0.01 kg CP/m^3).

The initial soil pH was 6.77 with organic carbon (OC) content of 0.75%. Initial NPK levels in soil were 175 kg N, 31.7 kg P and 145 kg K per ha. During the whole crop rotation, an amount of 2.6 t FYM (DM basis), 60 kg DAP, 40 kg murate of potash and 180-300 kg urea per ha were added to the soil. After a crop sequence, the final soil status was recorded as 111.2±1.44, 97.76±3.31 and 123.26±1.05 kg N/ha in oat-sorghum, berseem-sorghum and annual rye-sorghum, respectively. Similarly, in case of P, the highest retention in the soil was observed in annual rye-sorghum crop rotation (28.90±1.60 kg/ha) which was almost similar to oat-sorghum crop rotation (27.40±0.81 kg/ha). The highest uptake of P was observed in berseem-sorghum rotation. The OC content of soil after one year of different legume-cereal fodder crop rotation varied from 0.49 to 0.59 percent. The depletion of OC was maximum in berseem-sorghum crop rotation, hence, addition of FYM may be required every year to maintain soil OC level not less than 0.50 percent.

Fig. 19.17. Field view of fodder experiment

Carrying capacity under acidic soil

Experiment was conducted at ICAR-RCER Ranchi to study carrying capacity of fodder production under acidic soil condition. Napier and maize were taken for round the year fodder production and oat during winter by considering previous year results. Plot was prepared with addition of vermicompost (@ 5t/ha), DAP (60kg/ha) and lime (1t/ha). Fodder yields of different crops were recorded (Table 19.4) and carrying capacity calculated. The adult cattle unit (ACU) can be maintained by 19.78 or 14.26 per ha per year by producing napier or maize as round the year fodder crop.

Table 19.4. Fodder yield in acidic soil condition at Ranchi

Particulars	Fodder Crops		
	Oat var. Kent	Maize var. Hybrid Gold	Napier var. CO3
Cropping period (d)	135	105 x 3 times	Perennial
Nos. of cutting/yr.	6	3	9
Cummulative forage yield/yr. (t/ha)	34.87	104.07	144.42
Carrying capacity (ACU/ha)	18.55	14.26	19.78
Fodder availability (d)	94	365	365

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

Samples of fodder trees and local grasses from different districts of Jharkhand namely Hazaribagh, Ramgarh, Ranchi, Khunti, Lohardaga, Dumka, Deogarh, Saraikela, East Singhbhum and Palamau were collected and analyzed for proximate principles and major & trace minerals (Table 19.5). Tree leaves contained 1.11% Ca and 0.47% P, however, different local grasses contained 0.63% Ca and 0.26% P. Cu content of tree leaves was less than 0.001 ppm, except Dudhia leaves (*Cryptolepsis buchanani*) (0.11 ppm). Local grasses contained 0.06 to 0.22 ppm Cu. Zn content of tree leaves varied from 0.34 to 4.44 ppm and 0.44 to 5.39 ppm in local grasses. Mango (*Mangifera indica*) and Sal leaves (*Shorea robusta*) contained highest concentration of Zn, i.e., 4.44 and 4.05 ppm, respectively. Among local grasses, *Cynodon dactylon* and *Cyperus rotundus* contained the highest concentration of Zn, i.e., 3.69 and 5.39 ppm, respectively. Mn content of tree leaves varied from 0.52 to 7.8 ppm, out of which Dudhia leaves contained highest concentration. Fe content of all tree leaves and local grasses was less than the critical level.

Table 19.5. Mineral content of tree leaves and local grasses in Jharkhand

	Ca (%)	P (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
Critical level	<0.30	0.25	<8.0	<50.0	40.0	30.0
Tree leaves	1.11± 0.05	0.47± 0.07	0.09± 0.001	7.54± 0.21	1.91± 0.03	1.47 ± 0.01
Local grass	0.63± 0.04	0.26± 0.03	0.10± 0.002	259.78± 3.46	2.01± 0.32	1.75± 0.07

The nutrients content of different tree leaves and local grasses used for animal feeding in Jharkhand has been presented in Table 19.6**.** On an average, tree leaves contained 3.85 to 12.12% crude protein (CP), about 20% crude fibre (CF), 2.31 to 5.01% ether extract (EE) and more than 90% organic matter (OM). Local grasses contained 7.6 to 9.25% CP, about 20% CF, 1.31 to 1.91% EE and more than 90% OM.

Egg Quality Traits of Backyard Poultry Birds

Egg quality is a prime factor in a laying flock, which can fetch good economic return. A study was undertaken to find out the external and internal egg quality of backyard poultry birds at Regional Centre, Ranchi. Four varieties of backyard poultry birds namely Divyan red, Vanaraja, Kaveri and Kadaknath were reared at institute poultry research unit. In total 80 eggs, 20 from each variety were studied for egg quality traits. Result revealed that in external egg quality, egg weight was maximum in Divyan Red birds and the lowest in Kadaknath birds (Table 19.7). Same trend was followed in egg length, width also. No differences were observed in

Table 19.6. Proximate principles (%) of tree leaves and local grasses

Parameters	CP	CF	EE	OM	Parameters	CP	CF	EE	OM
Arjuna	10.23	20.47	4.23	89.36	Mahua	9.52	20.58	4.72	89.66
Bamboo	5.15	20.78	3.80	92.34	Mango	7.63	20.59	3.81	91.47
Ber	8.38	20.55	3.78	90.02	Motha grass	7.60	20.41	1.91	91.00
Dub grass	9.25	20.10	1.09	90.62	Palash	6.75	20.45	3.45	90.78
Gumhar	3.85	20.50	3.87	91.80	Pipal	7.10	20.59	4.50	89.50
Jackfruit	5.89	20.64	4.63	90.18	Sal	10.03	20.74	4.78	91.97
Jamun	12.12	20.55	5.01	90.03	Mixed grass	8.67	20.22	1.31	91.92
Kusum	6.34	20.50	2.99	90.97					

Table 19.7. External egg quality traits of backyard poultry birds

Parameters	Divyan Red	Vanaraja	Kaveri	Kadaknath
Weight of egg(g)	60.56 ± 0.83	55.30 ± 0.80	54.46 ± 0.73	47.13 ± 0.63
Length of egg(mm)	64.22 ± 0.39	62.81 ± 0.41	58.35 ± 0.32	51. 07 ± 0.38
Width of egg(mm)	42.38 ± 0.19	41.17 ± 0.18	40.86 ± 0.15	40. 38 ± 0.19
Shape index	77.16 ± 0.56	74.82 ± 0.46	72.46 ± 0.42	68.71 ± 0.21
Egg shell thickness(mm)	0.43 ± 0.005	0.43 ± 0.010	0.43 ± 0.002	0.43 ± 0.007
Egg shell weight(g)	5.96 ± 0.07	5.84 ± 0.05	5. 89 ± 0.08	5.71 ± 0.04
Shell (%)	12.57 ± 0.51	12.43 ± 0.49	11.99 ± 0.50	12.41 ± 0.43

egg shell thickness and weight. In internal quality of eggs it was observed that the albumin height, weight, index, yolk height, weight, and index were maximum in Divyan Red birds followed by Vanaraja, Kaveri and Kadaknath (Table 19.8).

Effect of Water Restriction on Growth Performance of Crossbred (T x D) Pigs

In pig the balance between water intake and water loss is affected by numerous factors including health status, nutrition and the environment. A trial on water restriction was conducted with 20 crossbred (T x D) pigs comprising 12 female and 8 male pigs divided in to 4 groups. Within each group 2 male and 3 female pigs of 90 days age with average body weight 32 kg were assigned four treatments. Experiment was conducted on restriction of water consumption at the rate of T_1 (0%, Control), T_2 (5%), T_3 (10%) and T_4 (20%). The feed was offered twice daily @ 2.00kg/pig/day on dry matter basis with half of the quantity in morning and half at evening. During 60 days trial it was observed that all the groups differed significantly (P=0.01) though initial body weight was non-significant. Maximum weight gain was observed in T_1 followed by T_2, T_3 and T_4. Same trend was followed in average daily gain also. The maximum weight loss with increasing level of water restriction up to 20% may be due to maximum non availability of water for metabolic activity in the body. It may be inferred from the above experiment that water restriction in pigs may cause a significant loss in body weight.

FISHERIES

Optimization of Production Efficiency in Livestock-Fish Integrated Farming System

Integrated fish farming system (IFFS) is a diversified and coordinated method of farming system, where agriculture, horticulture and animal husbandry are integrated along with fish culture in order to achieve higher production and economic sustainability. The study on integrated fish farming was carried out in the Institute farm. Results revealed that among different fish based

Table 19.8. Internal egg quality traits of backyard poultry birds

Parameters	Divyan Red	Vanaraja	Kaveri	Kadaknath
Albumen height (mm)	7.13 ± 0.14	6.59 ± 0.12	6.48 ± 0.11	6.09 ± 0.15
Albumen width (mm)	80.64 ± 0.99	77.59 ± 0.95	76.37 ± 0.89	75.88 ± 1.01
Albumen index (%)	9.12 ±0.32	8.15 ± 0.33	7.66 ± 0.42	7.99 ± 0.31
Yolk height (mm)	18.12 ± 0.26	17.85 ± 0.27	17.16 ± 0.19	17.59 ± 0.17
Yolk width (mm)	43.16 ± 0.58	41.42 ± 0.69	40.74 ± 0.18	39.87 ± 0.41
Yolk index (%)	51.41 ± 0.43	47.68 ± 0.40	46.12 ± 0.39	42.56 ± 0.14
Haugh unit (HU)	82.11 ± 0.87	81.57 ± 0.47	80.34 ± 0.39	78.56 ± 0.78
Albumen weight (g)	28.18 ± 0.46	27.91 ± 0.43	27.56 ± 0.55	26.32 ± 0.44
Yolk weight (g)	15.21 ± 0.23	14.12 ± 0.19	13.45 ± 0.18	12.25 ± 0.22
Albumen (%)	59.66 ± 0.64	58.74 ± 0.54	57.23 ± 0.49	56.12 ± 0.51
Yolk (%)	32.16 ± 0.13	31.11 ± 0.15	30.16 ± 0.13	28.45 ± 0.47
Yolk albumen ratio (%)	51.44 ± 0.45	50.12 ± 0.14	50.14 ± 0.39	49.55 ± 0.72

Effect of water restriction on growth performance of crossbred (T x D) pigs

integrated farming models, the highest production was achieved with cattle-fish integration (5.05t/ha) followed by pig-fish and buffalo-fish (3.57 t/ha) integration. Supplementary feed-based control showed marginally higher production of 5.31t / ha. Data indicates that the fish rearing with the concentrate feed was able to increase a fish yield only by 300 kg/ha as compared to productivity of cattle-fish integration.

Plankton analysis

The annual average plankton density was recorded to be the highest in fish-pig integration (1194.44 no./lit) followed by fish-cattle (1105.56 no./lit.) and fish-duck (1050.00 no./lit.) integrations.The lowest plankton population (888.89 no./lit) was recorded in fish-buffalo integration (Fig.19.18). The monthly variation in plankton density has been shown in Fig 19.19. The lowest plankton density was observed in the month of December due to peak winter season.

The most abundant and frequently recorded planktonic organisms [phytoplankton (Fig. 19.20) and zooplanktons (Fig. 19.21)] were Chlorophytes, Cladocerans, Rotifers, Copepods, Diatoms, Blue-Green algae, and Euglenoids etc. Abundance of zooplankton is more generally associated with the application of organic manure.

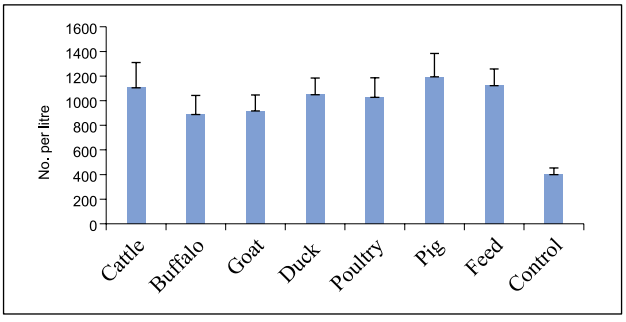


Fig. 19.18. Average plankton density (No./lit.) from different integrated fish farming system

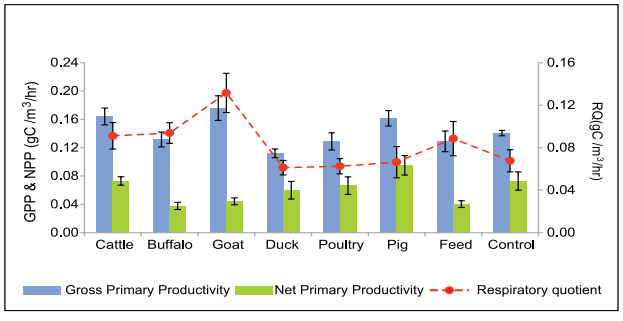


Fig. 19.19. Monthly variation in plankton density in different fish-livestock based integrated farming system

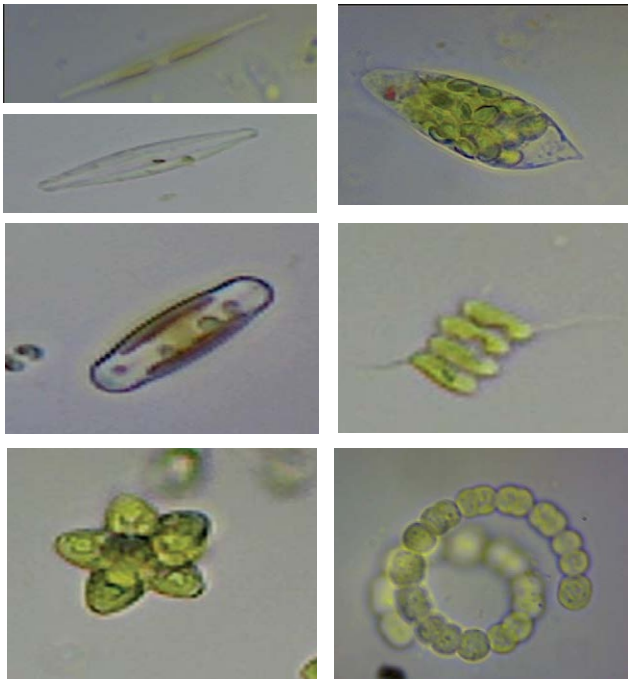


Fig. 19.20. Various phytoplankton species recorded during sampling

(a) Groups of Copepods

(b) Groups of Cladocerans

Fig. 19.21. Different zooplankton species (a & b) identified during sampling

Primary productivity and water quality parameters from different integrated fish farming system

Primary productivity and water quality management play vital role in integrated aquaculture system. Fig. 19.22 illustrates the primary productivity parameters of pond water under different integrated fish farming system. Gross primary productivity (GPP) was recorded the highest in fish-goat integration (0.18g C/m^3/h) followed by cattle- fish integration (0.16g C/m^3/h). Net primary productivity (NPP) was the highest in fish-pig integration (0.10 g C/m^3 /h) followed by cattle-fish integration (0.07 g C/m^3/h), while the respiratory quotient was higher in fish-goat integration (0.13 g C/m^3/h). Overall condition was more congenial in cattle-fish integration compared to other integration.

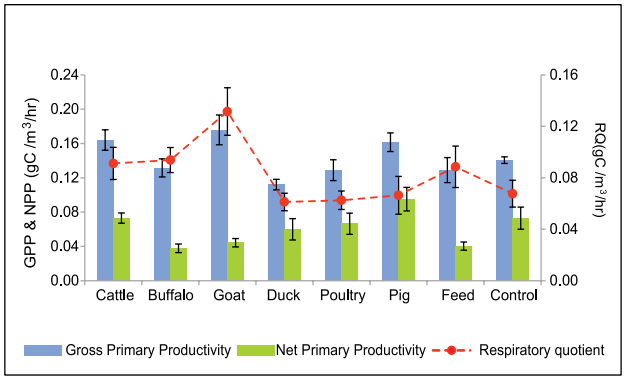


Fig. 19.22. Primary productivity (GPP, NPP and RQ) from different integrated fish farming system

Water quality parameters in different fish-livestock based integrated farming systems are depicted as Fig. 19.23 and 19.24. The ammonia (NH_3-N) content was maximum in fish-buffalo, fish-pig as well as in feed-based integration. Whereas, nitrite (NO_2-N) were also highest in feed based (0.02 ppm) farming followed by fish-goat (0.018 ppm). Phosphate (PO_4^{-2}) level was highest in fish-cattle (0.53 ppm) followed by feed-based farming (0.37 ppm). All the parameters recorded from other integration were also more or less sufficient for freshwater aquaculture system (Fig. 19.23). Alkalinity and hardness were also recorded within the acceptable limits in all the ponds (Fig. 19.24). Based on these findings, it can be concluded that livestock-based integration does not have significantly role in deterioration of water quality parameters.

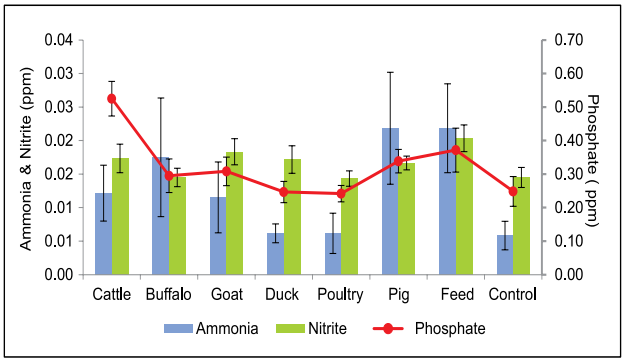


Fig. 19.23. Nitrite, ammonia and phosphate (ppm) content in different livestock - fish based integrated farming systems

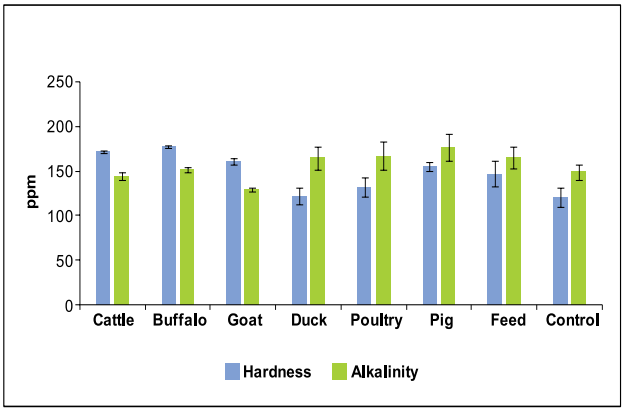


Fig. 19.24. Alkalinity and hardness level (ppm) in different livestock-fish based integrated farming systems

The temperature and pH of pond water from all the integrations ranged between 24.3-24.78°C and 7.47-8.12 ppm (Fig. 19.25) and no abrupt changes in pH have been recorded so far. Dissolved oxygen (DO) was almost maintained between 5.7 - 7.67 ppm, which is ideal for fish survival and growth.

