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ICAR

ICAR Research Complex for Eastern Region

ICAR Parisar, P.O. : Bihar Veterinary College
Patna-800 014 (Bihar)

Annual Report
2020

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Annual Report 2020

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Preface

It is a great pleasure for me to present the 20th Annual Report of the institute for the year 2020, focusing the significant research achievements and activities of the Institute. The Institute undertakes multi-disciplinary and multi-commodity research to enhance the productivity of agricultural systems through efficient management of available natural resources, and demonstration & dissemination of developed technologies in diverse agro-ecological zones of eastern region. The Institute has developed several viable technologies during the period under report for enhancing food and nutritional security and farmers' income in the region focusing mainly on smallholders and landless production system including tribal farming system. During 2020, the research and extension activities continued to gain momentum in spite of devastating situation due to COVID-19 pandemic. During this pandemic, alternate income generating activities have been suggested to the govt. of Bihar to accommodate reverse migrated human resources in agriculture. Several health and agro-advisories were provided to the farmers of the region to cope up with the situation. Emphasis has been given on development of stress tolerant crop varieties, management of rice-fallows, popularization of resource conservation technologies, integrated farming system mode of food production, crop diversification and carbon sequestration, water productivity enhancement, mechanization of small farms, weed management, restoration of degraded lands, solar energy application in agriculture, characterization of indigenous livestock and poultry resources, management of animal health and zoonotic diseases, feed& fodder production, integrated fish farming systems, etc. Eight promising advance breeding lines of rice have been nominated for multi-locational testing/evaluation under AICRP and five rice genotypes have been promoted from IVT to AVT 1 trial under AICRIP programme. One pigeon pea genotype has been registered with NBPGR, New Delhi as the donor for "cleisto" traits. In chickpea, one entry each for timely sown condition and rain-fed condition have been put to IVT of AICRP and one entry has been promoted to AVT-I for east central zone. Based on four years of selection, 4 lines of pigeon pea have been found suitable for cultivation under eastern plateau and hill region.

In order to strengthen the plant genetic resource management, promising genotypes of different fruits and improved lines of makhana, water chestnut, and pulses like lentil, chickpea and grass pea have been identified. Besides, quality seeds of rice, pulses, vegetables, and planting materials of fruits and flowers were produced and provided to the end users. In brinjal, one bacterial wilt resistant line and one F_1 hybrid and in tomato three bacterial wilt resistant and nematode tolerant crosses have been submitted for multilocation testing under IET of ICAR AICRP (VC). In oyster mushroom, the strain PL-19-04 was found to be most promising for cultivation in October to January and July to September. Under the DBT Biotech KISAN Hub project, technology demonstration on cultivation of high value horticultural crops has been undertaken in four districts of Jharkhand and three districts of Bihar. A Farmer Producer Organization (FPO) named "Greenery Agrotech Producer Company Limited" has been established at Itki block in Ranchi, Jharkhand. Two numbers of MoUs have been signed for large scale seed production of open pollinated varieties and grafted plants of brinjal and tomato while under the ABI project, two numbers of entrepreneurs have been registered as Incubatees.

Two new livestock population in Jharkhand, i.e., Palamau goat and Medini cattle have characterized and submitted for breed registration Studies on fish productivity, water quality, plankton density, etc. in fish-based integrations have been undertaken. Breeding techniques of minor carp has been studied. The Institute has also been providing technological support to the farmers, extension workers and state officials through its extensive extension network. IT played a major role during the pandemic situation. Climate resilient technologies have been demonstrated in 37 villages to improve the adaptive capacity of farmers to cope with the climate risks. A total of 150 training programmes, 13 Front Line Demonstrations, and 12 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 135 nos. of research papers in the journal of national and international repute, 02 books, 47 book chapter, 14 research/extention bulletins, 01 training manuals, 02 policy brief and 82 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. S.K.Chaudhari, DDG (NRM) and Dr. S. Bhaskar (ADG, AAF&CC) are duly acknowledged. All Heads of the Divisions/Research Centres deserve appreciation for submitting their research findings in time. I also express my appreciation to the Editorial team and other staff members of the institute for compiling and bringing out this report in time.

(Ujjwal Kumar)
Director (Acting)

Content

1. Executive Summary

The salient achievements of the institute during 2020 are summarized below:

- A high yielding multiple stress (drought, submergence, disease and insect pest) tolerant rice variety Swarna Samriddhi Dhan (IET 24306) has been released for cultivation in irrigated as well as rainfed shallow lowland ecosystems of Bihar. Swarna Samriddhi Dhan is a semi-dwarf, high yielding (5.5-6.0 t/ha), medium duration (135-140 days) and lodging resistant variety with desirable grain and good cooking quality traits.
- Rice genotypes *viz*., IR 106312-50-1-1-1, IR 93827-29-1-1-4, IR14L362, IR14L155, IR14L157, IR 90257-B-577-1-1–B, IRRI 123, IR14L613, IR 95817-5-1-1-2 and IR 93827-29-2-1-3 have been identified promising for reproductive stage drought tolerance with productivity range of 3.86-4.90 t/ha as compared to the check variety, Sahbhagi Dhan (3.42 t/ha).
- Rice genotypes, IR 96321-315-323-B-3-1-3, IR 102796-14-77-2-1-2, IR 96321-1447-521-B-2-1-2, IR 94391-131-152-3-B-3-1-1, IR 96321-558-563-B-2-1-1, IR 96322-34-223-B-1-1-1, IR 96321-558-209-B-6-1-1, IR 96321-315-294-B-1-1-1, IR 96321-558-257-B-4-1-2 and IR96321-315-323-B-3-1-3 have been found promising for multiple stresses (submergence and drought) tolerance with productivity range of 1.29-1.75 t/ha as compared to check variety, Swarna Sub 1(1.15 t/ha).
- Rice genotypes IR83929-B-B-291-2-1-1-2, IR84899 -B-182-3-1-1-2, IR 84899-B-183-20-1-1-, IR 93827-29-1-1-3, IR84898-B-168-24-1-1-1, IR83929-B-B-291-3-1-1, IR93827-29-1-1-2, IR97034-21-2-1-3, Swarna Shreya and IR93810-17-1-2-3 have been identified promising for multi-stages drought tolerance with productivity range of 1.18-1.91 t/ha as compared to Sahbhagi Dhan (0.875 t/ha).
- Breeder seed (5.7 t), nucleus seed (325 kg) and truthfully labeled seed (4.3 t) of rice varieties Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan have been produced by the institute during *kharif* 2020.
- More than seven quintals of quality seeds of rice varieties have been distributed among 200 farmers belonging to different districts of Bihar, Jharkhand, Assam, West Bengal and Odisha for demonstration and on-farm testing.
- Under seed hubs, 18.49 tons of quality seeds of different varieties of various pulses (pigeonpea, chickpea, lentil, green gram and black gram) have been produced.
- Eight promising advance breeding lines (RCPR 68, RCPR 69, RCPR 70, RCPR 71, RCPR 72, RCPR 73, RCPR 75, and RCPR 77) of rice have been nominated to AICRIP for multi-locational testing/ evaluation during *kharif* 2020. Moreover, five rice genotypes RCPR 60 (IET 28329), RCPR 62 (IET 28658), RCPR 63 (IET 28631), RCPR 64 (IET 28250) and RCPR 65 (IET 28242) have been promoted from IVT to AVT 1 trial after first year of testing during *kharif* 2019 under AICRIP programme.
- In pulses, pigeon pea genotype 'RCEA 14-5' has been registered with NBPGR, New Delhi as the donor for "cleisto" traits. It has been assigned the registration number *INGR 20024*.
- In chickpea, one entry each for timely sown condition (DBGC 1) and rainfed condition (DBGC 4) were put to IVT of AICRP on Chickpea during 2019-20. One entry 'DBGC 1' has been promoted to AVT-I for east central zone.
- Among four genotypes of chickpea (DBGC 1, DBGC 2, DBGC 3 and DBGC 4) and three genotypes of lentil (DBGL 62, DBGL 105 and DBGL 135), all the genotypes of chickpea and two genotypes (DBGL 62, DBGL 105) of lentil appeared high to moderately resistant against chickpea wilt and lentil wilt, respectively.
- Two-acre integrated farming system has resulted energy efficiency ratio as 1.66. Energy efficiency ratio (EER) was the highest for fodder crops (13.38) followed by field crops, vegetables, fruits, fish, cattle and duck (7.91, 2.7, 2.03, 0.64, 0.16 and 0.13, respectively).
- One acre (Field crops + Hort.+ Goat+ Poultry) and two-acre IFS models (Field crops + Hort.+ Fisheries + Duck + Cattle) provided an annual net return of Rs. 88,527/ ha (B:C, 1.96) and Rs. 1,47,236/- (B:C,1.94), respectively which is about 3-4 times higher over rice- wheat cropping system.