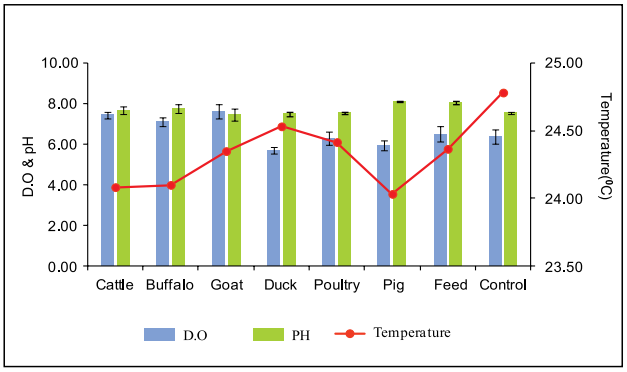


Fig. 19.25. Temperature, pH and DO in different livestock-fish based integrated farming systems

Formulation of Mineral Mixture for Indian Major Carp Based on Soil-Water and Fish Continuum

Minerals play a pivotal role in maintaining osmotic pressure as well in various biochemical reactions in a living body. To estimate the mineral status in soil, water and in different species of IMC, the present study was undertaken. Under this project acitivity soil, water and fish samples from IMC were collected from different agro-climatic zone of Bihar covering Nalanda, Bhojpur, Jehanabad and Sitamarhi district. Blood, serum and tissue samples (gill, liver, bone of fish species) as well as soil and water samples from the farmer's field were collected. The mineral concentration like Ca, Mg, P, I_2, Fe, Mn, Zn and Cu of Rohu, Catla and Mrigal were estimated using standard techniques (Table 19.10).

Wild Seed Collection and Identification of Fish Species from Different River System of Bihar

Fish culture at present is restricted to only six major fish species in India. One of the major thrust areas in aquaculture is the diversification and selection of new candidate fish species for aquaculture. Identification and selection of potentially suitable fish species, especially minor carps, available in different river systems and including them in the aquaculture system can not only reduce dependency on major cultivable fish species but will also boost profitability.

In order to meet these challenges a project was initiated with an aim to identify suitable and potential of fish species for future inclusion in the composite fish culture system. The wild fish seed was collected from Gandak (Gandakpul), Sone (Indrapuri barrage) and Ganga (Gaighat) river system and were reared separately in our Insitute fish farm. The wild collection generally consists of mixed fish species and rearing was necessary for further analysis. Different fish species such as *Glossogobius biocullatus, Labeo dero, Macrognathus aral, Puntius chola, Puntius conchonius, Puntius sophore, Xenentodon cancila, Botia lohachata, Catla catla, Chanda nama, Cirrhinus reba, Labeo calbashu, Parambassis baculis, Parambassis lala, Labeo rohita* and few Non-Penaeid prawn was identified (Fig. 19.26).

Table 19.10. Average mineral concentration (mg/100g) in different organs of Rohu, Catla and Mrigal sampled from different districts of Bihar

Species	Organ	Ca	Mg	P	I_2	Fe	Mn	Zn	Cu
Rohu	Bone	123.51 ±08.92	80.6 ±5.63	0.020 ±0.0020	4.41 ±0.66	26.98 ±2.04	5.07±0.48	25.25±2.79	19.45±1.64
	Gill	34.45±03.60	35.56±3.18	0.035±0.007	3.21±0.56	38.75±1.95	4.94±0.72	33.60±3.89	12.24±1.61
	Liver	197.17±15.14	158.4±11.3	0.23±0.032	15.06±1.45	469.34±46.72	10.83±1.17	54.55±4.99	18.50±2.09
	Muscle	137.15±13.52	51.36±5.99	0.39±0.049	3.60±0.24	16.15±1.17	3.04±0.46	6.35±0.70	16.39±0.92
Catla	Bone	240.2±24.67	49.25±7.48	0.035±0.009	4.43±0.58	13.64±1.31	4.62±0.74	16.00±1.08	11.17±1.48
	Gill	41.38±3.28	25.86±82	0.036±0.007	2.90±0.36	44.41±5.58	5.84±0.81	37.49±3.25	7.48±0.83
	Liver	659.16±24.4	157.39±11.66	1.28±0.17	17.81±1.29	148.96±12.86	6.10±0.81	24.68±1.84	56.50±3.96
	Muscle	296.44±25.64	30.29±1.51	0.22±0.04	3.15±0.46	15.98±1.28	2.69±0.24	6.34±0.73	0.35±0.04
Mrigal	Bone	119.34±12.68	129.12±7.65	0.06±0.009	4.0±0.47	24.93±2.48	3.90±0.56	17.86±1.78	14.13±0.96
	Gill	76.79±6.96	40.83±5.32	0.04±0.01	8.64±0.78	40.89±1.16	3.30±0.52	43.81±3.30	8.46±0.42
	Liver	560.85±17.46	149.64±4.7	1.38±0.03	15.72±1.7	186.54±12.73	13.20±0.48	14.86±1.00	73.96±8.38
	Muscle	166.47±7.97	144.57±12.28	0.031±0.007	3.13±0.36	14.73±1.50	0.30±0.06	5.24±0.51	19.43±1.78

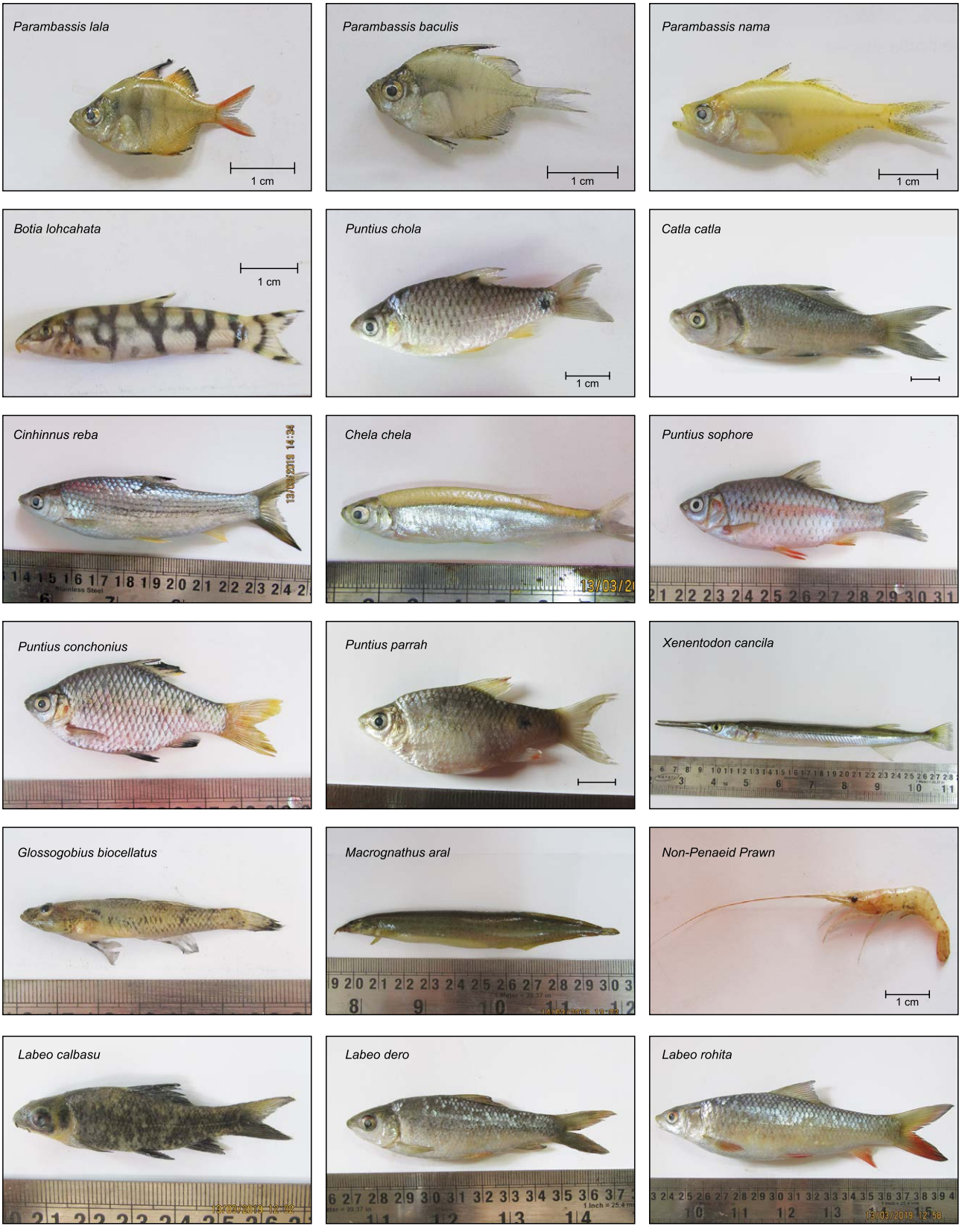


Fig. 19.26. Segregation and identification of fish species from wild collected mixed seed

20. Socio-economic Studies and Transfer of Technology

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

Purnea and Katihar districts of North Bihar have been selected to study the food and nutritional security of farm households. Seeds of 14 different vegetable crops have been distributed to the farmers for establishing nutri-garden at their home with model layout of 100 m^2 nutri-garden. During November to February, tomato followed by chilli in March to June and coriander during July to October can be grown. Similarly, from the other plots diversified crops can be harvested for household consumption. Provision has also been kept for production of perennial vegetables like green papaya, moringa, curry leaves and green banana. A compost pit has also been design at the corner of perennial plots so that the crop residues and household green waste can be composted.

A knowledge test was developed under the project to assess the level of awareness and knowledge about general nutrition. Initially 30 questions were selected based on opinion and knowledge of experts and secondary sources. These 30 questions were administered to 117 rural people of Purnea and Katihar districts to assess the construct validity and reliability. Based on the response difficulty index, discrimination index, and point-biserial correlation coefficient were calculated. The internal consistency of the test was found high (Cronbach's alpha = 0.81) and the reliability was also found well (KR Formula 20 value = 0.78) above the minimum requirement of 0.7. Based on the above analysis 21 questions were selected for final knowledge test.

Econometric Analysis of Zero Tillage Wheat in Eastern Region of India

The relevant data were collected through a well structure questionnaire from 46 farmers of Buxar and Madhubani districts and put to Logit model building. The probability plots of Zero Tillage Adoption (ZTA) with category of the farmers (CAT), experience in farming (EXP), family type (FMT) and extension of ZT in district (EZTD) at different age of the farmers were obtained. The probability plot indicated more likely adoption of ZT in general category of farmer at higher age group, farming experience in higher age group and joint family in higher age group, extension of ZT in district played greater role in adoption of zero tillage in wheat and it slightly interacts with the higher age of the farmer.

A generalized linear model with binary dependent variable ZTA is considered as logitMod<-glm(ZTA ~ AGE+CAT+EDU+EXP+FMT+EZTD, data=d, family=binomial(link="logit")). Based on Logit model the predicted and actual values were matched with 72 percent accuracy with Akakies Information Criteria (AIC) 80.6. This indicated reasonable accuracy of the model.

Socio-Economic Characterization of Farmers in Bihar and Jharkhand

The project is being undertaken to characterize the socio-economic status of farmers of Bihar and Jharkhand. For collection of data from farmers, a schedule was developed for finalization of indicators and sub-indicators of socioeconomic status scale and its pre testing has been done. Ranking of indicators of socioeconomic status (SES) were done by the eighty farmers and twenty experts. Farmers stated that employment is the most important indicator of SES followed by personal behaviour, income, education, land holding, caste & religion, neighborhood, housing and health & hygiene, respectively. Similarly, experts (social scientists and related specialists) also opined that employment is the most important indicator of SES followed by income, education, land holding, personal behaviour, material possession, access to institution, social participation, livestock, family, housing, health & hygiene, status of friends & relatives, neighborhood and caste & religion, respectively.

Enhancing food, nutritional and livelihood security of marginal and small farmers in Jharkhand through need based agricultural technologies

The programme is being implemented under the Farmers FIRST Project of ICAR since 2018 with the objective to assess the suitability of agricultural technologies for their application in farming systems for food, nutritional and livelihood security. The project implementation sites are situated in four villages *viz.* Kutiyatu, Tetri, Malti and Pindarkom of Khijri block of Ranchi district. The four villages are inhabited by a total of 955 numbers of households mainly belonging to ST and SC community. Based on land holding size, 58% farmers are marginal farmers (<1 ha), 26% are small holders (1 ha – 2 ha) and only 16% are medium holders (2 ha – 4 ha).

Technological interventions were made in the farmers' fields are depicted in Table 20.1

Table 20.1 Technological interventions were made in the farmers' fields

Crops	Technological interventions	Yield (t/ha)	Remarks
Direct seeded rice	Sahabhagi Dhan	0.8-2.1	Severe drought during August - September
Rainy season brinjal	Swarna Pratibha	21.25-35.0	Average net income of Rs 5500/- per family
Rainy season tomato	Swarna Sampada	46-65	average net income of Rs 16,500/- per family
Rice-fallow management	Wheat var. HD 3086	1.4-1.9	Average net income of Rs 1600/- per family
	Mustard var. Pusa 29	0.507-0.70	Average net income of Rs 500/- per family
	Garden pea var. Swarna Mukut	9.8-12.4	Average net income of Rs 8500/- per family

The other interventions include:

1. Vegetable cultivation with drip irrigation and mulching
2. Training on mushroom mushroom cultivation
3. Training programme on preservation of fruits and vegetables for development of value added products
4. Introduction of crossbred TxD boar
5. Animal health camp
6. Distribution of area specific mineral mixture
7. Distribution of fish fingerlings
8. Integrated farming systems

Socio-economic Profile of Sample Farmers of Jasaulipatti village in East Champaran

The benchmark data regarding socio-economic profile of farmers from Jasaulipatti village, one of the four adopted villages, was analyzed using simple descriptive statistics. A sample of 87 farmers was studied from this village in terms of their age, education, income, caste, land holding etc. It was found that majority of farmers (46%) belonged to middle age group, i.e., 35-50 years. 28.74% of farmers passed High School while nearly one fourth were illiterate. Only 11.5% of farmers were graduate or above. As far as family size is concerned, almost half of the sampled farmers had 4-5 family members. In Jasaulipatti, majority of farmers were found to be above poverty line. This is evident from average annual income of a farm family which stood at Rs. 1,00,822/- per annum during normal year. However, due to drought or flood in the village, there was 39.27% decrease in annual income because of crop and livestock losses and lack of temporary employment. The village has majority of general caste (48.3%) farmers followed by OBC category (31%), Scheduled Caste (SC) and Scheduled Tribe (ST). Land holding is also an apt indicator of socio-economic status and it was observed that nearly half of sampled farmers belong to marginal category having < 1 ha land holding while 27.6% were small farmers (1-2 ha land). Only 8% of farmers had more than 4 ha of land. Thus, nearly 80% of farmers were marginal and small farmers in this adopted village.

Capacity building of farmers through exposure visits, workshops, awareness camps, field days, trainings etc.

About 3800 farmers from different villages of East Champaran district of Bihar including four adopted villages under the project "Development of Climate Resilient Farming System Models for Livelihood Improvement" participated in various awareness programmes as depicted in Table 20.2 (Fig. 20.1).

Table 20.2. Various events and capacity building activities under DCRFSMLI Project

Name of the event/ programme	Venue	Duration	No. of participants
Agriculture Fair & Farmer's Interaction Meet (State Level Krishi Mela)	Zila School Maidan, Motihari, East Champaran	13-15 April 2018	265
Krishak- Scientist Sangosthi	Jasauli Patti, Kotwa, East Champaran	16 April 2018	90
Farmer's -Scientists Interaction Meet	MGIFRI, Piprakothi, East Champaran	02 October 2018	110
Training on Modern Techniques for Goat Rearing	ICAR-RCER, Patna	25-27 October 2018	30
Pashu Arogya Mela-cum- Scientists Interaction Meet	KVK, Piprakothi, East Champaran	23-25 December 2018	200
Krishi Kumbh- 2019	Gandhi Maidan, Motihari	09-11 February 2019	1580
Farmer's Exposure Visit	ICAR-RCER, Patna	03 March 2019	120
Field- day- cum- Exposure Visit	MGIFRI, Piprakothi, East Champaran	07-08 March 2019	1380
Field-day-cum-Farmers' training on "Operation and Maintenance of Tillage, Sowing and Harvesting Equipments"	ICAR-RCER, Patna	26-27 March 2019	25
		Total	3800

Fig. 20.1. Capacity building of farmers through exposure visits, awareness camps, field days and trainings

Mera Gaon Mera Gaurav (MGMG)

Table 20.3. Activities under MGMG programme

Name of activity	No. of activities conducted	No. of farmers participated & benefitted
Visit to village by teams	20	807
Interface meeting/ *Goshthies*	10	290
Training organized	6	165
Demonstrations conducted	10	152
Mobile based advisories (No of message)	132	132
Literature support provided (No)	394	394
Awareness created (No)	05	185
Other, if any		
	Total	2125

Table 20.4. Other activities organized under MGMG

Name of activity	No. /Area (ha)	No. of farmers benefitted
Linkages developed with other agencies (No. of agency)	03	2125
Facilitation for new varieties, seeds, technology		
New varieties (No.)		
Technology (No.)	05	900
Seeds/plants (q)	15	1500
New crops (No.)		
Other (Drip)	03	06

Table 20.5. Plant variety registration under PPV&FRA

Name of institute	Application/ registration no.	Name of variety/ crop	Date of filing/ registration	Application granted/ registered**
ICAR-RCER RC, Plandu, Ranchi, Jharkhand	REG/2018/597	Swarna Safal (Faba Bean)	04.07.2018	Acknowledgement received from PPV&FRA, New Delhi
ICAR-RCER RC, Plandu, Ranchi, Jharkhand	DL2509180001 (PVP Number)	Swarna Ratan (IC-620356) (Tomato)	28.08.2018	Acknowledgement received from PPV&FRA, New Delhi
ICAR-RCER RC, Plandu, Ranchi, Jharkhand	DL2509180001 (PVP Number)	Swarna Praphulya (IC-616624) (Chilli)	28.08.2018	Acknowledgement received from PPV&FRA, New Delhi
ICAR-RCER RC, Plandu, Ranchi, Jharkhand	DL2509180002 (PVP Number)	Swarna Atulya (IC-620357) (Capsicum)	28.08.2018	Acknowledgement received from PPV&FRA, New Delhi
ICAR-RCER RC, Plandu, Ranchi, Jharkhand	submitted	Swarna Tejaswi (IC 616625) (Chilli)	10.12.2018	Application filed under PPV&FRA, New Delhi
ICAR-RCER RC, Plandu, Ranchi, Jharkhand	submitted	Swarna Sneha (IC 620358) (Bottle gourd)	10.12.2018	Application filed under PPV&FRA, New Delhi
ICAR-RCER RC, Plandu, Ranchi, Jharkhand	submitted	Swarna Yamini (IC 616626) (Bitter gourd)	10.12.2018	Application filed under PPV&FRA, New Delhi
ICAR-RCER RC, Plandu, Ranchi, Jharkhand	submitted	Swarna Sawani (IC 617193) (Ridge gourd)	10.12.2018	Application filed under PPV&FRA, New Delhi

Training and Awareness Programmes, Animal Health Care Camps and Field Days

The following master training programmes for officials have been conducted at ICAR –RCER, Research Centre, Ranchi during year 2018-19. The details of training programmes are as follows:

Name of master training programme	Duration	No. of participants	Sponsoring authority
Integrated nutrient management in Horticultural crops	24th Jan. to 05th Feb., 2019	28 (16 Male and 12 Female)	Jharkhand Rai University, Ranchi (Students)

Table 20.6. Training programs organized at ICAR –RCER, Research Centre, Ranchi

Name of training programme	Duration	No. of participants	Sponsoring authority
Scientific techniques and management practices for mushroom production	26-28th November, 2018	25 (20 Male and 5 Female)	ATMA, Lohardaga
Scientific techniques and management practices for mushroom production	3-5th Dec., 2018	25 (12 Male and 13 Female)	ATMA, Lohardaga
Scientific techniques and management practices for mushroom production	10-12th Dec., 2018	23 (12 Male and 11 Female)	ATMA, Lohardaga
Fruit based production system establishment and their management	21-23th Jan., 2019	25 (20 Male and 5 Female)	AICRP on fruits under TSP
Fruit based production system establishment and their management	04-6th Feb., 2019	25 (11 Male and 14 Female)	AICRP on fruits under TSP
Scientific cultivation of banana and papaya	12-16th Feb., 2019	21 (21 Male)	ATMA, Sahebganj
Scientific techniques and management practices for mushroom production	18-22th Feb., 2019	22 (15 Male and 7 Female)	ATMA, Sahebganj
Nursery management	27th -29th March, 2019	25	Mother Dairy Fruit and Veg. Pvt. Ltd., Ranchi

Table 20.7. Sale of planting materials from ICAR RCER, RC, Ranchi

Type of crops	Plants sold (Nos)
Fruits	82,084
Ornamentals	9,267
Seasonal flowers	1,68,666
	2,60,017

Table 20.8. Sale of seeds (kg) from ICAR RCER, RC, Ranchi

Type of crops	Seeds sold (kg)	Sl. No	Type of crops	Seeds sold (kg)
Tomato (grafted plant)	412.00	19	Elephant foot yam	189.50
Tomato	63.17	20	Paddy (godadhan)	41.30
Brinjal (grafted plant)	740	21	Faba Bean	9.02
Brinjal	39.51	22	Ragi	307.00
Cucumber	14.41	23	Cow pea	453.26
Garden Pea	630.80	24	Pumpkin	4.46
Lima Bean	5.02	25	Ridge gourd	0.40
Onion	23.32	26	Bitter gourd	2.43
French Bean	625.17	27	Satputia	20.09
Water melon	6.29	28	Bottle gourd	23.90
Pigeon Pea	286.00	28	Turmeric	737.0
Black Pepper	1.30	30	Tephrosia	13.00
Chilli	23.16	31	Sponge gourd	47.97
Pointed gourd plant (No)	17260	32	Vegetable soybean	153.62
Kulthi	20.0	33	Dolicos bean	26.92
Green Gram	40.00	34	Capsicum	3.00
Mustard	3.5	35	Amaranth	7.50
Niger	179.0	36	Mushroom Spawn	4184.0

Linkages

Besides having linkages with leading ICAR institutions, SAUs and State Govt. of various eastern states, the details of other linkages is depicted in the tables.

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 tolerant rice varieties for flood plains 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.
Climate resilient cropping	NABARD, BAMETI (Bihar Government)

21. Trainings and Capacity Building

Following employees of the institute have undergone training during 2018-19

Table 21.1. List of employees undergone training

Category	Total no. of employees	No. of trainings planned for each category during 2018-19 as per ATP	Total no. of employees undergone training during April 2018 to March 2019	% realization of trainings planned during 2018-19
Scientist	67	12	6	50
Technical	61	12	3	25
Administrative & Finance	37	5	6	100
SSS	63	0	0	0
Total	228	29	15	51.72

Feedback of trainees were collected, consolidated and sent to ICAR, New Delhi. Annual Training Plan 2019-20 for all categories of staff of the institute was prepared and being implemented.

Table 21.2. Category-wise trainings attended by employees during 2018-19

Name of employee	Designation	Name of training programme attended
Scientific		
Dr. Abhay Kumar	Pr. Scientist	MDP on Priority setting, Monitoring and Evaluation (PME) of Agricultural Research Projects
Dr. Kamal Sarma	Pr. Scientist & Incharge, Head, DLFM	Management Development Program on Leadership Development (a-pre-RMP Program)
Ms. Manisha Tamta	Scientist	Training workshop on advances in Simunation modelling and climate change research towards knowledge based agriculture
Sh. Shailendra Mohan Raut	Scientist	Professional Attachment Training (PAT)
Sh. Jaspreet Singh	Scientist	Professional Attachment Training (PAT)
Miss Bavithra R	Scientist	Professional Attachment Training (PAT)
Dr Ujjwal Kumar	Pr. Scientist	MDP for HRD Nodal Officers of ICAR for effective implementation of training programme
Technical		
Sh. Amrendra Kumar	Sr. Technical Assistant	Training Programme on "Freshwater Pearl Farming"
Sh. Satish Kumar	Sr. Technical Assistant	Workshop on Institutional Digital Repository (IDR) for "National Digital Library of India (NDLI) Project"
Sh. Sarfaraj Ahmad	Technical Officer	Training Programme on "ICAR-ERP" for Finance Officials of ICAR
Administrative		
Sh. Rakesh Mani	Assistant	Workshop-cum-Awareness Programme on Pension & Retirement benefits
Sh. Ravi Shankar	Assistant	Workshop-cum-Awareness Programme on Pension & Retirement benefits
Smt. Sangeeta Chakraborty	Assistant	Workshop-cum-Awareness Programme on Pension & Retirement benefits
Smt. Ritu Rani	Lower Division Clerk	Workshop-cum-Awareness Programme on Pension & Retirement benefits
Ms Divyadarshnini	Assistant	OSP for Newly recruited assistant
Sh. Ajay Kumar Soni	Sr. Administrative Officer	MDP on Administrative and Financial Management

HRD fund allocation and utilization (Rs. in Lakh)

RE 2018-19 for HRD	Actual Expenditure 2018-19 for HRD	% Utilization
5.30	5.29	100

22. Events Organized

State Level Agriculture Fair-cum-Farmers' Scientists Interaction Meet

A state level agriculture Fair-cum-Farmers Scientists interaction meet was organized during 13-15th April, 2018 at Zila School Ground, Motihari, Bihar. Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture & Farmers Welfare, Govt. of India graced the occasion as Chief Guest and Shri Pramod Kumar, Hon'ble Minister of Tourism, Govt. of Bihar attended the inaugural function as Guest of Honour.

Dr. B.P. Bhatt, Director, ICAR-RCER, Patna welcomed the Chief Guest and other dignitaries. He outlined the objectives of the event and informed the gathering about the major attraction of the fair such as Farmers-Scientists interaction, exhibition and live demonstration of different agricultural implements, crop varieties, mobile solar operated pump, input supplies, samples of agricultural products and other technologies during this three day mega event.

Farmers' scientist interaction meet was organized on each day in different fields of agriculture and allied subjects. Scientists from different ICAR institutes and SAUs answered the queries of the farmers on these aspects during the meet. Sixty five public and private sector organizations including ICAR Institutes, SAUs, KVKs, NGOs, cooperative societies, input supply agencies, etc. put their stall and displayed different products, technologies, live samples, etc. for the benefit of farmers as well as other stakeholders. Nearly 6000 farmers, including members of FPOs, FIGs, entrepreneurs and other stake holders from different districts of Bihar, officials of state and central government scientists of different ICAR institutes and SAUs participated in the three-day event.

International Yoga Day

ICAR Research Complex for Eastern Region, Patna celebrated 4th International Yoga Day on 21st June, 2018. To mark the occasion, Director ICAR-RCER, Patna and Director ICAR-ATARI, Patna along with the scientists and staff of the institute performed Yoga from 8:00 AM to 9:30 AM under the instruction of Dr J.J. Gupta, Yoga Expert of the institute. He told that Yoga is for physical, mental, and/or spiritual practice attributed mostly to India. The role of Yoga in daily life was narrated by Dr S.K. Singh, Principal Scientist of the institute.

Zero tillage-Happy Seeder Summit Workshop

One day Zero tillage-Happy Seeder Summit Workshop on "Value chain and policy interventions to accelerate adoption of zero tillage in the rice-wheat Farming systems across the Indo-Gangetic Plains" was organized in collaboration with the University of Adelaide, Australia, ACIAR (Australian Centre for International Agricultural Research), TAAS (Trust for Advancement of Agricultural Sciences), CIMMYT (International Maize

and Wheat Improvement Centre) and ICAR-RCER, Patna on 27th June 2018 at ICAR Research Complex for Eastern Region, Patna. Around 50 participants from ICAR RCER Patna, BAU Sabour, Dr. RPCAU, Pusa, KVKS of Bihar and West Bengal, CGIAR (CIMMYT-CSISA), State Government Officials of Bihar, representatives from NGOs, FPOs, Machinery manufacturers and progressive farmers participated in this Workshop. Dr. B. P. Bhatt, Director ICAR-RCER, Patna welcomed the Chief Guest Padma Bhushan Dr. R.S. Paroda, Chairman TAAS and the former Secretary DARE and DG, ICAR, and other participants. He also gave the brief presentation on prospects and key issues related to the conservation agriculture (CA) in Eastern India. The main focus of this workshop was on discussions related to a draft Policy Position Paper featuring key recommendations merging out of the ACIAR project that has been executed by the University of Adelaide, aimed at convincing Government to create an enabling environment for faster adoption of HS/ZT seed drills. Dr. Adom Loch and Jay Cummins from University of Adelaide, Australia briefed about very purpose of the workshop and a detailed group discussion was held under six different themes.

Training Programme on Recent Advances in Integrated Fish Farming

The ICAR-Research Complex for Eastern Region (ICAR-RCER), Patna organised a 10-days farmers' training programme on "*Recent Advances in Integrated Fish Farming*" during 04-13th July 2018 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 25 trainees from Buxar district (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. Another programme was organized during 22-31 August, 2018 in which 25 trainees from Rohtas district (Bihar) participated.

Awareness Programme on Fish Disease Surveillance and Management in Bihar

An awareness programme on fish disease surveillance and management in Bihar was organized on 25.08.2018 at village Dighara Rampur under Mushahri block, district, Muzaffarpur, Bihar by ICAR Research Complex for Eastern Region, Patna in collaboration with department of fisheries, District Muzaffarpur under the "National Surveillance Programme for Aquatic Animal Diseases" project.

Model Training Course on Conservation Agriculture: Mitigating Climate Change Effects & Doubling Farmers Income

A Model Training Course on "*Conservation Agriculture: Mitigating Climate Change Effects & Doubling Farmers Income*" was successfully organized at ICAR Research Complex for Eastern Region, Patna during 11-18th September 2018. Twenty three

participants from different States participated in the programme.

Several experts working on Conservation Agriculture and Climate Change sector interacted with participants and shared their ideas for profitable farming and linking it with sustainable agricultural production system. Visit to long term CA field of BISA, Pusa, IARI RS Pusa and ICAR-Main research fields were also organized.

Training Programme on Tools and Implements for Weed Management

Three days training program on "*Tools and implements for weed management*" was conducted under CRP on Farm Machinery and Precision Farming at KVK, Ramgarh, Jharkhand from 24-26 September 2018. Total 48 farmers took part in this training programme. Farmers also visited Semina Agro Pvt. Ltd. Ranchi, a manufacturer of small tools used in agriculture. A similar programme was also conducted at KVK, Buxar, Bihar from 27-29 September 2018. Twenty five farmers took part in this training programme.

150th Birth Anniversary of Mahatma Gandhi Celebrated

On the occasion of Mahatma Gandhi's 150th Birth Anniversary, Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture & Farmers Welfare unveiled a large statue of Mahatma Gandhi for general public and laid the foundation stone of Farmer's Hostel and Training Hall of Mahatma Gandhi Integrated Farming Research Institute, Motihari on 2nd October, 2018 at the institute campus in Piprakothi (Motihari). Honb'le Minister also inaugurated a Farmers-Scientist interaction programme during this occasion.

In his inaugural address, Hon'ble Chief Guest, Shri Radha Mohan Singh narrated many inspiring quotes of Mahatma Gandhi and his vision about the farmers' welfare and sanitation. He urged farmers to take advantage of agricultural development schemes launched by the Government, like Pradhan Mantri Fasal Beema Yojna, Rashtirya Krishi Vikash Yojana, Gokul Mission, Integrated Farming System, Irrigation schemes etc. A Swachchhata Pledge was also taken by all the participants facilitated by the Chief Guest. Shri Pramod Kumar, Hon'ble Minister of Tourism, Govt. of Bihar graced the occasion as the Guest of Honour. Dr. B.P. Bhatt, Director, ICAR-RCER, Patna and OSD, Mahatma Gandhi Integrated Farming Research Institute, Motihari welcomed the Chief Guest and other dignitaries. Officials of Central and State Government and Scientists of ICAR institutes and more than 6000 of farmers participated in this event.

Training Programme on Land & Water Management, Climate Change and its Impact on Agriculture

Five days training programmes on "*Land and Water Management, Climate Change and its Impact on Agriculture*" were organized during 03-07 September 2018 and 03-07 October 2018 at ICAR-RCER Patna. The training programme was sponsored by ATMA, Purnea. Thirty farmers from Purnea district, Bihar participated in this training programme. Farmers were apprised about various technologies of water management and informed about the effect of climate change on crops, heat and drought stress occurring due to climate change.

Rooftop Solar Energy Harnessing Unit Inaugurated

Shri Chhabilendra Roul, IAS, Special Secretary DARE & Secretary, ICAR, New Delhi inaugurated 100 kWp Rooftop Solar Energy Harnessing Unit installed at the rooftop of main office cum laboratory building of ICAR Research Complex for Eastern Region, Patna on 12th September, 2018. Sri Roul emphasized on the use solar energy and advised to install rooftop systems in other government buildings to meet out their energy requirements. This 100 kWp solar unit is capable of generating

8000 – 15000 units of electricity per month which is sufficient to meet out the energy requirement of the entire campus of ICAR-RCER. Excess energy produced from the system will automatically be transferred to the local power grid. This system is installed under RESCO mode. Dr. B. P. Bhatt, Director, ICAR RCER, Patna explained about the functioning of installed rooftop solar energy system.

Hindi Chetna Maas

ICAR-RCER, Patna observed '*Hindi Chetna Maas*' on the occasion of '*Hindi Diwas*' 2018 from 14th September to 13th October, 2018. Prof.(Dr.) Bijay Kumar Singh, Director, Birla Institute of Technology, Patna inaugurated the '*Hindi Chetna Maas*' on 14th September, 2018. During the one-month programme, various competitions in Hindi, such as Essay writing, Hindi Typing, Hindi Grammar, Calligraphy, Antakshari, Hindi debate, Word meaning test and various other programmes including a three-day- Hindi workshop were held under the supervision of Hindi committee members. The closing ceremony of 'Chetna Maas' was held on 12th Oct, 2018. Prof. Raman Trivedi, Director, Students Welfare of Bihar Animals Science University, Patna

was the chief guest of the function. He discussed the importance of Hindi in our day to day life, and also stressed for working in Hindi as much as possible.

Training Programme on Operation, Repair and Maintenance of Motors and Pumps for Farm Operation

A three day training programme on "*Operation, Repair and maintenance of motors and pumps for farm operation*" was conducted from 09-11 October 2018 at ICAR RCER, Patna. Twenty farmers took part in the training programme. They were apprised about the common troubleshooting of pumps and motors commonly used in agriculture.

Active participation of farmers in training programme on Operation, Repair and Maintenance of motors and pumps.

Training Programme on Selection, Operation and Maintenance of Harvesting and Threshing Equipment

A three day training program on "*Selection, operation and maintenance of harvesting and threshing equipment*" was conducted under CRP on Farm Machinery and Precision Farming at KVK, Ramgarh, Jharkhand from 19-21 November 2018.

Forty farmers from Jharkhand participated in the training programme. Farmers were also apprised about various tools/implements used in agriculture during exposure visit to Department of Agricultural Engineering, Birsa Agriculture University, Ranchi.

Model Training Course on Advanced Technological Interventions for Livelihood Improvement of Resource Poor

A Model Training Course on "*Advanced Technological Interventions for Livelihood Improvement of Resource Poor*" was conducted during 22-29 November, 2018. The course was sponsored by Directorate of Extension, Ministry of Agriculture and Farmers Welfare, Govt. of India. Altogether 21 participants from State Development Departments, ICAR Institutes, SAUs, and KVKs participated in this training program. A total of 31 theory classes and 04 field visits were organized during the course. Training focused on various advanced technologies in agriculture and allied sector capable of increasing the productivity, profitability and livelihood improvement of resource poor farmers.