- Weed dynamics study comprising of 12 cropping systems was carried out in *rabi* season. Rice-cauliflower-onion-moong and jowar-chickpea–fallow cropping systems showed most diverse weed species during *rabi* season. Cereal-based cropping system, i.e., Rice-mustard-mungbean/ rice-lentil-mungbean had recorded higher weed infestations in terms of weed count per unit area (53.5). Broad leaved weeds (BLWs) were identified as the most dominant weed flora in all the cropping systems during *rabi* season.
- Yield and yield attributing traits declined due to delayed sowing of wheat. The reduction in grain yield was 25% under late sown combined stress (drought and heat) condition, while reduction in biomass was 24%. Reduction in ear length was 9.5%, while test weight was reduced by 3.9% under late sown combined stress conditions. Wheat genotypes WH730, NW1014, HD3118 and 3010 were found promising for late sown conditions.
- Rice–cauliflower-spring onion-greengram produced significantly higher rice equivalent yield (36.91 t/ha) with a net return of Rs. 26,2950 and benefit-cost ratio of 2.9 among all cropping systems followed by rice-broccoli-spinach-green gram (34.10 t/ha, B: C, 2.74) and Rice-tomato-greengram (28.49 t/ha, B:C, 2.6).
- Thirteen chickpea genotypes were screened against phyllody under late sown irrigated and rainfed conditions. Most of the genotypes (Pusa 256, Pusa 547, Pusa 372, DBGC 3, Pusa 1103, Pusa 3043, DBGC 4 and GNG 1581) were showing resistant reaction; however, genotypes ICC 4958 and JG 14 were highly resistant to phyllody under both the conditions.
- In varietal trial, twelve lentil varieties were screened for resistance to *Stemphyllum* blight and rust. All the varieties except Ranjan were resistant to *Stemphyllum* blight; Ranjan appeared to be highly susceptible. Except three varieties (HUL 57, Arun and Ranjan), all were found resistant to rust under field condition. Under heat stress, DPL 15, DPL 62, IPL220 and IPL 406 showed resistant reaction to *Stemphyllum* blight in both irrigated and rainfed conditions. DBGL 135 and Ranjan appeared to be highly susceptible in both irrigated and rainfed conditions.
- Combined foliar application of $ZnSO_4$ and $FeSO_4$ on 4 rice cultivars, Swarna Shreya, Swarna Shakti, Sahbhagi Dhan and DRR Dhan-42 showed significantly highest yield of 6.12 t/ha in Swarna Shreya over yield of 5.61 t/ha without foliar spray.
- In rice – vegetable pea-summer maize system efficient water management practices resulted in significantly higher grain yield (5.41t /ha) with IW: CPE=1.0. However, maximum irrigation water productivity (1.40 kg/m^3) was achieved with IW: CPE=0.4. In case of pea, significantly highest green pod yield (7.95 t/ha) was recorded with IW: CPE=0.8. Highest irrigation water productivity (10.93 kg/m^3) was achieved at IW: CPE=0.4.
- Studies on water productivity maximization by optimally allocating land under different crops and employing simplex linear programming technique indicated that water productivity can be enhanced from existing 29.61 Rs./m^3 from 6693 ha area to 32.62 Rs./m^3 from 3527 ha in Paliganj distributary command and from existing 18.28 Rs./m^3 from 946 ha area to 22.77 Rs./m^3 from 766 ha at Nalanda corridor site.
- Irrigation water price considering irrigation water applied through canal and tube well in Reach I, II and III of Paliganj distributary for rice crop was computed as 4.73, 5.19 and 4.80 Rs./m^3, respectively and for wheat crop as 5.61, 4.95 and 6.24 Rs./m^3, respectively. At Nalanda Corridor site, irrigation water price of rice, wheat and moong was estimated as 12.96, 29.59 and 9.02 Rs./ m^3, respectively.
- Multiple and conjunctive use of water was studied in Bharatpura sub-distributary in two ponds (size 33 m x 35 m) with fish culture under tube well command with 5 hp submersible pump. Para-lentil cultivation yielded in the range of 0.75 to 0.9 t/ha with a water productivity of 0.75 to 0.9 kg/ m^3. Pod yield of pea was obtained at 5.6 t/ha with water productivity of 2.24 kg/m^3 through mini sprinkler irrigation system which was 36.6% and 91.2% higher than that of check basin irrigation. The cost of irrigation through solar water pump was 73% and 21% cheaper than diesel and electric pump, respectively.
- Based on four years of selection, the pigeon pea lines IC 611683, IC 611232, IPA-203 and Type-7 have been found suitable for cultivation under eastern Plateau and Hill.
- One bacterial wilt resistant line and one F_1 hybrid of brinjal and three bacterial wilt resistant and nematode tolerant crosses of tomato have been submitted for multi-location testing under IET of ICAR AICRP (VC).