World Soil Day

World Soil Day was celebrated at ICAR RCER, Patna on 5th December, 2018. More than 40 farmers attended the program out of which 30 farmers were provided with Soil Health Cards. Shri Sanjeev Chaurasia, Member of Legislative Assembly was the Chief Guest at the occasion.

World Soil Day *cum* pre-*Rabi Kisan Mela* was also organised by KVK Ramgarh on 5th December 2018 jointly with Development Commissioner Ramgarh at collectorate office auditorium. A short film was displayed and soil health card and pamphlet was distributed during the celebration of programme. Soil health Cards were also distributed on the occasion. During the program DDC, DAO,

Project Director, ATMA and Soil Conservation officer, District Dairy development Officer and District Animal Husbandry Officer were also present.

Krishi Vigyan Kendra, Buxar also celebrated World Soil Day by organising one day training cum awareness programme on "*Soil health management*" on 5th December 2018. DAO and PD, ATMA distributed soil health cards to 55 farmers.

Pashu Arogya Mela cum Farmers– Scientists Interaction

A three day "*Pashu Arogya Mela -cum-Farmers-scientists interaction*" was inaugurated by Shri Radha Mohan Singh, Hon'ble Union Minister of Agriculture & Farmers Welfare at KVK, Piprakothi, Motihari on 23rd December, 2018. Free animal health camp was organized during 23-25 December, 2018. More than 40 organizations including ICAR-IVRI, ICAR-NDRI, ICAR-IGFRI, DRRPCAU, Pusa, KVKs, COMFED etc., depicted their technologies for the farmers and other stakeholders. Farmers-scientists interactions were also organized during three days.

Krishi Kalyan Abhiyan at KVK, Ramgarh

Working in close coordination with line departments viz. D.A.O, ATMA, Animal Husbandry, Dairy, Soil conservation, Horticulture and NABAD, KVK, Ramgarh achieved 1st rank in Jharkhand and 2nd rank in country under "KKA-II (*Krishi Kalyan Abhiyan-II*) and 5th rank in Jharkhand 20th rank in country is under KKA-I (*Krishi Kalyan Abhiyan*-I). KVK, Ramgarh was the nodal agency for coordination and monitoring the activity of line department.

Swachh Bharat Abhiyan

Swachhata Hi Seva activity by ICAR-RCER, Patna was organised during 15th September to 2nd October 2018. During the programme various types of activities related to swachchhta was organised at different places including ICAR RCER main campus, Patna and Baadipur village, Patna.

At ICAR RCER, RC Ranchi, *Swachchhata Pakhwada* was observed from 16-31 December 2018. The centre carried out series cleanliness awareness campaigns in nearby villages, market places, tourist spots and in the villages adopted under *Mera Gaon Mera Gaurav* scheme. Other activities like experts' lectures, essay writing, painting and quiz competitions were held for the staff and school students. The main aim of these activities was to create awareness about importance of cleanliness and hygiene among the residents of villages and school children. An awareness rally was carried out in collaboration with the students of Immaculate Heart of Merry School, Namkum Ranchi.

Training Programme for Undergraduate Agriculture Students

A ten day training programme on "Integrated Nutrient Management in Horticultural Crops" for

B.Sc (Ag) students from Jharkhand Rai University, Ranchi was organized at ICAR-RCER, Research Centre, Ranchi during 24.01.2019 to 05.02.2019 for 28 students (16 male and 12 female). This training was designed for under graduate agriculture students for improving their knowledge, skill and understanding of nutrient management in horticultural crops to solve real field problems and nutrient quantification in soil and plant using various innovative approaches.

Training of Youth Facilitators

Seven days training programme was organized at BAMETI, Patna during 25th Feb-3rd March, 2019 under the project 'Scaling up climate smart agriculture through main streaming climate smart villages in Bihar'. The youth facilitators selected for implementation of different activities of the project in the selected villages were made aware of their role in the project, conservation agricultural technologies, formation of FIGs, etc.

Training of Farmers

Five training-cum-visit programs for selected farmers from each block of Patna and Nalanda districts were conducted during from 26-29 March 2019 at ICAR RCER, Patna under the project 'Scaling up climate smart agriculture through main streaming climate smart villages in Bihar'. Around 50 farmers from each selected block participated in the programme. The very purpose of this training was to showcase them the recent technologies in climate resilient agriculture being adopted at the Institute.

Field days organized

Date	Topic	Places	No. of farmer participated
5th March, 2019	Improved practices on establishment and management of fruit based production systems	Konkel village of Gumla district	215
12th March, 2019	Improved practices on establishment and management of fruit based production systems	Lohajimi village of Khunti district	190
12th March, 2019	Improved practices on establishment and management of fruit based production systems	Salgi village of Lohardaga district	250
22nd Dec. 2018	Field Day on Horsegram	Rakua village, Gola block, Ramgarh	250
7th Dec., 2018	Field Day on Pigeonpea	Bhudhakhap, Mandu block, Ramgarh	200
28th Sept 2018	Mushroom cultivation	Ranchi, Khunti and Gumla districts	85
14th and 16th March, 2018	Animal health care	Pindarkom and Malti villages of Ranchi	100
15th March, 2018	Value addition of agri-horticultural produce	Tetri village of Ranchi	40

23. Krishi Vigyan Kendra

Krishi Vigyan Kendra, Buxar

Cluster demonstration on Oilseeds & Pulses

Krishi Vigyan Kendra, Buxar organized Cluster Demonstrations on oilseeds and pulses during 2018-19 under National Food Security Mission (NFSM) and National Mission on Oilseed and Oil palm (NMOOP). Details of crops, varieties, area, beneficiaries and demo sites are given bellow.

Details of Cluster Demonstration on Oilseeds & Pulses

Crop	Technology	Area (ha)	No of beneficiaries	Village covered
Pigeon-pea	Variety IPA 203+ seed treatment with FIR+foliar spray of micronutrient (MO and B) @1ml/lit water before flowering and management of legume pod borer (*Maruca vitrata*) using emamectin benzoate 10 g/15 lit water	20	40	Pandeypatti, Chousa, Kamarpur, Pavni, Chunni,
Chickpea	Variety GNG 1581+seed treatment with FIR+foliar spray of micronutrient (MO and B)@1ml/lit. water before flowering and management of gram pod borer (*Helicoverpa armigera*) by using bioinsecticide.	20	70	Rajdiha, Kasiya, Simri, Badka Rajpur, Niyazipur, Chotka Rajpur, Dharhara, Karuj, Siktha
Lentil	Variety PL 8 + seed treatment with FIR + management of aphid (*Aphis craccivora*) by using bioinsecticide	20	38	Badka Rajpur, Niyazipur, Chilhari, Dafadehri, Mangolpur, Majhariya
Field pea	Variety Vikash+seed treatment with FIR+ foliar spray of micronutrient (MO, Zn, Mn and B) @1 ml/lit. water before flowering	10	68	Hukha, Yurkpurva, Niyazipur, Badka Rajpur, Lalganj, Pandeypatti, Chilhari, Chakrahasi
Mustard	Variety RH 749 + Soil application of sulphur 20 kg/ha and management of aphid (*Lipaphis erysimi*) by using bioinsecticide	30	92	Bijhoura, Suroudha, Baksara, Lalganj, Mahdah, Bhatwaliya, Dharhari, Lalganj
Green gram	Variety IPM 2-3+seed treatment with FIR+foliar spray of micronutrient (MO and B) @1ml/lit water before flowering and management of white fly by using thaimathoxam 5g/15 lit water or acetamiprid 15 g/15 lit water.	10	40	Rajapur, Sondhila, Hukha, Barri,

Fig. 23.1. Field view of cluster demostration in pigeonpea, field pea, chickpea and lentil

Training Programmes Organized

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

Off campus training

Topics	Date	No of beneficiaries
In-situ crop residue management for sustainable soil health.	20-21/07/2018	20
Quality seed production of paddy	20-21/07/2018	20
Business module for rice nursery production	13-14/8/2018	20
Integrated crop management in pigeonpea	18 & 20/8/2018	20
Weed management in paddy	18 & 20/8/2018	20
Method of deep summer ploughing	18 & 20/8/2018	20
Best management practices for rice production	24-25/08/2018	20
Method of bunding and its importance	24-25/08/2018	20
Scientific production techniques of pearl millets and sorghum	27-28/8/2018	20
Seed production techniques of maize	27-28/8/2018	20
Weed & balance nutrient management techniques for maize production	29-30/8/2018	20
Method of soil and water sample collection	4-5/09/2018	20
Integrated farming system techniques	5-6/9/2018	20
Rain water harvesting methods	6-7/9/2018	
Quality seed production of pigeon pea	7-8/9/2018	20
Quality seed production techniques of urdbean	13-14/9/2018	20
Application of bio fertilizer in field crops	14-15/9/2018	20
Application of waste decomposer for composting of crop residue.	24-25/9/2018	20
Quality seed production of pigeon pea	24-25/9/2018	21
Seed production techniques of bajra	4-5/10/2018	20
Integrated nutrient management in rice	10-11/10/2018	20
Nitrogen management in paddy by the LCC	16-17/11/2018	20
Method of INM in potato	19-20/11/2018	20
Effect of climate change on agriculture & crop management	26-27/11/2018	20
Application of sulphur in pulses	26-27/11/2018	20
Seed production of mustard	27-28/11/2018	20
Method of INM in cauliflower	11-12/12/2018	20
Scientific production techniques of rapeseed & mustard	18-19/12/2018	20
Integrated nutrient management in wheat	19-20/12/2018	20
Seed production of onion	19-20/12/2018	20
Quality seed production of field pea	24-26/12/2018	21
Best management practices for rabi pulse production	26-27/12/2018	20
Promotion of organic farming	3-4/1/2018	20
Quality seed production of chick pea	3-4/1/2018	20
Foliar application of urea and micronutrients in pulses	5&7/1/2019	20
Scientific cultivation of potato	5&7/1/2019	20
Integrated crop management for wheat production	8-9/1/2019	20
Quality seed production of vegetable pea	8-9/1/2019	20
Method of foliar application of urea and micronutrients in fruit plants	8-9/1/2019	20
Weed management and foliar spray techniques of micro-nutrients in chickpea & lentil	10-11/1/2019	20
Quality seed production of potato	10-11/1/2019	20
Nitrogen management in wheat by LCC	10-11/1/2019	20
RCT in rice-wheat cropping system	21-22/1/2019	20
Quality seed production of berseem	21-22/1/2019	20
Scientific production techniques of linseed	23-24/1/2019	20
Quality seed production of wheat	23-24/1/2019	20
Quality seed production of moongbean	28-29/1/2019	20

Topics	Date	No of beneficiaries
Crop diversification through high value crops	2-3/3/2019	20
Water & nutrient management techniques in wheat	9-10/3/2019	20
Organic farming and crop production	12-13/3/2019	20
Summer moong cultivation for crop intensification in rice-wheat cropping system	14-15/3/2019	20
Contingent crop planning	16-18/3/2019	20
Quality seed production of sunflower	20-22/3/2019	20

On campus training

Topics	Date	No of beneficiaries
Techniques for micro nutrient application in pulses and oilseed crops	1-2/2/2019	20
Management of false smut in rice crop	11-12/2/2019	20
Use and management techniques of farm implements (Happy seeder) in agriculture	12-13/2/2019	20
Management of damping off in vegetable crop	13-14/2/2019	20
IPM techniques for wilt management in pulse crop	19-20/3/2019	20

Training for rural youth

Topics	Date	No of beneficiaries
Integrated farming system: principal and use	28/11/18 - 3/12/18	20
Production techniques of high value crops	22-26/03/19	20
Qualuity seed production of okra		19
Quality seed production of *Rabi* pulses		20
Mushroom production for nutritional security	6-10/2/2019	20
Bee keeping for livelihood improvement	20-24/2/2019	20

Training for extension functionaries

Topics	Date	No of beneficiaries
Organic farming	14-15/11/2018	20
Resource conservation techniques in rice-wheat cropping system	19-20/03/2019	20
Seed production of paddy		20

Skill development training

Topics	Date	No of beneficiaries
Tools and implements for weed management	27-29/9/2018	26
Vermicompost producer	24/01/2019 – 28/02/19	20
Quality seed producer	16/02/2019-19/03/2019	20

Training for fertilizer input dealers

Topic	Date	No of beneficiaries
Integrated nutrient management	1/3/19-18/3/19	39

On farm trials

Topics	No of beneficiaries	Village covered
Assessment of different sowing schedule of ZT wheat on yield and yield attributes character	05	Mahdah, Rajapur, Milki
Effect of water and boron management on terminal heat of late sown ZT wheat	05	Dhansoi, Chunni
Effect of micronutrient zinc management on growth and yield of rice – wheat cropping system.	10	Kukurah, Suroudha
Integrated nutrient management on chickpea	10	Kukurah, Dhansoi
Assessment of varietal & nutrient management of pigeon pea in Buxar district	10	Milki, Chunni

Front line demonstrations

Crop	Technology	Area	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	10	18	Mahdah, Chotki basouli, Rajapur, Dumrao
Bajra (Hybrid)	Super Boss+seed treatment with Azotobactor	5	14	Ahirouli, Chotka Rajpur
Wheat	ZT sowing of wheat variety HD 2967 and HD 3118	15	54	Rajapur, Dhansoi, Mahdah, Chougai, Geruabandh, Dumrao, Chotka Rajpur

Live telecast of *Pradhan Mantri Kisan Samman Nidhi* yojna

On the occasion of launching programme of Pradhan Mantri Kisan Samman Nidhi Yojna, Sri Narendra Modi Jee addressing the farmers on 24th February 2019. The live telecast broadcasting of the programme and Krishak Vaigyanik Vartalap was arranged by KVK, Buxar. The total number of 256 farmers participated in the programme. Officers of line department also attended the programme.

Fig. 23.2. A view of PM Kisan Samman Nidhi Yojna live telecast programme

Technology demonstration

Under technology demonstration component of NICRA Project, following activities were undertaken during 2018-19

a) Crop production

Crop and variety	Area (ha)	No of beneficiaries
Paddy - Swarn shreya	8.5	26
Paddy - Rajendra sweta	6.0	19
Paddy - Rajendra kasturi	3.0	22
Paddy - Swarna sub-1	3.0	08
Pigeonpea - IPA 203	0.25	35
Lathyrus - Ratan	0.50	06
Lentil - PL 8	5.0	23
Chickpea - GNG 1581	8.0	29
Mustard - RH 0749	8.0	19

b) Natural resource management

Intervention	Area (ha)	No of beneficiaries
Deep summer ploughing through MB Plough in month of June	5	11
Sowing of *Dhaincha* after first rainfall in month of June	4	8
Raising bund height around paddy transplanted field	30	90
Cleaning of water harvesting structure	4	4
Puddling in paddy field for retention of water	120	490
Maintain earthen check dam manually by farmers to check runoff water from field	1	11
Levelling of undulating field by farmers in month of June	8	13

c) Livestock and fisheries

Intervention	No of beneficiaries
Vaccination against cattle diseases *viz.* Anthrax, BQ, FMD, Mastitis	343
Fodder production of MP Chary	23
Exhibition organized in Nation Livestock Mission fair at NICRA village Kukurha (08.03.19 to 09.03.19)	52

d) Seed production

Crop and variety	Production (q)
Rice - Swarna Shreya	10.0
Rice - Swarna Sub 1	2.0
Wheat - HD 3118	2.5
Chickpea - GNG 1581	8.0

e) Capacity building programme

Topic	Date	No of beneficiaries
Rain water harvesting methods	6-7/9/18	20
Nitrogen managemnet in paddy crop by using leaf colour chart, LCC.	16-17/11/18	21
Integrated nutrient management in potato	19-20/11/18	21
Production of mushrrom for women empowerment and nutritional security	3/12/18	23
Integrated nutrient management in cauliflower	11-12/12/18	20

Seed production

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

Crop	Variety	Area (ha)	Quantity (t)
Kharif 2018			
Paddy (Foundation seed)	Rajendra kasturi	1.0	1.3
Paddy (Certified seed)	BPT 5204	2.0	4.2
Paddy (Certified seed)	Rajendra Sweta	1.0	1.5
Paddy (Certified seed)	MTU 7029	1.3	2.3
Pigeonpea (TL seed)	IPA 203	0.3	0.25
Rabi 2017-18			
Wheat (Certified seed)	HD 2967	1.2	4.5
Field pea (TL seed)	Vikash	0.4	0.4

Exposure visit of students

Students of DAV Public School visited the KVK Buxar and interacted with the SMSs and PC of the KVK. They were made aware about the different activities, *viz.*, duck-cum-fish integrated farming module, bee keeping, poultry, high density guava planting, fish farming and rice-cum-fish farming

Fig. 23.3 School students visited the demonstration unit of KVK, Buxar

modules being carried out by the KVK. They also visited the soil testing lab.

Web telecast of Prime Minister interaction programme with farmers

KVK arranged the web telecast of Prime Minister interaction programme with farmers on 20th June 2018. Total 70 farmers participated in the programme. Similarly the web telecast of Prime Minister interaction programme with farmers on 12th July 2018 was also arranged by the KVK. Total 53 farmers participated in the programme.

Training programme on contingent crop planning

One days training programme on contingent crop planning on 27 July 2018 was organized by KVK Buxar. A total of 56 farmers participated in the programme. They were made aware of the new short duration variety of rice and technology for delayed monsoon. Management techniques for

Fig. 23.4. Training programme on Contingent Crop Planning

different *Kharif* crops, vegetables and animal health management were also discussed.

Visit of Minister of State for Health and Family Welfare

Shri Ashwani Kumar Choubey Jee, MoS, Health & Family Welfare visited the KVK, Buxar on 15 July 2018 to review the ongoing activities of KVK and need of improvement for doubling the farmers' income by 2022. He interacted with the KVK staff and progressive farmers of the Buxar district.

Fig. 23.5. Sh Ashwani Kumar Choubey MoS, Health & Family Welfare interacting with scientist and farmers

Scientific Advisory Committee meeting

The 9th Scientific Advisory Committee (SAC) Meeting of KVK Buxar was held on 25th July, 2018 at KVK, Buxar under the Chairmanship of the Director, ATARI, Patna. The meeting was also attended by Dr. Ujjwal Kumar, Head DSEE, ICAR RCER, Patna. Dr. R. K. Malik Senior Agronomist CSISA-CIMMYT India, Sri Ranbeer Singh, 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 famrers/member of this meeting and Officials from State Agriculture Department/other department.