- In oyster mushroom, the strain PL-19-04 has been found most promising for cultivation in October to January and July to September.
- Under the DBT Biotech KISAN Hub projects, technology demonstration on cultivation of high value horticultural crops has been undertaken in 1373 number of farmers' fields in four districts of Jharkhand and three districts of Bihar and technology demonstration on integrated farming system has been undertaken in 99 farmers' fields in Ranchi district of Jharkhand. A Farmer Producer Organization (FPO) named "Greenery Agrotech Producer Company Limited" has been established at Itki block in Ranchi, Jharkhand
- Two numbers of MoUs have been signed for large scale seed production of open pollinated varieties and grafted plants of brinjal and tomato while under the ABI project, two numbers of entrepreneurs have been registered as Incubatees.
- Production and reproduction performances of Seemanchali sheep and Kosi buffaloes were studied in their breeding tract. The body weight of the sheep at three months of age was recorded 9.23±0.14 kg which increased to 15.60±0.22 kg in 6 months registering 69.0% of the incremental gain. Similarly, the height, body length and chest girth for an adult buffaloes were found to be 144.33 cm, 151.33 cm and 200.66 cm for males 138.34 cm, 141.25 cm and 195.14 cm for females, respectively.
- The performance of Murrah buffaloes was found to be consistent as the total lactation milk yield, standard lactation milk yield and the average peak yield observed during the period were 2356.45±132.11 kg, 1977.05±109.36 kg and 11.51±0.43 kg, respectively.
- The births of 1869 kids were recorded from 1008 kidding in Black Bengal goats with the prolificacy rate of 185.4%. Age of does at breeding (>27.38 month), body weight at breeding (>18.49 kg) significantly influenced (P<0.01) the triplet, quadruplet or quintuplets litter sizes.
- A significant increase in transcriptional abundance of CCL8 gene was observed throughout the peri-implantation period in pregnant buffaloes with the value of 0.014 ± 0.001 at day 12 post AI to 0.062± 0.002 at day 21, respectively (p<0.05). The expression level of CCL8 gene remained unchanged (p>0.05) throughout the peri-implantation period in case of non-pregnant buffaloes.
- Two genotypes AB with three distinct bands (403 bp, 250 bp and 153 bp) and AA with two distinct bands (250 bp and 153 bp) were observed while assessing genetic variability in ducks of eastern states using Restriction Fragment Length Polymorphism (RFLP) with XbaI restriction enzyme.
- Average flock size of duck population was more in Chhattisgarh (11.76±0.60 nos.) as compared to Jharkhand (9.51 ±0.67 nos.) and Odisha (9.47± 0.52 nos.). The average annual egg production per duck in Jharkhand, Odisha and Chhattisgarh ranged to be 50-70, 60-80 and 52-111 eggs per annum, respectively.
- Bovine Theileriosis' was observed high (60.23%) among infected bovines with tick-transmitted haemo-parasites. The highest percentage was infected with *Theileria* spp., followed by *Anaplasma marginale* and least with *Babesia spp*. Among the infected bovine samples, 35.85% samples had co-infection of both *Theileria spp*. and *A. marginale* parasites.
- Highest sero-positivity of Brucellosis was found in agro-climatic zone I of Bihar where Brucella sero-positivity was 5.74%. In goats, 3.16% (7/221) samples were positive for brucella antibodies by Rose Bengal plate test.
- Experiment with Biofloc technology showed that fish and prawn combination performed better in terms of specific growth rate, feed conversion efficiency and maximum survivability for fish (97.4%) and prawn (61.33%).
- Integrated prawn cum fish (rohu and catla) farming resulted in highest growth of catla fingerlings (151g to 1170.6 g), while rohu (133.75 g) attained 830.8 g during the 390 days of culture period. At the end of culture period, the productivity of catla, rohu and prawn was recorded at 1.58, 1.06 and 0.37 t/ha, respectively.
- During the period under report, the Institute published 135 nos of research papers in journals of national and international repute, 47 book chapters, 02 books, 82 popular articles, 14 technical/ extension bulletin, 01 training manuals and 02 policy brief.
- During the year 2020, thirty seven villages in six districts of Bihar and Jharkhand were covered under *Mera Gaon Mera Gaurav*, and 1025 farmers were directly benefitted through various activities.
- Further, total of 150 training programmes, 13 Front Line Demonstration and 12 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. 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 in the Eastern region is very low due to erratic climate variations, population explosion, land degradation, small and scattered land holdings, lack of quality seed and planting materials, poor extension mechanism, etc. However, the Eastern region of the country 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. Though Eastern region is rich in natural resources, its potential could not be harnessed in terms of improving agricultural productivity, poverty alleviation and livelihood improvement.

ICAR Research Complex for Eastern Region (ICAR-RCER), Patna came into existence on the 22nd February 2001 to address diverse issues relating to land and water resources management, crop husbandry, horticulture, 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. Geographically, the Institute is located at 25°35'30" N latitude, 85°05'03" E longitude, at an altitude 52 m above mean sea level.

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

Finance

Summary of budget allocation and expenditure during the financial year 2020-21 of the complex is presented in Table 2.1.

Mandates

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

Modalities to achieve the mandates

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

Table 2.1. Financial allocation and expenditure during the year 2020-21 (Rs. in Lakhs)

Head of accounts	BE allocation	Actual expenditure*
Establishment Charges	2392.05	2391.95
TA	10.15	10.15
HRD	3.51	3.51
Capital	51.17	48.74
Other charges	1100.38	1078.35
Total	3557.26	3532.70

*up to 31st December, 2019

Table 2.2. Staff position as on 31st December 2020.

Staff	Position	
	Sanctioned	Filled
Scientific*	91	70
Technical	61	53
Administrative	35	21
Skilled Supporting Staff	63	53
Total	252	199

*Including Director

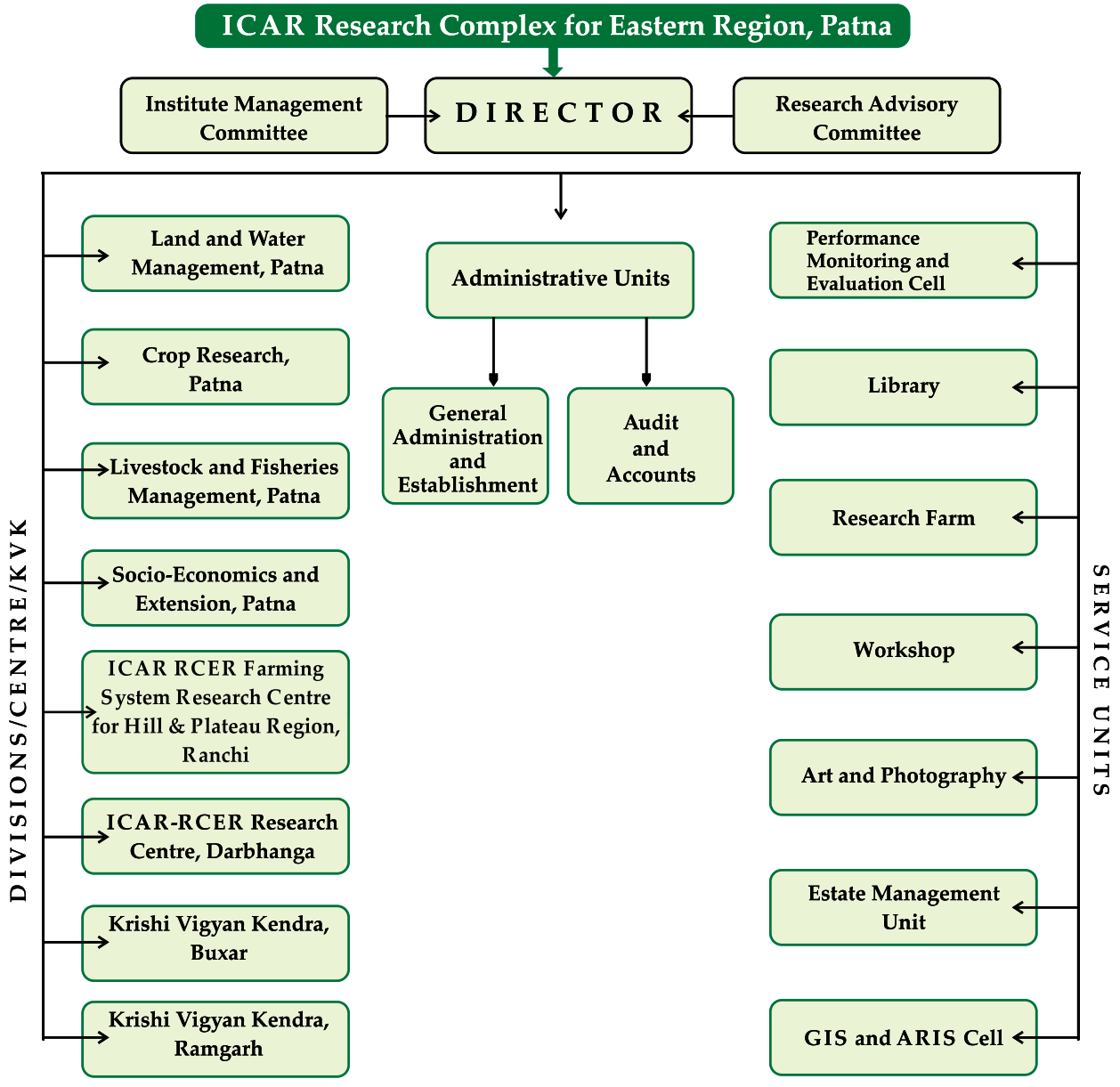


Fig. 2.1. Organogram of ICAR Research Complex for Eastern Region, Patna

3. Weather

Weather parameters *viz.* air temperature, relative humidity, bright sunshine hours, rainfall, evaporation, wind speed and direction were recorded regularly twice in a day at Agrometeorological Observatory of ICAR-RCER, Patna. Table 3.1 shows mean monthly values for weather parameters observed along with the monthly normal values. Mean monthly maximum temperature ranged from 19.4°C during January to 34.4 °C during May showing that on an average May month remained warmest for the year 2020. Similarly, the mean monthly minimum temperature varied from 10.4 °C during January to 27.3 °C during August, depicting January as the coldest month for the location. Mean monthly relative humidity was reported to be lowest in November (61.9 %) and highest in July (79.3 %). Daily weather conditions changes with the change of seasons in a year, usually relative humidity peaks during monsoon season and becomes lower during summer and autumn season. Similarly, relatively lesser amount of rainfall was received during winter and summer season, however, on the otherside water loss in the form of evaporation also remains active during these months. Mean monthly bright sunshine hours (BSSH) was more during March and April (7.2 hrs.) but during monsoon month, presence of clouds leads to less number of BSSH. The mean wind speed reached its maximum during August (8.0 km/hr). These mean monthly variations for weather parameters 2020 have been depicted in Fig. 3.1.

Year 2020 was surplus or sufficient rainfall year based on total amount of rainfall received throughout the year. Total amount of rainfall which was progressively accumulated at the end was 1367.4 mm, which was 121.3 % of long period rainfall average (1127.3 mm) for the station. Total annual rainfall was repoted as "surplus" for the year 2020 as rain-

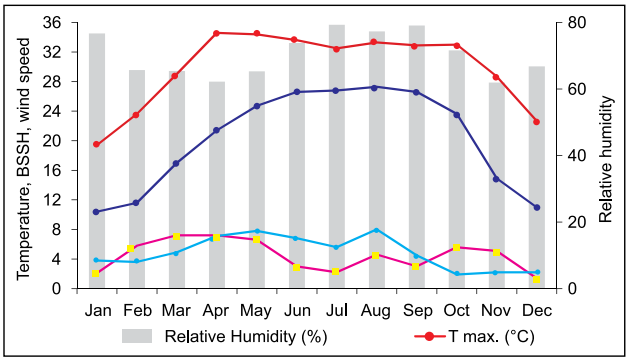


Fig. 3.1. Mean monthly variation of weather parameters during the year 2020 at ICAR RCER, Patna

Table 3.1. Mean monthly weather data of the year 2020 at ICAR-RCER, Patna

Month	Mean temperature (°C)				Mean relative humidity (%)	Mean bright sun-shine (hrs/day)	Total rainfall (mm)		Total rainy days	Total pan evaporation (mm)	Mean wind speed (km/hr)
	Max	Normal	Min	Normal			Observed	Normal			
Jan	19.4	23	10.4	9.3	76.7	2.1	18.3	20.4	1	46.2	3.8
Feb	23.6	26.1	11.6	11.6	65.7	5.8	17.3	11.1	1	71.1	3.6
Mar	29.0	32.4	17.0	16.4	65.4	7.2	23.1	11.4	2	104.1	4.9
Apr	34.6	37.4	21.4	22.1	62.2	7.2	44.8	9.0	2	147.3	7.1
May	34.4	38.4	24.7	25.1	65.3	6.6	94.5	35.6	6	166.4	7.8
June	33.6	36.7	26.6	26.7	73.8	3.0	327.0	141.1	14	118.5	6.8
July	32.5	32.9	26.8	26.1	79.3	2.2	351.9	319.2	14	117.9	5.6
Aug	33.3	32.5	27.3	26.1	77.3	4.6	177.0	279	12	129.5	8.0
Sept	32.9	32.2	26.6	25.3	79.1	3.0	189.2	212.6	11	114.2	4.5
Oct	33.0	31.7	23.6	21.6	71.6	5.6	124.3	72.3	3	133.2	1.9
Nov	28.7	28.9	14.9	14.8	61.9	5.1	0.0	8.2	0	131.7	2.2
Dec	22.7	24.6	11.0	10.1	66.8	1.4	0.0	7.4	0	70.2	2.2
Annual	29.8	31.4	20.2	19.6	70.4	4.5	1367.4	1127.3	66	1350.3	4.9

fall departure was + 21.3 % over the normal rainfall whereas, monsoon season rainfall (June to September) was 1045.1 mm which was found as "normal" with rainfall departure of + 9.8 % over normal rainfall. In the year 2020, it rained for 66 days in total where all the months received rainfall except for November and December. Total open pan evaporation was 1350.3 mm, which was recorded minimum in January (46.2 mm) and maximum in May (166.4 mm). A comparative analysis of total monthly rainfall received, normal rainfall as a LPA and water loss from surface as evaporation has been depicted in Fig. 3.2.

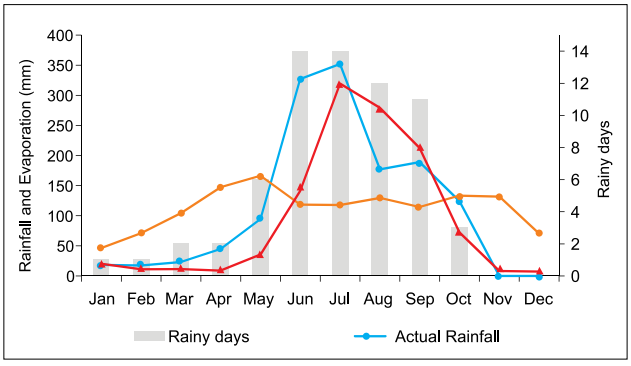


Fig. 3.2. Comparative analysis of total monthly rainfall, normal rainfall, rainy days and evaporation at ICAR RCER, Patna

The comparison of mean monthly maximum and minimum temperatures over the normal values of temperature for the location have been depicted in Fig. 3.3, where maximum temperature actually observed at the station remained lower than then the normal maximum temperature and actual minimum temperature was reported to be very close to normal minimum temperature of the location. A dip of -4.0°C during May and a shoot of +1.3°C were reported during October for mean monthly maximum temperature over normal values whereas, for mean monthly minimum temperature a dip of -0.7°C during April and a shoot of +2.0°C during October was observed over normal values.