Fig. 23.6. Scientific Advisory Committee meeting

Training on weed management

Three days training programme on weed management was organized from 27 to 29 September, 2018. Total 30 nos. of farmers participated in the programme. They were made aware of different methods of weed management in various field crops, herbicide use, spraying technique, etc. Total 30 farmers participated in the programme.

Mahila kisan diwas

Mahila Kisan Diwas was organized by KVK, Buxar on 15th October 2018. District Statistics Officer Mrs Sarita Kumari was the Chief Guest of the programme. She urged farm women to come forward for their upliftment and shared new agricultural technologied for doubling the farmers' income. A total of 54 farm women participated in the programme.

Fig. 23.7. Celebration of Mahila Kisan Diwas

Kisan gosthi

One day *kisan gosthi "Jo Upjaye Ann Wo Kyo N ho Sampann"* was organized in collaboration with Danik Jagran Hindi News Paper on 4rth December, 2018. A total of 88 farmers and officers of line department participated in the programme.

World Soil Health Day-cum-*Rabi Kisan Gosthi*

KVK Buxar celebrated World Soil Health day cum Kisan Gosthi on 5th Dec, 2018 at its premises. A total of 75 farmers and State Government Officials participated in the programme, and 25 Soil health cards were distributed. Scientist of the KVKs advised to the farmers to avoid the crop residue burning and use waste decomposer for easily decomposition of crop residue.

Fig. 23.8. Celebration of World Soil Health Day

Kisan Diwas

KVK Buxar celebrated the *Kisan Diwas* on the birth anniversary of Late Shri Choudhary Charan Singh on 23rd December, 2018. Kisan Leader Shri Parsuram Chaturvedi was the Chief Guest. A total of 72 farmers participated in the programme.

Fig. 23.9. Celebration of Kisan Diwas at KVK, Buxar

Community rice nursery

Rice transplanting in Buxar is normally done in August, which is late for optimal crop production and results in low paddy yields. KVK prioritized work on the timely production of healthy rice seedlings, helping farmers and entrepreneurs supply appropriately aged rice nurseries 'just in time,' when the monsoon rain starts. Creation of awareness among the farmers KVK, Buxar grown the rice nursery in one acre land and 10 farmers of the district also started the rice nursery entrepreneurship and sold to the farmers with the price of Rs 800 for one acre area of transplanting. This helped in timely transplanting of rice nursery, higher yield of rice and timely sowing of wheat.

Fig. 23.10. Community rice nursery production field

District level Technical Training Programme

Two days training programme for extension workers of agriculture department of Buxar district was organized during 9-10 April, 2018. Agriculture Coordinators, Kisan Salahkar, Block Technology Managers and Assistant Technology Managers of

Fig. 23.11. Training programme for extension workers

Agriculture department attended the programme. They were trained about the *Kharif* season planning, selection of crops and varieties, and management practices. More focus was given on management of crop residue by using crop waste decomposer. A total of 164 participants were present in the programme.

Training on seed production techniques of improved rice varieties

One day training programme on seed production techniques of improved rice varieties was organized by KVK on 25th May, 2018 and total 25 rural youth participated in the programme. More emphasis was given on seed selection, seed treatment, seed certification and post-harvest management process.

Fig. 23.12. Training programme on seed production

Animal Health Camp

An animal health camp was organized on 25th June under NICRA project. Total 98 animals (cattle and buffalo) from 32 farmers were vaccinated for Foot & Mouth Diseases (FMD), Hemorrhagic Septicemia (HS) and Black Quarter (BQ).

Fig. 23.13. Vaccination of animals during Animal Health camp

Skill development programme

One skill development training programme of vermicompost producers covering 200 hrs was organized at KVK, Buxar from 24 January 2019 to 28 February, 2019. Total number of 20 participants were enrolled under the training programme. Training programme covered the 90 hrs under theory classes and 110 hrs under practical classes.

Fig. 23.14. Skill development training programme of vermicompost producers

Another skill development training programme of Quality Seed Growers covering 200 hrs was organized at KVK, Buxar from 16 February 2019 to 19 March, 2019. Total number of 20 participants were enrolled under the training programme. Training programme covered the 80 hrs under theory classes and 120 hrs under practical classes.

Fig. 23.15. Skill development training programme of quality seed grown

Training programme on seed production and certification

One day training programme on seed production and certification was organized with the collaboration of Bihar State Seed and Organic Certification Agency (BSSOCA) on 6 February,

Fig. 23.16. Training programme on seed production and certification

2019. Total 52 number of farmers participated in the training programme.

Training programme on integrated nutrient management

A training programme of 15 days certificate course for fertilizer input dealers was organized by KVK, Buxar during 1-18 March 2019. Total number of 39 input dealers were enrolled for training programme.

Fig. 23.17. Training programme on Integrated Nutrient Management

Station trial

Topics	Area (ha)	Places
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 (RWCS) productivity using different crop establishment methods	0.25	KVK, Buxar, Chotki Basouli, Geruabandh, Mahdah

On farm trial under KVK-CSISA project

Topics	No of beneficiaries	Places
Improving rice –wheat cropping system (RWCS) productivity using different crop establishment methods	10	Rajapur, Konawali, Basahi, Bocsa, Chotki Basouli, Mahdah, Mango dehri, Chougai, Gerua bandh
Comparative performance of rice establishment methods in different ecologies of Bihar and EUP	10	Indapur, Rajapur, Mahdah, Chotki Basouli, Gerua bandh
Effects of delayed transplanting on the growth and the yield of rice.	5	Rajapur, Gerua Bandh,Mahdah, Chotki Basouli
Impact of age of rice nursery on the growth and yield of transplanted rice	5	Konawali, Mango dehri, Geruabandha
Developing entrepreneurship on rice nursery marketing	5	Geruabandha, Diwan ka Badkagaon, Chotki Basouli
Performance of conventional till DSR with and without pre-sowing irrigation	5	Bocsa, Mahdah, Geruabandha, Diwan ka Badkagaon
Weed management in direct seeded rice dominated with *Cyperus rotundus* based mixed weed flora	7	Rajapur, Konawali, Basahi, Bocsa, Chotki Basouli, Mahdah, Mango dehri, Chougai, Gerua bandh
Performance of short duration (SDVs) and long duration variety (LDVs) under different sowing schedules across ecologies.	10	Rajapur, Konawali, Basahi, Bocsa, Chotki Basouli, Mahdah, Mango dehri, Chougai, Gerua bandh
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

Topics	No of beneficiaries	Places
Impact of herbicide application technology on the performance of herbicide in wheat.	5	Rajapur, Gerua Bandh,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
Quantifying the gains in wheat productivity through zero-tillage mediated advance sowing of wheat	10	Bocsa, Mahdah, Geruabandha, Diwan ka Badkagaon, Rajapur
Residue management in rice – wheat system.	3	Jogiya, Geruabandha, Kukurah

Performance of custom hiring centre

NICRA Project (Kukurah Village site)			
Implements use	No. of farmers benefitted	Area covered (ha)	Revenue generated (Rs.)
M B Plough, Rotavator, Happy seeder, Zero tillage, Seed drill, Power weeder, Leveller	47	23.75	9470.00
CRP on FM & PF Project			
Tractor, Multi-crop Thresher, Rotavator, Seed drill, Disc plough, Power harrow, Post hole digger, Knapsack power, sprayer, Planker, Case wheel	76	38.75	76152.00

Krishi Vigyan Kendra, Ramgarh

Training programme for practicing farmers (Off-campus)

Topics	No. of training	Total beneficiaries
Training on kitchen garden	6	530
Training on off Season vegetable cultivation	2	222
Training of IPM in cereals	6	540
Training on plantation technology of fruits crops	3	300
Training on Integrated Nutrient Management In Cereals crops	5	415
Training programme on value addition of tomato, potato and other locally available vegetables	4	385
Training programme on vermi composting	8	582
Training on paddy cultivation	3	310
Training programmes on value addition	4	315
Training programmes on cultivation of vegetables	2	108
Training on plantation Technology of fruits and vegetables crops	3	163
Training programme in Mushroom cultivation	3	148
Training programme on passion fruit cultivation and Value addition	1	62
Total	50	4080

Training programme under CRP on farm mechanization & precision farming

Topics	Date	Total beneficiaries
Tools and implements for weed management	24-26/09/2018	32
Selection operation and maintenance of harvesting and threshing equipment	19-21/11/2018	38
Operation and maintenance of tillage, sowing and harvesting equipment	20-21/02/2019	47
Operation and maintenance of tillage, sowing and harvesting equipment	25-26/02/2019	39
Total		156

Skill development training programme

Organized 200 hours skill development training sponsored by Agriculture Skill Council of India, New Delhi on the topic "Quality Seed grower" and "Nursery Worker" at KVK Ramgarh. During the skill development training 20 farmers/youth were selected for each of the training course.

Fig. 23.18. Skill development training sponsored by Agriculture Skill Council of India, New Delhi on the topic "Quality Seed grower" and "Nursery Worker" at KVK Ramgarh

On-farm trials conducted at farmers fields for assessment of suitable technologies for Ramgarh district

Thematic areas	Title	Treatment	No. of farmers
Integrated Nutrient management	Assessment of Integrated Nutrient management in Cabbage	**T O1**:Farmers practices- FYM@2t/ha + $N_{80}P_{40}K_{0}$) **T O 2**: $N_{100}P_{40}K_{20}$)+ vermi-compost (1 t/ha). **T O3**: RDF($N_{120}P_{60}K_{60}$) + FYM @20 t/ha	10
Plant Protection	Assessment of bio-intensive package for insect pest complex in tomato.	**T O 1: Farmers practices**: (First spray Spray of Rogor @2 ml/l at 45 DAT, Spray of Imidacloprid @1ml/l spray at 7 days interval of 60 DAT) **T O 2- Bio-intensive module** • Neem cake application@250kg/ha at the time of sowing • Sowing of marigold as trap crop @one after 10 row of tomato • Raising seed lings under net house • Eraction of pheromone traps@10/ha for mass trapping • Erection of yellow sticky traps@10/ha traps for sucking pests • First spray of *Verticillium lecanii*@4 g/lit+ cow milk@5 ml/lit(spray at evening hours) at 30 DAT • Second spray of Neemastra @10 ml/ltr at 40 DAT • Third spray of *Bt* formulation@2gm/lit at 50 and 70 DAT • Fourth spray of *B. bassiana*@4gm/ltr at 60 DAT **T O 3-IPM Module** • Seed treatment with Thiomethoxam 70WS@4g/kg • Seedling root dip in Imidacloprid @2ml/ltr for three hours before transplanting • Sowing of marigold as trap crop @one after 10 row of tomato	10
		• Eraction of pheromone trap @10 traps/ha for mass trapping of FB • Eraction of Yellow sticky trap @10 traps/ha for sucking pests • First foliar spray of NSKE4% at 30DAT • Second foliar spray of Imidacloprid 200SL@0.5ml/ltr at 40 DAT • Third foliar spray of Spinosad 45 SC@0.3ml/ltr at 50 DAT • Fourth foliar spray *Bt* formulation @ 2gm/ltr at 60 DAT • Fifth foliar spray of Azadiractin (10000ppm)@5ml/ltr at 70 DAT	

Horticulture (Rainfed vegetable farming)	Assessment of performance and evaluation of bacterial wilt resistant varieties of brinjal	• TO_1: Farmers practices • TO_2: Swarna Shyamali • TO_3: Swarna Pratibha • TO_4: Swarna Shakti	10
Integrated nutrient management	To assess integrated nutrient management of sweet potato (var. Shree bhadra) for higher yield under Rainfed farming condition	• Farmer's practice: Farmers/local variety with traditional management practices (NPK-20:30:0) • TO_1: Shree Bhadra + RDF (NPK): 60:60:60 • TO_2: Shree Bhadra + STCR (NPK) • TO_3: Shree Bhadra + STCR (NPK) + B (1%)	10

Front line demonstration

Crop and demonstration technology	Variety	Area (acre)
FLD on pheromone trap for Cucurbits fruit fly	Cu Lure	5.0
Demonstration of oyster mushroom	Oyster sp	20 Unit
Sponge gourd	Swarna Sneha	1.0
Tomato	Swarna Sampada	1.0
Brinjal	Swarna Shyamli	1.0
Cowpea	Swarna Mukut	1.0

Exposure visit of farmers

Visiting place	Date	No. of Farmers
Birsa Agriculture University, Ranchi	21/02/2019	40
Birsa Agriculture University, Ranchi	26/09/2018	30
Birsa Agriculture University, Ranchi	26/02/2019	40
ICARRCER, RC, Plandu Ranchi	26/02/2019	20
ICARRCER, RC, Plandu Ranchi	12/03/2019	20
	Total	150

Celebration of important days

Nature of extension activity	No. of activities	No. of participants
Environment Day (05/06/2018)	1	33
Live telecast honourable PM with farmers at KVK, on 20/06/2018	1	170
International Yoga Day (21/6/18)	1	38
Live telecast of the interaction of Honourable PM with members of SHG and women farmers (12/07/18)	1	93
Parthenium eradication week (16/08/2018 to 22/08/2018)	4	86
Swachta He Sewa Hai (15/09/2018 to 20/10/2018)	6	185
Mahila Kisan Diwas (15/10/2018)	1	270
National Integration Day (21/10/2018)	1	12
Vigilance Awareness week 29/10/2018)	1	9
Swachhata Pakhwara (16/12/2018 to 31/12/2018)	1	172

Details of extension activities

Nature of extension activity	No. of activities	Farmers	Extension officials	Total		
		Total	Total	Male	Female	Total
Field day	4	451	26	125	326	477
Kisan mela cum exhibition	3	1580	125	677	903	1705
Kisan ghosthi	6	223	13	193	43	236
Lectures delivered as resource persons	25	1250	153	795	608	1403
Advisory Services	2150	3000	65	2550	450	3065
Scientific visit to farmers field	189	906	-	497	407	906
Farmers visit to KVK	613	1688	121	1167	642	1809
Diagnostic visits	65	497	-	360	197	557
Exposure visits	6	200	-	125	75	50
Soil health camp	25					2265
Animal health camp (Vaccination)	6	515	5	195	320	520

Nature of extension activity	No. of activities	No. of partici-pants
Celebration of (Jai Kisan Jai Vigyan Di-vas) 23/12/2018 &24/12/2018	2	242
Rabi workshop cum Kisan Mela organised at KVK 24/01/2019	1	300
Live telecast of Honorable PM, on dated 24/02/2019 on the occasion of inauguration of PM Kisan Samman Nidhi scheme	1	350
Total	23	1783

Participation in different programs

Date	Name of program	Activity
09/01/2019	District level Rabi workshop at Ramgarh organised by District Agriculture Office	Delivered a lec-ture and interac-tion with farmers
09/01/2019	Sakhi Samwad organ-ised by Sakhi Mandal, Ramgarh	Delivered a lecture
27/01/2019	Inauguration of IARI, Hazaribag Jharkhand.	Participate with 500 farmers
15/02/2019	Farmers Fair and Ex-hibition organised by ATMA, Ramgarh	Judging the various stall and agriculture produces, deliver the lecture
19/02/2019	Mahila Kissan sam-melan organised by Kalyani Mahila Sangh, Gola	Delivered a lecture and interaction with woman SHG's farmers
12/01/2019	9th Annual Flower and Vegetable show organised by Tata Steel West Bokaro Division, Ghato Ramgarh	Judging the various stall and agriculture produces, deliver the lecture

Inauguration of farmers' hostel at ICAR-RCER, KVK, Ramgarh

Dr. Trilochan Mohapatra, Secretary (DARE) and DG (ICAR) inaugurated farmers' hostel on 25th August 2018 at ICAR-RCER, KVK, Ramgarh. On the occasion, a Farmers gosthi was also organized. In this programme, Dr. D. K. Yadav, Head, division of seed science and technology, IARI, New Delhi, Dr.P. Kausal, Vice Chancellor, BAU, Ranchi, Dr. K. K. Sharma, Director, IINRG, Ranchi, Dr. T.R. Sharma, Director, Indian Institute of Agricultural Biotechnology and Mr. Amrendra Kumar Gupta,

Fig. 23.19. Inauguration of farmers' hostel at ICAR-RCER, KVK, Ramgarh

member of regional advisory committee, NABARD, Jharkhand, were present. Dr. B. P. Bhatt, Director, ICAR-RCER, Patna welcomed the Chief Guest, other dignitaries and farmers. The Chief Guest said that Jharkhand is rich in natural sources, still depends on other states for its requirements. He emphasized that rural youth should establish entrepreneurship in agriculture. There is a need to work with all line departments in convergence mode for effective implementation of schemes. He felicitated ten farmers of the district for their excellent work in agriculture.

Rastriya Mahila Kisan Diwas

KVK, Mandu, Ramgarh (Jharkhand) celebrated *Rastriya Mahila Kisan Diwas* on 15th November 2018 at Nawadih Panchayat Bhawan of Mandu block of the district. Dr. Dushyant Kumar Raghav incharge, KVK, Ramgarh welcomed the guests and farm-ers and told about different roles and activities of agriculture and allied sectors like mushroom cultivation, livestock production, fisheries, dairy, poultry, goatry, duckery etc. to doubling the

Fig. 23.20 *Rastriya Mahila Kisan Diwas* organised at Nawa-dih Panchayat bhawan of Mandu Block

farmer's income by 2022. Dr. Dharamjit Kherwar, SMS (Horticulture) spoke about role of women in agriculture i.e. nursery raising, nutritional garden, farming of value added crops, timber, bamboo, drumstick etc. for their better livelihood through forming of SHG or in a cluster approach. Smt. Bhagwati Devi Nawadeeh Mukhiya, told about women power in every sector especially on agriculture, livestock's production, fisheries and dairy through adoption of new technology by training of women farmers. Certificates were distributed among women farmers for their excellent performance/work. About 270 women farmers were participated in the programme.