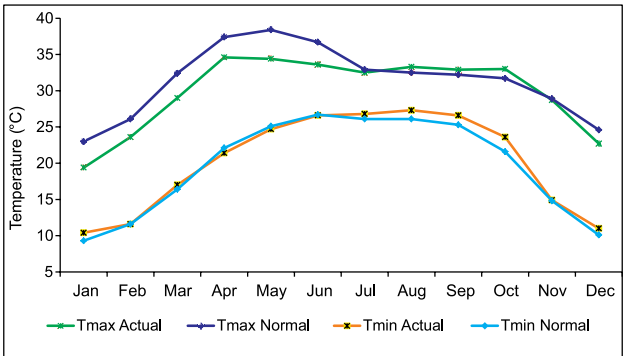


Fig. 3.3. Comparison of mean monthly maximum and minimum temperatures over the normal values at ICAR RCER, Patna

Extremes in weather variables for the year 2020 have been reported in Table 3.2, where 26th May was recorded as hottest day of the year (39.7°C) while 28th December was reported as coldest day of the year (5.8°C). Maximum amount of rainfall in a day (Most rainy day) was recorded on 18th June (87.4 mm), highest wind speed in a day was reached on 27th May (19.4 km/hr) and highest maximum relative humidity was observed on 20th July (94.0 %) but the least humidity was reported on 6th April (46.0 %). Maximum bright sunshine hours of 10 hrs 58 min were recorded on 7th June.

Table 3.2. Extremes of weather observed during the year 2020

Parameter	Date	Value
Warmest day	26th May 2020	39.7°C (Tmax)
Coldest day	28th Dec. 2020	5.8°C (Tmin)
Most humid day	20th July 2020	94.0% (RH)
Least humid day	6th April 2020	46.0% (RH)
Most rainy day	18th June 2020	87.4 mm (Rainfall)
Most shiny day	7th June 2020	10 hrs 58 min (BSSH)
Most windy day	27th May 2020	19.4 km/hr (Wind speed)

At Farming System Research Centr for Hill & Plateau Region (FSRCH&PR), Ranchi, the annual rainfall for the reporting year was 1487mm which was about 6% higher over normal rainfall (1398 mm). Rainfall receipts during monsoon months (June-September) was 85.8 % of the annual rainfall. The summer months (March-May) also received a significant amount (166 mm) of rainfall. Total rainfall recorded for the month of August was 70% in excess of long term normal average rainfall of the month, while it was 10, 28 and 86 % deficient in July, September and October, respectively. Comparison of monthly rainfall receipts

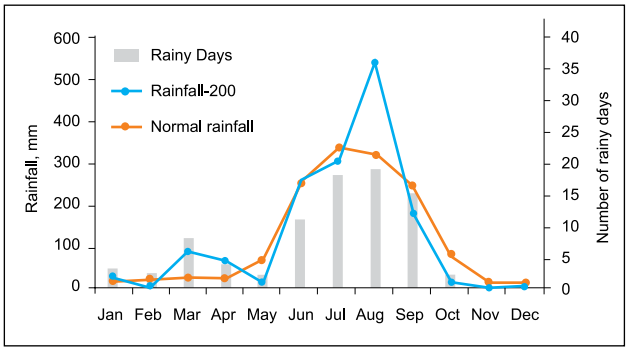


Fig. 3.4. Comparison of monthly normal rainfall with monthly rainfall at FSRCH&PR, Ranchi

with the monthly normal rainfall is presented in Fig. 3.4. The year 2020 had 85 numbers of rainy days, out of which 63 rainy days occurred during the monsoon season with August recorded the maximum (19) number of rainy days. The average monthly relative humidity ranged from 82.0% in November to 92.2% in June. Summary of monthly climatic parameters at FSRCH&PR, Ranchi is presented in Table 3.3. December was the coldest month with mean monthly minimum temperature of 8.9°C while May was the hottest month with mean maximum temperature of 34.5°C. The lowest temperature of 4°C was recorded on 21st December while the highest temperature of 40°C was recorded on 26th May. The diurnal variation in temperature was close to 6°C at the beginning of the monsoon season while it increased to 16°C during the winter months (Fig. 3.5).

Table 3.3. Mean monthly weather parameters at FSRCHPR, Ranchi for the year 2020

Month	Total rainfall (mm)		Number of rainy days	Temperature (°C)		Relative humidity (%)
	Normal rainfall	Rainfall		Minimum	Maximum	
Jan	17	23	3	10.0	23.4	88.3
Feb	21	7	2	10.0	26.1	89.3
Mar	25	85	8	14.7	29.3	83.7
Apr	22	64	4	20.5	33.0	91.9
May	62	17	2	22.8	34.5	90.4
Jun	249	254	11	25.1	31.1	92.2
Jul	337	304	18	26.1	32.1	91.2
Aug	319	541	19	25.4	30.7	90.2
Sep	247	177	15	24.9	31.9	89.2
Oct	77	11	2	20.7	30.8	88.8
Nov	11	0	0	13.2	28.0	82.0
Dec	12	4	1	8.9	25.4	87.1
Annual	1398	1487	85	18.5	29.7	88.7

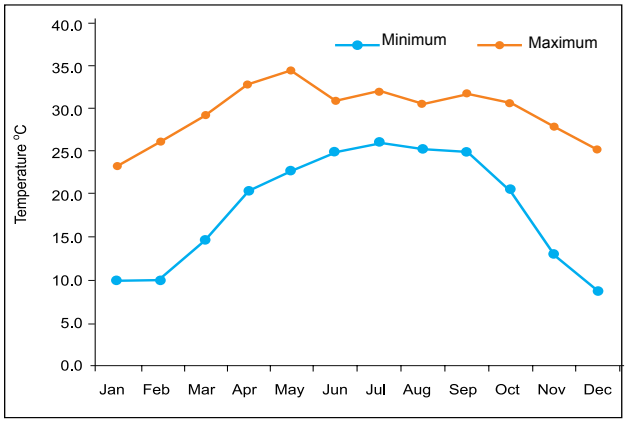


Fig. 3.5. Variations in average monthly minimum and maximum air temperature at FSRCH&PR, Ranchi

4. Climate Change

Simulating Production Potential of Rice and Wheat under Changing Climate over Bihar

During *kharif* 2019-20, rice variety Swarna Shreya was transplanted at 15 days interval on 3 different dates (20 July, 5 August and 20 August, 2019) along with 3 irrigation levels (Fig. 4.1). Soil moisture depletion in the root zone was monitored using the concept of "pani pipe" and quantity of irrigation water applied was calculated as and when the water was applied in the plots along with the rainfall received in the region. Grain yield of rice was reduced significantly by 12 % with delayed transplanting of 15 days (4.7 t/ha) and further by 28 % for another 15 days delay (3.8 t/ha) as compared to rice transplanted on 20th July 2019 (5.3 t/ha). However, the effect of irrigation treatment was found non-significant due to no clear difference in amount of irrigation water applied in different irrigation treatments, which was due to water stagnation situation for nearly 20 days in the crop fields (Fig. 4.2).

Fig. 4.1. Experimental field with rice crop during *kharif* season

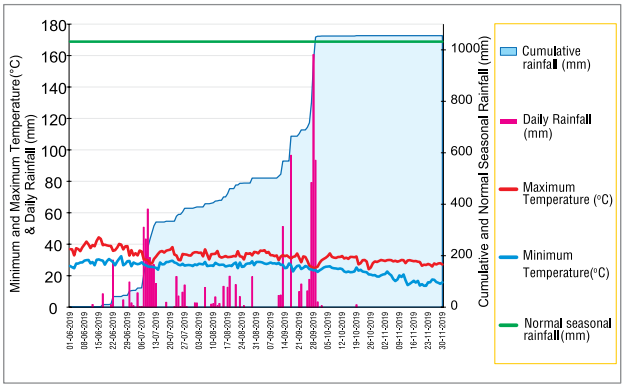


Fig. 4.2. Daily weather condition during *kharif* season

Similarly, Wheat variety HD-2967 was sown during *rabi* season of 2019-20 with similar treatment combinations of date of sowing at 15 days interval (8 November, 23 November and 8 December 2019) with three sets of irrigation treatments (Irrigation at 5 stages (I1), irrigation at 3 stages (I2) and irrigation at 2 stages (I3) (Fig. 4.3). Irrigation was applied in the crop fields on critical growth stages of wheat crop. Wheat crop sown on D1 reported highest grain yield of 4.8 t/ha which was reduced by 12 % due to delayed sowing of 15 days (23 November 2019) and further by 25 % due to 30 days delayed sowing (8 Dec 2019) as compared to wheat sown on 8 November 2019. Effect of delay in sowing was clearly evidenced in terms of heat use efficiency with similar pattern of reduced value as sowing date progressed beyond November 8.

Fig. 4.3. Experimental field with wheat crop during *rabi* season

Relevant input files for model calibration were prepared in due course of time and after so many iterations. Crop simulation model was calibrated well with an agreement index ≥ 0.83 and R^2 value ≥ 0.75 when calculated using observed and simulated values of days to physiological maturity and grain yield of crop. These higher values of statistical parameters indicate the correctness of varietal coefficients generated and performance of simulation model with nearly parallel and overlapping lines running side by side to line of equality (1:1 line) (Fig. 4.4).

Diversity of Bacterial Communities Associated with Melon Fly, *Zeugodacus cucurbitae* (Diptera: Tephritidae)

Melon fly, *Zeugodacus cucurbitae* (Coquillett, 1899) earlier known as *Bactrocera cucurbitae* is considered

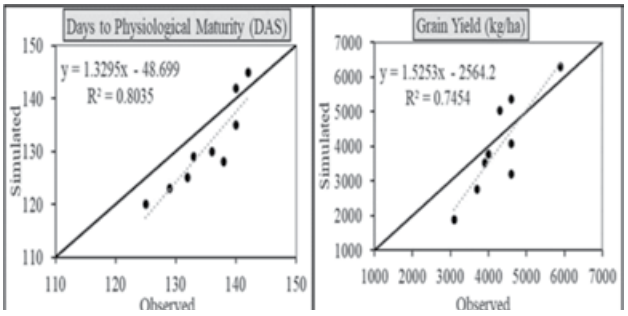


Fig. 4.4. Graphical representation of model calibration for wheat variety HD 2967

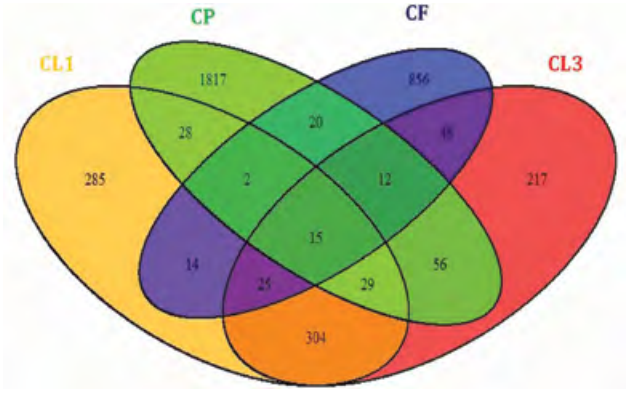


Fig.4.5. Venn diagram showing unique and shared OTUs, of which 15 OTUs shared between all developmental stages of *Zeugodacus cucurbitae* at 97% similarity.

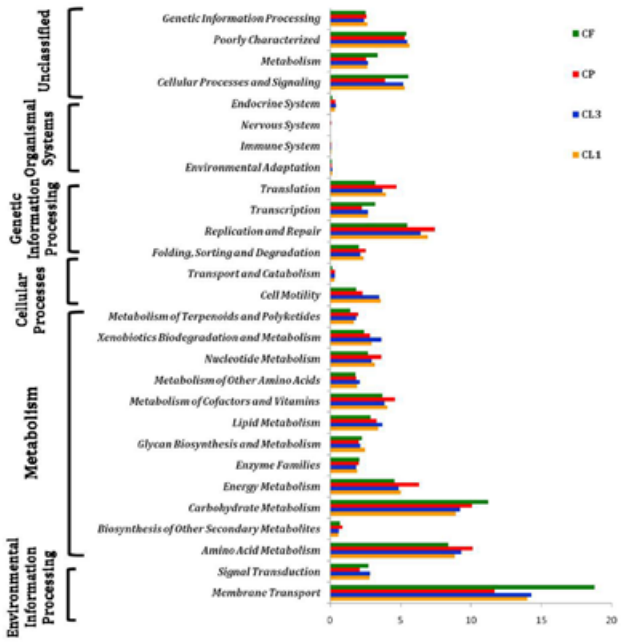


Fig. 4.6. Predicted metabolic functions of bacterial communities associated with different developmental stages of *Zeugodacus cucurbitae.*

an invasive and most *staid* polyphagous pest of cucurbitaceous and other related crops. Due to its wide adaptability, high fecundity and establishment capacity in new environment, *Z. cucurbitae* needs special approaches in pest management strategies. Insects harbour a range of microorganisms in their gut (haemocoel) on the exoskeleton and within the insect cells. These microorganisms play significant role in providing specific nutrients such as amino acids and vitamins, enabling their hosts to tolerate temperature extremities, pathogen defence and detoxification of plant toxic secondary metabolites. Taxonomic and functional characterizations of bacterial community associated with different developmental stages of *Z. cucurbitae* using 16S rRNA (V3-V4 region) gene amplicons metagenomics were studied. The taxonomic analysis indicated that bacterial community associated with *Z. cucurbitae* consists of a total of 23 bacterial phyla (including unclassified and unassigned bacteria), comprising of 32 classes, 69 orders, 99 families and 130 genera. Relationship between OTUs depicted through venn diagram displayed only 15 shared operational taxonomic units (OTUs) among all studied developmental stages of *Z. cucurbitae* at 97% similarity cut off (Fig. 4.5 & 4.6). Proteobacteria, Firmicutes, Actinobacteria and Tenericutes were dominant phyla, of which family Enterobacteriaceae was the most abundant in the larval and adult female stages whereas Mycoplasmataceae was dominant in the pupal stage. Genera *Providencia* and *Comamonas* were the most abundant in larval stages whereas, genera *Candidatus-Bacilloplasma* and *Klebsiella* were the most dominant in pupae and adult females of *Z. cucurbitae*, respectively. PICRUSt analysis was performed for prediction of metabolic activities revealed that associated microbiota may involved in membrane transport, carbohydrate metabolism, amino acid metabolism, energy metabolism, replication and repair processes as well as cellular processes and signalling. The high numbers of OTUs were annotated for phosphoglycerate mutase and transketolase in adult females followed by larval stages, which may support the digestive function of the microbiota in larvae and adult females. Present findings provide insights about the high variation in microbiota across developmental stages and basis for microbiota based management strategies of fruit flies.