Krishi Kalyan Abhiyan from 1st June - 15 August 2018

- Conducted 75 training to 3750 farmers
- Constructed 300 NADEP pit which used for 3000 tones crop residue waste for composting
- Distribute 12500 seedlings of mango, guava and lemon for 2500 farmers
- Monitoring and reporting of KKA activities as nodal agency and achieved the target and secured
- 5th rank in Jharkhand and 20th rank in the country

Fig. 23.21. Different activities of Krishi Kalyan Abhiyan programme

Swachhata Hi Sewa activities

KVK Ramgarh organized various activities from 15/09/18 to 2/10/2018. These include: toilet pit-digging exercise and other toilet construction activities, cleaning of streets, drains and back alleys through awareness drives, waste collection drives in households and common or shared spaces, door-to-door meetings to drive behaviour change with respect to sanitation, awareness campaigns around better sanitation practices like using a

Fig. 23.22. *Swachhata* related activities

toilet, hand washing, health and hygiene awareness etc. swachchhata related *Nukkad -Nataks*/street plays, folk song and dance performances, village or school-level rallies to generate awareness about sanitation, make wall paintings in public places on the theme of *swachhata*, volunteer for segregation of solid waste into non-biodegradable and biodegradable waste, mobilize community to build compost pits, where organic matter decomposes to form manure.

Interaction of Hon'ble PM with members of SHG and women farmers

Live telecast of Hon'ble Prime Minister's address to members of SHG and women farmers was displayed on 12thJuly 2018 at Gargali village, Mandu block, Ramgarh and which was watched by more than 100 SHG members and women farmers. An awareness video show was also displayed in respect to pulses and oilseeds cultivation, soil health and importance of swachhata in the society. The farmers were also addressed by Dr. Indra Jeet (SMS, Agricultural Extension) and Dr. Dharamjit Kherwar (SMS, Horticulture) with farmers regarding agricultural techniques and livestock management during technical session.

Fig. 23.23. Live telecast of the interaction of Hon'ble PM with members of SHG and women farmers

World Soil day celebration and soil health card distribution

World Soil Day was organized on 5th December 2018 jointly with district administration at collectorate office auditorium. A short film was displayed and soil health card and pamphlet was distributed during the celebration of programme. Soil health card were also distributed on the occasion. During the program DDC, DAO, Project Director, ATMA and Soil Conservation officer, District Dairy development Officer and District Animal Husbandry Officer were also present. In this program more than 100 farmers and farm women of different places of Ramgarh participated.

Fig. 23.24. World Soil day celebration and Soil health card distribution

Farmers- scientist interaction and animal health camp

Four animal health camps were organized by KVK, Ramgarh at Arakata village, Mandu, Ramgarh on 10th October 2018 on animal health issues. During the programme 100 animals (cattle and buffalo) were treated and vaccinated (FMD) at Arakata by Veterinary officer, Mandu block, Ramgarh and detail information about animal health was also given. Farmers were interacted on animal health issues. Medicines for animals were also distributed during the entire above programme.

Fig. 23.25. Farmers- Scientist Interaction and Animal health camp

Cluster front line demonstrations on oilseed and pulses under NFSM (NMOOAP) during 2018-19

Crop	Area (in ha)	Variety	No. of demonstration	No. of villages	Technology intervention
Kharif					
Pigeonpea	40.00	NDA-2	100	8	Seed treatment with *Trichoderma viridi* + line sowing + need based insecticide spray
Horsegram	40.00	Birsa kulthi-1	100	6	Seed treatment with *Trichoderma viridi* + line sowing + need based insecticide spray
Rabi					
Lentil	10.00	HUL-57	100	6	Seed treatment with *Trichoderma viridi* + use of dolomite + line sowing + need based insecticide spray
Chickpea	10.00	Pusa-547	100	7	Seed treatment with *Trichoderma viridi* + use of dolomite+ line sowing +need based insecticide spray
Mustard	20.00	Pusa-30	100	6	Seed treatment with Carbendazim (50%wp) + use of sulphur+ need based insecticide spray

24. Awards and Recognitions

Awards and Recognitions

A. Dey received **Distinguished Scientist Award** by Science & Technology Society for Integrated Rural Improvement, Thorrur, Mahabubabad, Telangana on the occasion 2nd National Conference on doubling Farmers Income for Sustainable and Harmonious Agriculture, DISHA-2018, 11th-12th August, 2018, Ranchi, Jharkhand.

A. Upadhyaya was conferred '**ISAE Fellow Award – 2018' for** his valuable contributions to the field of Agricultural Engineering by Indian Society of Agricultural Engineers (ISAE), New Delhi at BHU on 28th January, 2019 at BHU, Varanasi.

A.K. Singh has been awarded with '**Fellow of National Academy of Agricultural Sciences 2019'**, conferred by National Academy of Agricultural Sciences, New Delhi

A.K. Choudhary has been awarded '**Gold Medal'** by the Society for Upliftment of Rural Economy (SURE), Varanasi, Uttar Pradesh, India during International Conference on Rural Livelihood Improvement for Enhancing Farmers' Income through Sustainable Innovative Agri and Allied Enterprises (RLISAAe), October 30th -November 01st, 2018 at BIT, Patna (Bihar).

A.K. Choudhary received the '**Best Researcher Award**' from EET CRS, Research Wing for Excellence in Professional Education & Industry, Noida (Delhi NCR) on January 27, 2019.

A.K. Singh received '**Distinguished Scientist Award'** in the field of Agricultural Research conferred by Science and Technology Society for Integrated Rural Improvement, Thorrur, Telangana on the occasion of National Conference on Doubling Farmers Income for Sustainable and Harmonius Agriculture (DISHA-2018) held at Ranchi during 11th-12th August, 2018.

Anil Kumar Singh has been awarded '**Raj Bhasha Gaurav Award -2107'** by Raj Bhasha Division, Ministry of Home Affaire, Govt. of India at Vigyan Bhawan, New Delhi 0n 14 September, 2018.

B.P. Bhatt received **'Edunuri Agaiah Memorial Award'** for outstanding contribution in the field of Agricultural Research, conferred by Science & Tech Scociety for Integrated rural Improvement (S&T SIRI), Thorrur, Mahabubabad, Telangana in the 2nd National Conference on Doubling Farmers Income for Sustainable & Harmonious Agriculture (DISHA)- 2018 held at IINRG, Ranchi during 11th – 12th August, 2018.

Jaipal Singh Choudhary received '**Young Scientist Award'** for outstanding contribution in the field of Agricultural Research conferred by "Science & Tech Society for Integrated Rural Improvement" Telangana on the occasion of 2nd National Conference on Doubling Farmers Income for Sustainable and Harmonious Agriculture (DISHA-2018), held at Ranchi during 11-12 August, 2018.

J.S. Mishra received '**ISA Gold Medal-2016**' of Indian Society of Agronomy in XXI Biennial National Symposium of Indian Society of Agronomy on 'Doubling Farmers' Income through agronomic interventions under changing scenario, 24th-26th October, 2018, MPUA&T, Udaipur.

Kirti Saurabh received '**Young Scientist Award-**2018' in 2nd International conference on "Advances in Agricultural, Biological and Applied Sciences for Sustainable Future (ABAS-2018) organized by Swami Vivekanand Subharti University, meerut (U.P.), India on 20-22 October, 2018.

Md. Monobrullah has been awarded '**Distinguished Scientist Award'** for outstanding contribution in the field of Entomology by Science & Tec Society for Integrated Rural Improvement (S&T SIRI), Thorrur,

Telangana for the year 2018 during 2nd National Conference on Doubling Farmers Income for Sustainable and harmonious Agriculture (DISHA- 2018) held during 11-12 August, 2018 at ICAR-Indian Institute of Natural Resins and Gums, Ranchi.

Nongmaithem Raju Singh has been awarded **ASPEE Foundation Gold Plated Silver Medal** in the Fourteenth Annual Convocation of Navsari Agricultural University, Navsari held on January 10th, 2019 for securing the highest Overall Grade point Average and rating of the thesis in the Degree of Ph.D. (Forestry).

Pankaj Kumar received **Best Scientist Award** from EET CRS, Research Wing for Excellence in Professional Education & Industry, Noida (Delhi NCR) on January 27th, 2019.

R.C. Bharati received '**Gold Medal Award- 2017'** by Society for Upliftment of Rural Economy, Varanasi in 1st International Conference on Rural Livelihood Improvement for Enhancing Farmers' Income through Sustainable Innovative Agril. And Allied Enterprises held at Patna during 30th Oct-1 Nov 2018.

Sanjeev Kumar received the '**Best Centre Award'** for AICRP on IFS at ICAR-RCER, Patna during V Biennial Workshop on AICRP-IFS at UAS, Bengaluru September 20th-23th December, 2018.

Santosh Kumar has been awarded with '**Scientist of the Year Award'** by S&T SIRI (Science & Tech Society for Integrated Rural Improvement), Mahabubabad (Telangana) on the occasion of "2nd National Conference on doubling farmer's income for Sustainable & harmonious agriculture (DISHA-2018)" during 11th-12th August, 2018 at ICAR-IINRG, Ranchi, Jharkhand.

S.K. Naik received '**Outstanding Achievement Award'** in the field of Agricultural Research, conferred by Science and Technology Society for Integrated Rural Improvement, Thorrur, Telangana on the occasion of National Conference on Doubling Farmers Income for Sustainable and Harmonius Agriculture (DISHA-2018) held at Ranchi during 11th-12th August, 2018.

Best Paper/Poster/Honours Received

Jaipal Singh Choudhary received **Best Oral Presentation** for outstanding presentation of research work entitled "Assessing impact of climate change on future distribution and abundance of peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) in mango growing regions of India using phenology models and Spatial Mapping" on the occasion of 2nd National Conference on Doubling Farmers Income for Sustainable and Harmonious Agriculture (DISHA-2018), held at Ranchi during 11th-12th August, 2018.

Manibhushan received B**est Research Paper Presentation Award** by the Society of Tropical Agriculture, International Journal of Tropical Agriculture (IJTA) in 8th "International Conference on Agriculture, Horticulture and Food Science (ICAHFS)" from 29th-30th December, 2018 at Hotel Hans, New Delhi.

Md. Monobrullah received '**Best Paper Presentation Award'** for "Integration of Agroforestry species for multiple production system to reduce poverty by improving productivity, profitability and sustainability" during 2nd National Conference on Doubling Farmers Income for Sustainable and harmonious Agriculture (DISHA-2018) held during 11th-12th August 2018 at ICAR-IINRG, Ranchi.

P.K. Sarkar received **Article of the Year Award** for article entitled "CO_2FIX model: A tool for estimating carbon sequestration potential of any agroforestry systems" volume 1 issue 3 in Agriculture & Food: e-Newsletter (ISSN: 2581-8317).

Pankaj Kumar received **Best Paper Presentation Award** (Second) by Indian Society for Sheep and Goat Production and Utilization Session in National Seminar on Current Scenario and future strategies for augmenting productivity of small ruminants organized during 14th-16th February, 2019.

S.S. Mali has been awarded the **Best Oral Paper Presentation Award** in national conference on 'Doubling farmers income for sustainable & harmonious agriculture – DISHA-2018', held at ICAR-IINRG, Ranchi during 11th-12th August 2018.

S.S. Mali received **Journal of Agricultural Engineering Best Reviewer Award (Soil and Water Engineering)** conferred by Indian Society of Agricultural Engineers (ISAE) during 53rd ISAE Annual Convention held during 28th-30th January, 2019 at BHU, Varanasi.

Sudarshan Maurya received **Popular Extension Worker Award** for outstanding contribution in the field of 'Plant Pathology' conferred by Science and Technology Society for Integrated Rural Improvement, Thorrur, Telangana on the occasion National Conference on Doubling Farmers Income for Sustainable and Harmonius Agriculture (DISHA-2018) held at Ranchi during 11th-12th August, 2018.

Fig. 24.1. Dr. Arun Kumar Singh receiving NAAS Fellow Award

Fig. 24.2. Dr. J.S. Mishra receiving ISA Gold Medal

Fig. 24.3. Dr. Anil Kumar Singh receiving *Rajbhasha Gaurav* Award

Fig. 24.2. Dr. A. Upadhyay receiving ISAE Fellow Award

25. Seminars and Symposia

Participation in Conferences/Seminars/ Workshops/ Symposia/ Meetings

Bhatt BP, Mishra JS, Kumar Abhay, Monobrullah, Md, Singh AK, Pan RS, Jha BK, Kumar Rakesh, Sarkar B, Kumar Sanjeev, Priya Ranjan, Yadav VK, Das B, Naik SK, Maurya S, Kumar Santosh, Mali SS, Bhavana, P, Choudhary JS, Dhakar MK, Sarkar PK, Shinde R, Seth T and Tamta M. 2nd National Conference on Doubling Farmers Income for Sustainable and Harmonious Agriculture "DISHA-2018" held at ICAR-Indian Institute of Natural Resins and Gums, Ranchi, Jharkhand during 11th-12th August, 2018.

Bhatt BP and Sarkar B. National Seminar on "Challenges and Opportunities for Farmers' Prosperity in Hill Agriculture", held at ICAR Research Complex for NEH Region, Umiam, Meghalaya during 29th-30th November, 2018.

Bhavana P. National Agricultural Business Entrepreneurship Conclave NABEC 2019, held at ICAR RC NEH, Umiam from 9th – 11th February, 2019

Choudhary AK. Harvest Plus Stakeholder Meeting held on March 2nd, 2019 at The Lemon Tree Hotel, Patna for promotion of biofortified wheat (zinc), rice (zinc) and lentil (iron).

Choudhary AK. International Conference on Rural Livelihood Improvement for Enhancing Farmers' Income through Sustainable Innovative Agri and Allied Enterprises (RLISAAe) organized during October 30th-November 01st, 2018 at BIT, Patna (Bihar), India.

Das B and Choudhary JS. Annual Review Meeting of NICRA, held at NASC Complex, New Delhi during 7th – 8th August, 2018

Das B and Dhakar MK. 6th Group Discussion on ICAR AICRP on Fruits held at AAU, Jorhat during 14th – 16th February, 2019

Debnath Mridusmita. International Conference on "Hydro-2018 International" held at NIT Patna from 19th-21th December, 2018.

Jha BK. Workshop-cum-Meeting on Weed Management in Conservation Agriculture held at ICAR-Directorate of Weed Research, Jabalpur (Madhya Pradesh) during 11th – 12th September, 2018

Jha BK. Workshop on Conservation Agriculture in India: Key Learning's, Research Gaps and Way Forward for Impact at Scale under the Consortia Research Project on Conservation Agriculture, jointly organized by ICAR and CIMMYT at NASC Complex, Pusa, New Delhi during 9th-10th July, 2018.

Kumar Abhay. National Seminar on "Current Scenario and Future Strategies for Augmenting Productivity of Small Ruminants" organized by ISSGPU at BASU, Patna from 14th-16th February, 2019.

Kumar Ajay. Annual Review Meeting of the ACIAR Project "Improving water use for dry season agriculture by marginal and tenant farmers in the eastern Gangatic Plains" held at ICAR-NIRJAFT, Kolkata during 1st - 5th October, 2018.

Kumar Ajay. Review Meeting of TATA Trusts funded Project "Systematic Approach to Research and Adoption of SRI" at Bhubaneshwar during 23th-24th December, 2018.

Kumar Ajay. Review Meeting of the Agri-CRP on Water Project "Evaluation of irrigation system and improvement strategies for higher water productivity in Sone canal command" held at ICAR-IIWM, Bhubaneswar on 7th December, 2018.

Kumar Sanjeev. Fourth QRT meeting held at ICAR Research Complex for NEH Region, Barapani (Meghalaya) during 12th-13th December, 2018.

Kumar Sanjeev. National Agronomy Congress on "Redesigning Agronomy for nature conservation and economic empowerment at GBPUA&T., Pantnagar during 20-22 February, 2018.

Kumar Sanjeev. V Biennial Workshop on AICRP-IFS at UAS, Bengaluru on 20th September-23rd December, 2018.

Kumar Sanjeev. Workshop on Restructuring Course Syllabus on physical sciences (soil Science, Agronomy, Agril. Meteorology) at BAU, Sabour 11th-12th September, 2018.

Kumar Santosh. 53rd Annual Rice Research Group meeting, held at Assam ICAR-IIRR, Hyderabad during 13th-16th April, 2018.

Kumar Santosh. Annual Review and planning workshop, Stress-Tolerant Rice for Africa and South Asia (STRASA Phase 3) held at New Delhi during 30th April- 3rd May, 2018.

Kumar Ujjwal. Consultative workshop on agriculture, food security and nutrition in Bihar at Hotel Maurya, South Gandhi Maidan, Patna organised by Indira Gandhi Institute of Development Research, & Institute for Human Development, New Delhi on 29th October, 2018.

Kumar Ujjwal. RKVY-RAFTAR- Agribusiness Incubators meeting in Ministry of Agriculture & Farmers Welfare, Krishi Bhawan, New Delhi on 22th November, 2018.

Mali SS. National Workshop on 'Application of Spatial Data Infrastructure for Irrigation Management' organised at Water Technology Centre, IARI, New Delhi during 25th – 27th July, 2018.

Manibhushan. 2018. National Consultation on ICT in Agriculture held on 6 March, 2019 at NASC Complex, New Delhi.

Maurya S. XXth Annual AICRP on Mushroom Workshop held at Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan during 4th – 5th May, 2018.

Mishra JS and Singh SK. ISWS Golden Jubilee Conference on 'Weed and Society: Challenges and Opportunities' 21st-24th November, 2018, Indian Society of Weed Science, Jabalpur.

Mishra JS and Kumar Santosh. "Review Meeting for Foreign Aided Projects under NRM Division, ICAR, held at Pusa, New Delhi on 4th July, 2018.

Mishra JS, Kumar Ujjwal, Kumar Santosh, Dwivedi SK and Rao KK. "Review Meeting for Foreign Aided Projects under NRM Division, ICAR, held at NASC, Pusa, New Delhi on 24th January, 2019.

Mishra JS, Singh SK and Kumar Sanjeev. XXI Biennial National Symposium of Indian Society of Agronomy on 'Doubling Farmers' Income through agronomic interventions under changing scenario, 24th-26th October, 2018, MPUA&T, Udaipur.

Mishra JS. Departmental Research Review Meeting at BAU Sabour on 16th February, 2019.

Mishra JS. Harvest Plus Stakeholder Advisory Committee meeting on 1st March 2019 in Patna.

Mishra JS. Panel discussion on 'Doubling the income of farmers in agriculture and allied sector through sustainable skill and entrepreneurship intervention' organized by India Skills-Bihar 2018 on 21st April, 2018 at BV College, Patna.

Mishra JS. Review and planning workshop of EC-IFAD funded project on "Improved Crop Management and strengthened Seed supply System for Drought prone rainfed lowlands in South Asia at NASC, Pusa New Delhi on 4th May, 2018.