5. Cereals

Evaluation and Identification of Rice Genotypes for Tolerance to Reproductive Stage Drought

Among abiotic stresses, drought has been identified as the single most critical threat to the world food security and one of the major factors that lead to a decline in rice production in the rainfed as well as poorly irrigated areas. Further more, in most rainfed regions of eastern India, the probability of occurrence of terminal reproductive-stage drought is high due to the early withdrawal of monsoon rains. Forty eight rice genotypes comprised of advanced breeding lines and check varieties were evaluated under reproductive stage drought stress and non-stress (irrigated) conditions during *kharif* 2020. Fifty five days old plants were subjected to drought by withholding irrigation and withdrawing water from the stress field. Thereafter crop was left rainfed and there was no standing water upto the maturity. Non-stress irrigated experimental field was kept continuously flooded after transplanting until 20 days before harvest. Grain yield varied from 3.75 to 5.79 t/ha and 2.97 to 4.90 t/ha under non-stress and drought stress conditions, respectively. Irrespective of genotypes, drought stress at reproductive stage caused significant reduction in plant height (8.4%), tillers (14.7%), grain yield (23.5%) and biological yield (21.4%); however, the responses varied among genotypes. Among rice genotypes, IR 106312-50-1-1-1 (4.90 t/ha), IR 93827-29-1-1-4 (4.80 t/ha), IR14L362 (4.42 t/ha), IR14L155 (4.27 t/ha), IR14L157 (4.21 t/ha), IR 90257-B-577-1-1–B (4.17 t/ha), IRRI 123 (4.11 t/ha), IR 108199-24-32-1-1-B (4.07 t/ha), IR14L613 (4.03 t/ha), IR 95817-5-1-1-2 (4.02 t/ha), and IR 93827-29-2-1-3 (3.86 t/ha) showed better drought tolerance at reproductive stage as compared to check varieties Sahbhagi Dhan (3.42 t/ha) and IR64 (3.08 t/ha). On average 23.5% yield reduction was observed under drought stress trial (3.77 t/ha) as compared to non-stress (4.94 t/ha) condition.

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

Twenty four rice genotypes were evaluated under submergence, drought and combine stress (submergence + drought) and control (non-stress) conditions during *kharif* 2020. Under the submergence experiment, after eleven days of transplanting the crop was kept submerged under 1.0 to 1.25 m water depth for sixteen days and thereafter water was drained out from the field. Under drought stress experiment, crop faced stress at the reproductive stage. Sixty day old seedlings were subjected to drought by withholding irrigation and withdrawing water from the field. Thereafter crop was left rainfed. Under combined stress, crop faced 16 days submergence at vegetative stage and later drought at the reproductive stage. The control trial was maintained by applying irrigation as and when required. The average grain yields of 5.64, 3.89, 1.96 and 1.04 t/ha was recorded under no-stress, drought, submergence and combine stress condition, respectively. Results of the study revealed that irrespective of the genotypes, there was a significant reduction in grain yield of rice under drought (30.9%), submergence (65.2 %) and combined stress (81.6%) conditions as compared to non-stress condition (control). Among rice genotypes, IR 96321-315-323-B-3-1-3, IR 102796-14-77-2-1-2, IR 96321-1447-521-B-2-1-2, IR 94391-131-152-3-B-3-1-1, IR 96321-558-563-B-2-1-1, IR 96322-34-223-B-1-1-1, IR 96321-558-209-B-6-1-1, IR 96321-315-294-B-1-1-1, IR 96321-558-257-B-4-1-2 and IR96321-315-323-B-3-1-3 have been found promising for multiple stress tolerance. Grain yield of different rice genotypes varied from 2.72-4.85 t/ha, 0.33-2.81 t/ha, 0.25-1.75 t/ha and 3.95-6.40 t/ha under drought, submergence, combine stress and no-stress conditions, respectively.

Resource remobilization during grain filling under drought

Resource re-allocation during grain filling is reflected by harvest index. A field drought- screening of rice was done during *kharif* season 2020 with aim to identify drought tolerant genotypes/donor lines having high harvest index and mobilization efficiency. Seven hundred and ten rice genotypes comprising of four mapping populations (175 nos. from each population along with eight parents and check varieties, i.e., Sahbhagi Dhan and IR 64) were evaluated under two conditions i.e. stress (reproductive stage drought) and non-stress (irrigated) conditions (Fig. 5.1). In addition, fourteen rice genotypes were grown for detailed physiological characterization at anthesis

Fig. 5.1. Evaluation of mapping populations of rice under drought condition.

and physiological maturity stages. Genotypes having high harvest index (HI) with good grain yield under drought conditions have been identified. The average grain yield of 1.88 and 3.00 t/ha was observed under drought and control conditions, respectively. Study showed that irrespective of genotypes, drought stress (reproductive stage) caused significant reduction in grain yield (37.3 %) and biological yield (26.2%); however, the responses varied among genotypes. Under drought condition, higher grain yield was recorded in rice genotype IR 134118-6-B RGA-B RGA-B RGA-28 (5.45 t/ha) followed by IR 134116-5-B RGA-B RGA-B RGA-25 (4.37 t/ha), IR 134116-3-B RGA-B RGA-B RGA-12 (4.25 t/ha), IR 134117-6-B RGA-B RGA-B RGA-19 (4.06 t/ha) and IR 134119-4-B RGA-B RGA-B RGA-6 (3.86 t/ha), IR 134118-6-B RGA-B RGA-B RGA-30 (3.85 t/ha), IR 134117-1-B RGA-B RGA-B RGA-26 (3.72 t/ha), IR 134117-5-B RGA-B RGA-B RGA-8 (3.51 t/ha), IR 134118-5-B RGA-B RGA-B RGA-3 (3.46 t/ha), IR 134119-2-B RGA-B RGA-B RGA-14 (3.37 t/ha), IR 134119-2-B RGA-B RGA-B RGA-4 (3.12 t/ha), IR 134119-3-B RGA-B RGA-B RGA-7 (3.06 t/ha), and IR 134117-4-B RGA-B RGA-B RGA-4 (3.04 t/ha), These promising genotypes also showed better harvest index (37.2-49.8%) as well as drought tolerance at reproductive stage as compared to check variety Sahbhagi Dhan (2.1 t/ha). Among parents, maximum grain yield under drought stress was recorded in Camponi Sml (3.31 t/ha) followed by Gul Murali (2.4 t/ha) and AUS 257 (2.25 t/ha). Under drought condition, maximum mobilization efficiency was observed in Camponi Sml followed by Wanni Dahanala, AUS 257 and Jabour Sail while lowest mobilization efficacy was observed in rice genotype IR 74371-70-1-1. The average reduction in chlorophyll was 61% at physiological maturity stage compared to anthesis under drought condition. Results also revealed that under drought condition, the maximum mobilization efficiency (86.6%) of assimilates was observed in second node of stem followed by first node (83.2%) and sheath (78.9%) part. Similar trend was also observed in non-stress condition.