Mishra JS. Review meeting of AICRP-Weed Management during 7th-8th June, 2018 at GBPUA&T, Pantnagar.

Mishra JS. Round Table Conference on 'Unleashing Bihar's Agriculture Potential: Sources and Drivers of Agriculture Growth' organized by Indian Council for Research on International Economic Relations on 27th April, 2018 at Hotel Maurya, Patna.

Mishra JS. Workshop on 'Strategizing pulse production in rice -fallows in Eastern India' in Raipur on 8th September, 2018.

Naik SK, Seth T, Mali, SS, Choudhary JS and Pan RS. Workshop on Competency framework for Agricultural Research and Extension Scientists organized by NAARM, Hyderabad held on 6th March, 2019 at IINRG, Ranchi.

Pan RS, Jha BK and Das B. 8th Indian Horticulture Congress-2019 on Shaping Future of Indian Horticulture held at IGKVV, Raipur, Chhattisgarh during 17th-21st January, 2019.

Pan RS. 36th AICRP (VC) Group Meeting organized by RARI, Durgapura, Jaipur, Rajasthan during 18th–21st May, 2018.

Sarkar PK. National conference on recent advances in creation, conservation, management and utilization of tree resources for sustainable future, organized at College of Forestry, Ponnampet, Coorg, Karnataka during 21st-22nd March, 2018.

Seth T. National Conference on Harmony with Nature in Context of Biodiversity Conservation & Ecosystem Management "HARMONY-2018" organized at St. Xavier's College, Ranchi during 28th – 30th October, 2018.

Shivani. National workshop on *ICAR me Rajbhasha Prabandhan ki Nai Dishayen* held at ICAR-CRIDA during 24th -25th April, 2018.

Singh AK, Kumar PR and Mali SS. National Conference on Intensification and diversification of agriculture for livelihood and rural development, organized at Dr. RPCAU, Pusa, Samastipur during 28th – 31st May, 2018.

Singh AK. Annual Meeting Varietal Identification Committee of AICRP Soybean held at Birsa Agricultural University, Ranchi on 16th March, 2019.

Singh AK. National Conference on Rural Entrepreneurship for inclusive economic development- opportunities and challenges, held at ICFAI University, Ranchi, 26th March, 2019.

Singh DK. ISEE National Seminar on "Integrated farming system for enhancing farmer's income and Nutritional Security" at WBUAFS, Kolkata during 5th-7th December, 2018.

Singh IS. National Conference on "Arid Horticulture for Enhancing Productivity and Economic Empowerment" held at ICAR-Central Institute for Arid Horticulture, Bikaner (Rajasthan) from 27th-29th October, 2018.

Sundaram PK. Annual Review Workshop of CRP on Farm Machinery and Precision Farming held at NASC Complex, New Delhi from 11th-12th February, 2019.

Tamta M. Training workshop on "Advances in Simulation Modelling and Climate Change Research Towards Knowledge Based Agriculture" organized by ICAR-IARI at New Delhi under ICAR-HRM Training Programme for Scientific Staff (2018-19) during 13th November- 3rd December, 2018.

Upadhyaya Ashutosh, Sundaram PK and Jeet Pawan. 53rd Annual Convention of Indian Society of Agricultural Engineers (ISAE) and International Symposium on Engineering Technologies for Precision and Climate Smart Agriculture held at Banaras Hindu University, Varanasi during 28th-30th January, 2019.

Upadhyaya Ashutosh. Global Water Security Conference for Agriculture and Natural Resources organized by American Society of Agricultural and Biological Engineering and Indian Society of Agricultural Engineers at Hotel Taj Krishna, Hyderabad during 3rd-6th October, 2018.

Upadhyaya Ashutosh. National Seminar on Waste Management for Sustainable Development organized by Sustainable Development Forum, The Institution of Engineers (India) at The Institution of Engineers (India) Bihar State Centre, Patna on 3rd June, 2018.

Upadhyaya Ashutosh. State level Workshop on Climate Change Adaptation Planning Tool, organized by Bihar Rural Livelihoods Promotion Society (JEEVIKA) at Hotel Patliputra Ashoka, Patna on 30th May, 2018.

Yadav VK. International Seminar on "Global partnership in agricultural education and research" at BHU, Varanasi from 22nd – 24th December, 2018.

Research Paper Presented in Conferences/Seminars/Symposia

Aishwath OP, Dubey PN, Yadav, RK and Meena RL, Jha BK and Lal G. 2019. Performance of Nigella (*Nigella sativa*) with Sodic irrigation water in Typichaplustepts. Paper presented in 28th National Conference on Farmers Friendly Soil and Water conservation Technologies for Mitigating Climate Change Impact organized by ICAR-Indian Institute of Soil and Water Conservation, Regional Centre, Udhagamandalam (TN) during 31st January- 2nd February, 2019.

Aishwath OP, Jha BK, Dubey PN, Yadav RK and Meena RL. 2018. Liming influence on Dill (*Anethum graveolens*) under acid soils of Eastern plateau hill regions of Ranchi. Paper presented in 27th National Conference on Sustainable management of soil and water resources for doubling farmers income, held at Assam Agricultural University, Jorhat during 25th – 27th October, 2018.

Bhavana P, Singh AK and Maurya S. Breeding for bacterial wilt resistance in brinjal. Paper presented in 2nd National Conference on Doubling Farmers Income for Sustainable and Harmonious Agriculture (DISHA-2018), held at ICAR-IINRG, Ranchi during 11th -12th August, 2018.

Choudhary AK, Bhavana P, Dwivedi SK and Dubey AK. 2018. Yield gains through breeding improved varieties in warm season pulses: Present status and way forward. International Conference on Rural Livelihood Improvement for Enhancing Farmers' Income through Sustainable Innovative Agri and Allied Enterprises (RLISAAe), 30th October-1st November, 2018 at BIT, Patna (Bihar), India. Proceedings of the Conference, SURE, Varanasi, Uttar Pradesh, India, pp: 1-5.

Choudhary AK. 2019. Improving the content and bioavailability of Fe and Zn in pulses for alleviating micronutrient malnutrition. In. National Seminar on 'Recent Advances in Agriculture for Sustainable Rural Development' *(RAASRD-2019)*, 15th-17th March, 2019 at Veer Kunwar Singh College of Agriculture, Dumraon, Buxar, and published in the *Abstract Book cum Souvenir* of the National Seminar, pp: 76-79.

Choudhary JS, Mali SS, Das B, Singh AK and Bhatt BP. 2018. Assessing impact of climate change on future distribution and abundance of peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) in mango growing regions of India using phenology models and Spatial Mapping. Paper presented in 2nd National Conference on Doubling Farmers Income for Sustainable and Harmonious Agriculture (DISHA-2018), held at ICAR-IINRG, Ranchi during 11th -12th August, 2018.

Das B, Kumar S, Dhakar MK, Choudhary JS, Naik SK, Maurya S, Mali SS, Singh AK, Ranjan R, Kumar A, Bhatt BP. 2019. A success story of hand holding between research institution and developmental organization for transfer of horticultural technologies. Paper presented in 8th Indian Horticulture Congress-2019 organized at IGKVV, Raipur, Chhattisgarh during 17th – 21st January, 2019.

Dwivedi SK. 2018. Exploration of mechanism behind heat tolerance in wheat: photosynthesis, anti-oxidants activity, assimilates mobilization, pollen viability and grain yield. International Conference on Novel applications of biotechnology in agricultural sectors: towards achieving sustainable development goal-2018 (INABASDG-2018), at BHU, Varanasi during 20-21 March, 2018.

Dwivedi SK. 2018. ROS- scavenging mechanism with effective reserve mobilization during grain filling in wheat contributes to heat stress tolerance and sustain optimum yield. 4th International Plant Physiology Congress 2018, at NBRI, Lucknow during 2-5 December 2018.

Gupta JJ and Dey A. 2018. Fodder Cultivation on Field Bunds for Increasing Household Forage Availability: A Case Study. Paper presented in ANACON: 2018 held at BASU, Patna from 19th-21st November, 2018.

Harshini SP, Kumar Pankaj and Kumar Manish. 2018. Clonning and Expression of sporozoite and macroschizont (spm2) protein from genomic DNA of Theileria annulata isolated from the cattle blood sample. In compendium of XXV Annual convention of ISVIB and National Conference VIBCON-2018 on Innovative Biotechnological Approaches for improving animal health and productivity held at ICAR-NRC on Mithun during 13th-15th December, 2018.

Jha BK, Mali SS and Naik SK. 2018. Efficacy of growth stage based fertigation and crop geometry in Sweet corn. Paper presented in National Conference on Doubling of farmers Income for sustainable and Harmonious Agriculture (DISHA-2018) held at ICAR - IINRG, during 11th -12th August, 2018.

Jha BK, Mali SS. and Naik SK. 2019. Efficacy of irrigation methods and bicolour polyethylene mulch on growth, yield and water productivity of cabbage-okra-tomato in Eastern Plateau Hill Region of India. Paper presented in 8th Indian Horticulture Congress-2019 held at IGKVV, Raipur during 17th - 21st January, 2019.

Jha BK, Mali SS, Naik SK, Singh AK and Kumar, A. 2019. Technology of growth stage based fertigation and crop geometry in vegetables for enhancing water productivity and doubling of income. Paper presented in 8th Indian Horticulture Congress-2019 held at IGKVV, Raipur during 17th - 21st January, 2019.

Kumar Abhay, Sinha MK, Singh RKP, Kumari RR and Kumar Pankaj. 2019. Implications of *Pest des petits ruminants* on small goat farms in Gangetic plains. Paper presented in National Seminar on Current Scenario and Future Strategies for Augmenting Productivity of Small Ruminants. Organized by ISSGPU at BASU, Patna from 14th-16th February, 2019.

Kumar P, Dey A, Kumar A, Ray PK, Kumari RR, Shekhar P and Roy RK. 2019. PPR Outbreaks and its Management in Black Bengal goats and PPR associated Reproductive Disorders in Bihar. Paper presented in National Seminar on "Current Scenario and Future Strategies for Augmenting Productivity of Small Ruminants" organized by ISSGPU at BASU, Patna from 14th-16th February, 2019.

Kumar Pankaj, Dey A, Kumar A, Ray PK, Kumari RR, Shekhar P, Roy RK. 2018. PPR outbreaks and its management in Black Bengal goats and PPR associated reproductive disorders in Bihar. In Compendium of National Seminar on Current Scenario and future strategies for augmenting productivity of small ruminants, Organized by Indian Society for Sheep and Goat Production and Utilization at BASU, Patna during 14th-16th February, 2019, pp. 179-180.

Kumar Pankaj, Ray PK, Kumar Prabhas, Kumari RR, Kirtishree and Kumar M. 2018. Molecular detection of bovine Anaplasmosis and its characterization using msp5 gene from peri-urban regions of Patna, Bihar. In compendium of 17th Convocation of NAVS and National Seminar on Livestock Sector towards One Health, Food Security and Safety. At OUAT, Bhubaneshwar during 19th-20th December, 2018, pp. 192-193.

Kumar Rakesh, Mishra JS, Kumar S, Rao KK, Hans H and Bhatt BP.2018. Productivity, profitability and weed dynamics of direct seeded rice (*Oryza sativa* L.) genotypes as influenced by weed management practices under the Eastern Himalaya. Paper presented during 2nd National Conference on Doubling Farmers Income for Sustainable & Harmonious Agriculture "DISHA-2018" during 11th–12th August, 2018 held at the ICAR-Indian Institute of Natural Resins & Gums, Ranchi, Jharkhand, pp: 61–62.

Kumar Sanjeev. 2018. Integrated Farming Systems for small and marginal farmers of Bihar. National Conference on Doubling Farmers Income for sustainable and harmonious agriculture (DISHA-2018) at IINRG, Kanke, Ranchi during 11th-12th August, 2018.

Kumar Sanjeev. 2018. Progress report (2012-17) of AICRP on IFS, Patna centre at ICAR Research Complex for NEH Region, Barapani (Meghalaya) during Fourth Meeting of Quinquennial Review Team during 12th-13th December, 2018.

Kumar Sanjeev. 2018. Progress report of AICRP on IFS at ICAR-RCER, Patna in the V Biennial Workshop on AICRP-IFS at UAS, Bengaluru during 20th-23th December, 2018.

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27. 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, Scientist (Plant Breeding)
Dr. Manoj Kumar, Scientist (Soil Science) up to 12.12.2018
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. T.L. Bhutia, Scientist (Horticulture) up to 25.06.2018
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 (Veg. Science) w.e.f. 16.07.2018

Division of Livestock and Fishery Management

Scientists

Dr. A. Dey, Pr. Scientist (Animal Nutrition) & Head up to 30.06.2018
Dr. J.J. Gupta, Pr. Scientist. (Animal Nutrition)
Dr. Kamal Sharma, Pr. Scientist (Fishery) & I/c Head
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) w.e.f. 08.10.2018
Mr. Jaspreet Singh, Scientist (FRM) w.e.f. 08.10.2018

Technical Officers

Dr. S. K. Barari, Chief Technical Officer
Mr. 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, Scientist (SS) (Comp. App.)
Dr. P.K. Sundaram, Scientist (FMP)
Dr. Surjit Mondal, Scientist (Soil Science)
Dr. Pawan Jeet, Scientist (L&WME) w.e.f. 25.06.2018
Er. Akram Ahmed, Scientist (L&WME) w.e.f. 06.07.2018
Mrs. Mridusmita Debnath, Scientist (L&WME)

Division of Socio-Economics and Extension

Scientists

Dr. Ujjwal Kumar, Pr. Scientist (Agril. Extension) & Head
Dr. Abhay Kumar, Pr. Scientist (Agril. Statatics)
Dr. R.C. Bharti, Pr. Scientist (Agril. Statatics)
Dr. N. Chandra, Pr. Scientist (Agril. Economics)
Dr. Virendra Kumar Yadav, Pr. Scientist (Ag. Extension) up to 05.08.2018
Dr. Tanmay Kumar Koley, Scientist (Horticulture)
Dr. Dhiraj Kumar Singh, Scientist (Agril. Extension)
Dr. Anirban Mukherjee, Scientist (Agril. Extension) w.e.f. 16.07.2018

Technical Officer

Mr. Sanjay Rajput, Technical Officer

Performance Monitoring & Evaluation Cell

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

Technical Officer

Mr. Sarfaraj Ahmad, Technical Officer (Computer)

ARIS Cell

Dr. R.C. Bharti, Pr. Scientist (Agril. Statatics) I/c ARIS

Technical Officer

Sh. Anil Kumar, Senior Technical Officer

Farm Section

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

Workshop and Estate Management Unit

Sh. M.L. Swarnkar, Chief Technical Officer

ICAR RCER, Research Centre, Ranchi

Scientists

Dr. A.K. Singh, Pr. Scientist (Vegetable Science) & 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. Virendra Kumar Yadav, Pr. Scientist (Ag. Extension) w.e.f. 06.08.2018
Dr. P.R. Kumar, Sr. Scientist (Seed Technology)
Dr. Sudarshan Maurya, Sr. Scientist (Plant Pathology)
Dr. Asit Chakrabarti, Sr. Scientist (LPM)
Dr. S.S. Mali, Scientist (SWCE)
Dr. (Mrs.) P. Bhavana, Scientist (Plant Breeding)
Dr. Jaipal Singh Choudhary, Scientist (Entomology)
Ms. Reshma Shinde, Scientist (on study leave)
Mr. P.K. Sarkar, Scientist (Agroforestry) (on study leave)
Mr. M.K. Dhakar, Scientist (Fruits Science)
Dr. Tania Seth, Scientist (Vegetable Science)

Technical Officers

Dr. G. P. Singh, Chief Technical Officer
Shri Y. N. Pathak, Assistant Chief Technical Officer
Sh. Paul Sanjay Sircar, Assistant Chief Technical Officer (Computer)
Shri Om Prakash, Senior Technical Officer (Civil)
Shri Suresh Kumar, Senior Technical Officer (Farm)
Shri Ganga Ram, Senior Technical Officer (Lab.)
Shri Chandrakant, Senior Technical Officer (Lab.)
Shri Chandra Shekher Prasad, Senior Technical Officer (Lab.)
Shri B. P. Mishra, Senior Technical Officer (Farm)
Shri Dhananjay Kumar, Technical Officer (Farm)
Shri Arun Kumar, Technical Officer (Electricity)
Shri Pradip Kumar Singh, Technical Officer (Laboratory)
Smt. Anima Prabha, Technical Officer (Press & Editorial)
Shri Vijay Kumar Singh, Technical Officer (Lab.)
Shri Manual Lakra, Technical Officer (Farm)
Shri Dev Charan Kujur, Technical Officer (Mechanical)
Sh. Kushal Kesariar, Tech. Officer up to 28.02.2019

ICAR RCER, Research Centre for Makhana, Darbhanga

Scientists

Dr. Rajvir Sharma, Pr. Scientist (Agronomy) & Head up to 14.09.2018.
Dr. Md. Idris, Pr. Scientist (Entomology) up to 23.06.2018
Dr. I.S. Singh, Sr. Scientist (Soil Science)
Dr. B.R. Jana, Scientist (Horticulture)
Dr. Manoj Kumar, Scientist (Soil Science) w.e.f. 13.12.2018
Mr. Shailendra Mohan Raut, Scientist (FRM) w.e.f. 12.03.2019

ICAR RCER, Krishi Vigyan Kendra, Buxar

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

Technicals

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

ICAR RCER, Krishi Vigyan Kendra, Ramgarh

Dr. Dushyant Kumar Raghav, SMS (Plant Protection)
Dr. Indrajeet, SMS (Ag. Extension)
Dr. Dharmjeet Kherwar, SMS (Agro Forestry/Horticulture)

Technical

Sh Sunny Kumar, Farm Manager

Adminiatration & Finance Section

Sh. Pushpanayak, Chief Administrative Officer
Sh. Ajay Kumar Soni, Senior Administrative Officer w.e.f. 06.09.2018
Sh. Vipul Raj, Administrative Officer
Sh. K.K. Lal, Jr. Accounts Officer
Smt. Prabha Kumari, AAO (E&A)
Sh. Dayanand Prasad, Assistant up to 03.03.2019
Sh. Ravi Shankar, Assistant
Sh. Rakesh Mani, Assistant
Sh. Md. Sajid Mustaque, Assistant

Sh. Madan Paswan, Assistant
Ms. Divyadarshini, Assistant

New Joining

Scientists

Dr. Pawan Jeet, Scientist (SWM) w.e.f. 25.06.2018 after getting transferred from ICAR-IINRG, Ranchi.

Er. Akram Ahmed Scientist (Soil & Water Conservation Engg.) w.e.f. 06.07.2018 after getting transferred from ICAR-IGFRI, Jhansi.

Dr. Anirban Mukherjee Scientist (Agril. Extn.) w.e.f. 16.07.2018 after getting transferred from ICAR-VPKAS, Almora.

Dr. Kumari Subha Scientist (Vegetable Sc.) w.e.f. 16.07.2018 after getting transferred from ICAR-NBPGR, New Delhi.

Ms. Bavithra R, Scientist (FRM) w.e.f. 08.10.2018

Mr. Jaspreet Singh, Scientist (FRM) w.e.f. 08.10.2018

Mr. Shailendra Mohan Raut, Scientist (FRM) w.e.f. 08.10.2018

Technicals

Mr. Umesh Kumar Mishra, Technical Assistant (Hindi Translator) w.e.f. 06.08.2018.

Mr. Abhishek Kumar, Technician (Lab.) w.e.f. 13.12.2018.

Mr. Alok Kumar, Technician (Field/Farm) w.e.f. 13.12.2018.

Miss Usha Kiran, Technician (Field/Farm) w.e.f. 14.12.2018.

Mr. Anand Ranu, Technician (Field/Farm) w.e.f. 17.12.2018.

Administrative

Mr. Ajay Kumar Soni, Senior Administrative Officer w.e.f. 06.09.2018

Mr. Alok Raj, LDC w.e.f. 16.11.2018

Mr. Rajnish Kumar, LDC w.e.f. 12.11.2018

Mr. H.N. Prasad, LDC w.e.f. 12.11.2018

Promotion

Scientists

Dr. Sudarshan Maurya, Sr. Scientist (Plat Pathology) promoted to Sr. Scientist (Level-13A) w.e.f. 05.08.2014.

Dr. S.K. Dwivedi, Scientist (Plant Physiology) promoted to Scientist (Level-11) w.e.f. 02.07.2016.

Dr. P.C. Chandran, Scientist (Animal Gen. & Breeding) promoted to Sr. Scientist (Level-12) w.e.f. 08.01.2017.

Dr. Reena Kumari Kamal, Scientist (LPM) promoted to Scientist (Level-11) w.e.f. 01.07.2017.

Administrative

Smt. Sangeeta Chakrabarty, UDC promoted to Assistant w.e.f. 31.03.2015

Sh. Francis Murmu, LDC promoted to UDC w.e.f. 01.01.2019.

Sh. Dayaanand, Assistant promoted to AAO w.e.f. 04.03.2019.

Transfer

Scientists

Dr. Md. Idris, Pr. Scientist transferred to ICAR-NCIPM, New Delhi w.e.f. 23.06.2018

Dr. T.L. Bhutia, Scientist transferred to ICAR-NRC on Orchids, Sikkim w.e.f. 26.06.2018.

Dr. Virendar Kumar Yadav, Pr. Scientist transferred to RC, Ranchi w.e.f. 06.08.2018.

Dr. Rajbir Sharma, Head RCM, Darbhanga transferred to IARI, New Delhi w.e.f. 15.09.2018.

Dr. Manoj Kumar, Scientist transferred to RCM, Darbhanga w.e.f. 13.12.2018.

Technical

Sh. Abhishek Kumar, Technician (Lab.) transferred to RC, Ranchi w.e.f. 04.02.2019.

Administrative

Sh. Dayanand Prasad, AAO transferred to RC, Ranchi w.e.f. 04.03.2019.

Sh. Alok Raj, LDC transferred to RC, Ranchi w.e.f. 22.02.2019.

Retirements

Administrative

Smt. G.M. Pradhan, AAO w.e.f. 28.02.2019

Technical

Sh. Kushal Kesariar, Tech. Officer w.e.f. 28.02.2019

Skilled Supporting Staff

Sh. Paulus Lakra, SSS w.e.f. 30.04.2018
Smt. Kunchi Lakra, SSS w.e.f. 31.07.2018
Sh. Didu Kujur, SSS w.e.f. 30.09.2018
Sh. Dhani Ram Mochi, SSS w.e.f. 31.10.2018
Smt. Basanti Kesariar, SSS w.e.f. 31.10.2018
Smt. Shanti Mahli, SSS w.e.f. 31.12.2018
Sh. Mareya Oraon, SSS w.e.f. 31.01.2019
Sh. Budhwa Kesariar, SSS w.e.f. 31.01.2019
Sh. Makund Oraon, SSS w.e.f. 28.02.2019
Smt. Ugan Karkusa, SSS w.e.f. 31.03.2019
Sh. Birsa Kachhap, SSS w.e.f. 31.03.2019

28. On-going Research Projects

Theme wise Ongoing and New Institute Research Projects 2018-19

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	June 2010	Mar. 2018	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	June 2011	May 2018	ICAR RCER
1.3	ICAR-RCER/ DLWM/ 2016-17/ **182**	Evaluation and optimization of IFS	Manibhushan Sanjeev Kumar S.S. Mali R.C. Bharati	2016	2019	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 Rajvir Sharma	July 2014	June 2019	ICAR RCER
1.5	ICAR-RCER/ DLFM/ 2014/ **143**	Multiplication and production profiling of improved poultry germplasm under Backyard farming system	Reena K. Kamal P.C. Chandran Pankaj Kumar	July 2014	June 2019	ICAR RCER
1.6	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	ICAR RCER
1.7	ICAR-RCER/ DLWM/ 2016-17/	Eco-energetic analysis of different cropping system in Eastern India.	Bikash Sarkar Ajay kumar S.S. Mali Rakesh Kumar	July 2016	June 2019	ICAR RCER
1.8	ICAR-RCER/ DLFM/2014/**155**	Optimization of production efficiency in Livestock Fish integrated farming system	Kamal Sarma A. Dey S.K. Gupta S. Mohanty Tarkeshwar Kumar	Aug, 2014	July, 2019	ICAR RCER
1.9	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
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. 2019	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	ICAR RCER
2.4	—	Cereal Systems Initiative for South Asia (CSISA) Phase III	J.S. Mishra Md. Monobrullah K.K. Rao Rakesh Kumar S.K. Dwivedi Kirti Saurabh	2016	2020	CIMMYT
2.5	ICAR-RCER/ RC RANCHI /2018/**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
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	Jan. 2011	Mar. 2018	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	ICAR RCER
3.4	—	Developing and defining climate smart agriculture practices portfolios in South Asia (CCAFS)	K.K. Rao Rakesh Kumar Manoj Kumar	2016	2019	CIMMYT
3.5	—	Development of climate resilient farming system models for livelihood improvement	Md. Monobrullah Sanjeev Kumar Bikash Das Pankaj Kumar Manoj Kumar Ravi Kumar Dhiraj Kr. Singh A. Raizada Manisha Tamta	Nov. 2016	Dec. 2019	NMSA, DAC & FW, Ministry of Agriculture & Farmers' Welfare, GoI
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 Rakesh Kumar	July 2018	June 2021	ICAR RCER
3.7	New	Effect of water deficit 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 S.K.Dwivedi R.C. Bharati Shivani	2018	2021	ICAR RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Comp Year	Funding agency
Theme- 2. Genetic Resource Management and Improvement of Field, Horticultural and Aquatic crops						
4.0	**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	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/**142**	Evaluation and identification of rice genotypes for tolerance to drought stress at different growth stages.	Santosh Kumar N. Bhakta S. K. Dwivedi	July 2014	June 2019	ICAR RCER
4.4	ICAR-RCER/ DCR/ 2014/**160**	Breeding for submergence tolerance in rice	N. Bhakta Santosh Kumar S. K. Dwivedi	July 2014	June 2019	ICAR RCER
4.5	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
4.6	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 Md Monobrullah	July 2015	June 2019	ICAR RCER
4.7	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
4.8	—	Evaluation of different genotypes of water chestnut	Rajvir Sharma I.S. Singh B.R.Jana	2015	2020	ICAR RCER
4.9	ICAR-RCER/ RC Ranchi/ 2017/**215**	Genetic resource management in vegetable crops	A.K. Singh P. Bhavna R. S. Pan Anil K. Singh V.K. Yadav	Sept 2017	Long term project	ICAR RCER
4.10	New	Identification of traits, genes, physiological mechanisms to develop climate smart varieties for unfavourable environment	S.K. Dwivedi Santosh Kumar	2017	2022	IRRI
Theme- 3. Improved Production and Protection Technologies for Agri-Horti Crops						
5	**Production Technologies**					
5.1	ICAR RCER/ RCM Darbhanga/ 2014/ **158**	Sustainable crop intensification through the development of suitable plant type in cool season pulses under rice-fallow and makhana-fallow cropping system in Eastern India	A.K.Choudhary I.S. Singh	July 2014	June 2019	ICAR RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Comp Year	Funding agency
5.2	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 Extd2020	ICAR RCER
5.3	ICAR-RCER/ RC Ranchi/ 2014/**152**	Nutritional characterization and value addition of potential underutilized leafy vegetables of Jharkhand	Tania Seth R. S. Pan T.K. Koley	Sept 2014	Sept. 2017 Extd 2018	ICAR RCER
5.4	ICAR-RCER/ DCR/ 2015/	Integrated Weed Management (i) Integrated weed management in makhana	Rajvir Sharma	2015	2020	ICAR RCER
	ICAR-RCER/ DCR/ 2015/**163**	(ii) Integrated weed management in rice-wheat system.	Sanjeev Kumar	2015	2020	ICAR RCER
5.5	ICAR-RCER/ DLWM/ 2016-17/	Ergonomic study of farmers' friendly farm implements in Eastern region.	Bikash Sarkar Rakesh Kumar	2016	2019	ICAR RCER
5.6	ICAR-RCER/ DCR/ 2017/**212**	Diversification of rice-wheat system with vegetables	Shivani Kirti Saurabh	2017	2021	ICAR RCER
5.7	—	Creation of seed hubs for increasing indigenous production of pulses in India	A.K. Choudhary		2019	ICAR
5.8	New	Development of year round seed production technologies in chillies (Capsicum annum, L.) for Jharkhand	P. R. Kumar	Apr 2018	Mar 2020	NABARD (Externally funded)
5.9	New	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	(Externally funded)
6.0	**Protection Technologies**					
6.1	—	Identification, incidence and population dynamics of major insects pests of Gorgon nut (Makhana) and water chestnut (Singhara) in wet-land ecosystem of North Bihar	I.S. Singh B.R. Jana	July, 2017	June, 2020	ICAR RCER
6.2	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
6.3	ICAR-RCER/ RC Ranchi/ 2018/**198**	Seasonal incidence and evaluation of management strategies against insect-pests of cauliflower and chilli	J.S. Choudhary D.K. Raghav Md. Monobrullah Rakesh Kumar	2018	2021	ICAR-RCER
6.4	New	Development of native *Trichoderma* based bioformulations for management of soil-borne diseases	A.K. Dubey A.K. Choudhary Kirti Saurabh	2018	2021	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	A. Rahman Kamal Sarma Ajay Kumar B. Sarkar	Aug. 2014	July, 2017	ICAR RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Comp Year	Funding agency
		(iii) Design and assessment of solar humidifier for animal shed (iv) Design and assessment of solar watering system for animal shed.				
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	ICAR RCER
7.4	ICAR-RCER/ EF/ ACIAR/ 2015/**39**	Improving water for dry season agriculture by marginal and tenant farmers in the Eastern Gangetic Plains	S.S. Mali Ajay Kumar A. Rahman A. Upadhyaya Manibhushan	Aug. 2015	Jul 2018	ACIAR
7.5	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
7.6	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
7.7	New	Refinement of soil test methods for middle IGP	Manoj Kumar K. K. Rao Kirti Saurabh S.K. Naik			ICAR-RCER
7.8	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	July 2018	June 2021	ICAR-RCER
7.9	New	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
7.10	New	Improving rabi/ summer maize productivity through efficient land and water management	Anil. K. Singh A. Upadhyaya Manoj Kumar	July 2018	June 2021	ICAR-RCER
7.11	New	Assessment of land use and land cover change for crop planning using remote sensing and GIS of Nalanda district.	Manibushan A. Raizada A.K.Singh	2018	2021	ICAR-RCER
7.12	New	Optimization of cropping pattern to maximize water productivity	A. Upadhyaya Akram Ahmed Anil K. Singh Surajit Mondal			ICAR-RCER
7.13	New	Studies on irrigation water pricing and influencing factors	A. Upadhyaya			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	ICAR RCER

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Comp Year	Funding agency
8.2	ICAR-RCER / DLFM/EF/ 2011/ **31**	Buffalo improvement	P.C. Chandran A. Dey Pankaj Kumar 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	ICAR RCER
8.4	ICAR-RCER/ DLFM/ 2014/**140**	Assessing stocking density of livestock under different land use system of fodder production.	J.J. Gupta A. Dey S.K.Naik	April 2015	Mar. 2019	Net-work project
8.5	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
8.6	ICAR-RCER/ DLFM/ 2015/**175**	Characterization and evaluation of duck germplasm in Eastern region.	Reena K.Kamal P K Ray	Aug 2015	Aug 2020	ICAR RCER
8.7	ICAR-RCER/ DLFM/ 2015/**180**	Epidemiological study of Respiratory viral diseases in calves.	P.K. Ray Pankaj Kumar	2016	2019	ICAR RCER
8.8	ICAR-RCER/ DLFM/ 2017/**192**	Effect of Glucosamine supplementation on reproductive efficiency in poultry	M.K. Tripathi Reena K. Kamal	2017	2020	ICAR RCER
8.9	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
8.10	ICAR-RCER/ DLFM/ 2018/**209**	Molecular epidemiology and therapeutic management of bovine Theileriosis	Pankaj Kumar P.K. Ray NIAB, Hyderabad IIT, Guwahati, LRSA, Patna	2018	2021	ICAR RCER
8.11	ICAR-RCER/ DLFM/ 2018/**203**	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
8.12	New	AICRP on goat	R.K. Kamal P.C. Chandran A. Dey P.K. Ray	2018	2020	Exter-nally funded
8.13	New	Characterization of indigenous animal germplasm in Jharkhand and Bihar	P.C. Chandran A. Dey R.K. Kamal	2018	2019	Exter-nally funded
8.14	New	Outreach programme on zoonotic dis-eases	P.K. Ray Rajni Kumari Scientist from BASU, Patna	2018	2020	Exter-nally funded
9.0 Fisheries Management						
9.1		National Surveillance Programme for Aquatic Animal Disease (NSPAAD)	Kamal Sarma S.K. Ahirwal	Nov. 2015	Sep. 2019	NFDB

Sl. No.	Project code	Project Title	Name of PI & Co-PI	Start year	Comp Year	Funding agency
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	2016	2019	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
9.4	ICAR-RCER/ DLFM/ 2018/**201**	Culture potential of selected Indian minor carp	S.K. Ahirwal T. Kumar Ravi Kumar Kamal Sarma	2018	2021	ICAR RCER
Theme- 6. Socio-Economics, Extension and Policy Research						
10.0 Socio-economic Research						
10.1	ICAR-RCER/ DSEE/ 2012/**179**	Econometric analysis of diffusion of zero tillage in wheat in eastern region.	R.C.Bharati Abhay Kumar Ujjwal Kumar N. Chandra B.Sarkar	2016	2019	ICAR RCER
10.2	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
10.3	ICAR-RCER/ DSEE/ 2017/**190**	Socio-economic characterization of farmers in Bihar & Jharkhand	V. K. Yadav A.K. Singh Pankaj Kumar Ujjwal Kumar R. C. Bharati	2017	2020	ICAR RCER
10.4	ICAR-RCER/ DSEE/ 2017/**187**	Standardization of shoot bending as canopy management technique for crop regulation in guava	T. K. Koley T.L Bhutia M.K. Dhakar	2017	2020	ICAR RCER
10.5	ICAR-RCER/ DSEE/ 2017/**189**	Production and value chain analysis of makhana	Dhiraj Kumar Singh Abhay kumar N.Chandra I.S. Singh	2017	2020	ICAR RCER
10.6	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
10.7	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 Deokaran D.K. Raghav	2018	2020	ICAR RCER
10.8	New	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

Approved activities of IRC 2018

S. No.	Title of Activities	PI
1.	Development of Farm Machinery Information System	P.K. Sundaram
2.	Development of makhana based Integrated Farming System models for low land eco-system	Rajvir Sharma
3.	Impact of elevated CO_2 and temperature on growth and yield of rice-wheat cropping system under predicted climate change scenario.	S. K. Dwivedi
4.	Genetic enhancement of Tomato for nematode and bacterial wilt resistance through Molecular markers	P. Bhavana
5.	Cultural practices (irrigation levels and different bio mulches) for intercropping mustard with potato	S. K. Singh
6.	Controlling of internal breakdown of mango using post-harvest techniques	T. K. Koley
7.	Improving rice-lentil-moong bean system productivity through water management.	A. K. Singh
8.	Management of heat stress in buffalo	S. Dayal
9.	Design and development of low cost irrigation system for smart farming	Akram Ahmed
10.	Assessment of soil health under different land use systems	Surajit Mondal
11.	Multi-objective optimization of integrated farming system	Akram Ahmed

Approved New Research Projects

S. No.	Project Title	PI & Co-PI	Remarks
New Projects			
	Water conservation under different irrigation and tillage management in rice based cropping system	Surajit Mondal Rakesh Kumar	Project approved Cropping sequence be followed: Rice-Wheat-Summer Mung Rice-Mustard-Summer Mung Rice-Lentil-Summer Mung
	Performance evaluation of medicinal and aromatic plant in EIGP	T.K. Koley N. Raju Singh N.A. Gajbhiye (DMAPR, Anand)	Project approved
	Status of food and nutritional security of rural households in Eastern India	Anirban Mukherjee Shubha Kumari V.K. Yadav Tania Seth	Project approved Representative samples should be taken for the study
	Studies on irrigation water pricing and influencing factors	A. Upadhyaya Pawan Jeet M. Debnath S. Mondal	Project approved Total water pricing and irrigation water pricing (canal and groundwater) to be done in rainfed area Rice-wheat-mungbean cropping system Soil type also be tested Paliganj for canal & groundwater and Patna-Nalanda corridor for groundwater

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