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

Multi stages drought tolerant rice genotypes are required to improve rice productivity in drought prone areas to achieve food self-sufficiency at the regional as well as national level. Under present study, twenty eight rice genotypes were evaluated under multi-stages drought (MSD), reproductive stage drought (RSD), vegetative stage drought (VSD), seedling stage drought (SSD) stress and non-stress (irrigated) conditions during *kharif* 2020. In MSD experimental field, water was provided only once on the day immediately after sowing so that the seeds could properly germinate. In RSD, VSD and SSD experimental field, drought stress was imposed at respective stages by withholding irrigation and withdrawing water from the stress field. The non-stress experimental trial was maintained by applying irrigation as and when required. Grain yield of different genotypes varied from 0.243 to 1.045 t/ha, 1.053 to 2.468 t/ha, 2.276 to 4.078 t/ha, 2.356 to 4.425 t/ha and 4.652 to 6.327 under, MSD, SSD, RSD, VSD and non-stress conditions, respectively. Results of the study revealed that irrespective of the genotypes, significant reduction in mean grain yield under MSD (80.4%), SSD (69.7%), RSD (42.6%) and VSD (33.4%) stresses was observed as compared to non-stress condition. Among rice genotypes; IR83929-B-B-291-2-1-1-2 (1.91 t/ha), IR84899-B-182-3-1-1-2 (1.56 t/ha), IR 84899-B-183-20-1-1-1(1.50 t/ha), IR 93827-29-1-1-3 (1.47 t/ha), IR84898-B-168-24-1-1-1 (1.43 t/ha), IR83929-B-B-291-3-1-1(1.42 t/ha), IR93827-29-1-1-2 (1.35 t/ha), IR97034-21-2-1-3 (1.34 t/ha), Swarna Shreya (1.31 t/ha) and IR93810-17-1-2-3 (1.18 t/ha) were identified promising for multi-stages drought tolerance compared to Sahbhagi Dhan (0.873 t/ha).

Release and Notification of Rice Variety Swarna Samriddhi Dhan

A high yielding multiple stress tolerant rice variety Swarna Samriddhi Dhan (IET 24306) has been

released by State Seed Sub-Committee (Bihar) and notified by Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops, Govt. of India for the cultivation in the state of Bihar (Fig. 5.2). Swarna Samriddhi Dhan is a medium duration (135-140 days), semi-dwarf, high yielding (5.5-6.0 t/ha), multiple stresses (drought, submergence, disease and insect pest) tolerant, lodging resistant with desirable cooking quality traits and having long slender grain type. Swarna Samriddhi Dhan is suitable for cultivation under transplanted condition in irrigated areas as well as rainfed shallow lowland ecosystems. Quality wise, Swarna Samriddhi Dhan possesses 77.8% hulling, 62.0% milling, 55.6% head rice recovery (HRR) with desirable intermediate alkali spreading value, amylose content (24.33%) with long slender grain type. Beside drought (reproductive stage) tolerant, this variety can also tolerate 8-10 days submergence.

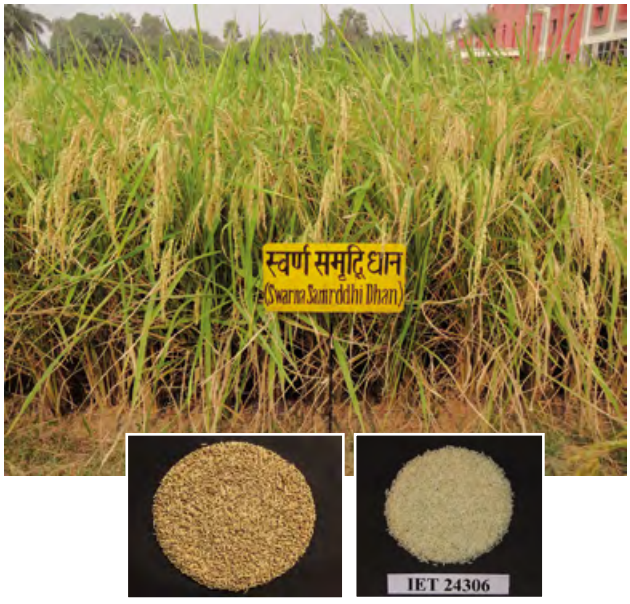


Fig. 5.2. Swarna Samriddhi Dhan

Nomination and Promotion of Rice Entries under AICRIP Programme

Eight promising advance breeding lines (RCPR 68-IR83929-B-B-291-2-1-1-2, RCPR 69-IR88964-24-2-1-4, RCPR 70- IR 84899-B-184-16-1-1-1 , RCPR 71- IR 93827-29-2-1-3, RCPR 72-IR 14L613, RCPR 73- IR 106312-50-1-1-1, RCPR 75- IR 93810-17-1-2-3 and RCPR 77-IR 96321-315-294-B-1-1-1) of rice have been nominated to AICRIP for multi-locational testing/ evaluation during *kharif* 2020. Moreover, five rice genotypes RCPR 60 (IET 28329), RCPR 62 (IET 28658), RCPR 63 (IET 28631), RCPR 64 (IET 28250) and RCPR 65 (IET 28242) have been promoted from IVT to AVT 1 trial after first year testing during *kharif* 2019 under AICRIP programme. In addition, one rice genotype RCPR 58 (IET 27892) has been promoted from AVT 1-E-TP to AVT 2-E-TP trial after second year testing. During *kharif* 2020, two hundred eighteen advance breeding lines of rice belonging to six AICRIP trials (AVT 1-E-TP, AVT 2-E-TP, IVT-IME, AVT 2-IM, IVT-aerobic and AVT-1-aerobic) were conducted at ICAR RCER, Patna (Fig. 5.3). Evaluation of AICRIP trials were conducted at regular interval by monitoring team.

Fig. 5.3. Frontline demonstrations of rice varieties

Frontline Demonstrations (FLDs) of Rice Varieties

The Frontline Demonstrations (FLDs) of rice varieties Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan were conducted during *kharif* 2020 at 74 beneficiary farmers' (including 15 women farmers) fields covering an area of 15.6 ha in three districts (Nawada, Jamui and Buxar) of Bihar and Ramgarh district of Jharkhand under National Food Security Mission (NFSM) programme of Government of India (Fig. 5.3). The performance of the demonstrated rice varieties (Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan) were found superior compared to the respective check varieties. Rice variety Swarna Shreya recorded an average of 4.31 t/ha yield with a maximum yield of 5.36 t/ha. Compared to the check variety, Swarna Shreya recorded yield advantage of 26.9% and was found suitable for increasing the rice productivity and production in the demonstrated districts. Moreover, Swarna Shakti Dhan recorded an average grain yield of 3.75 t/ha and showed 16.7% yield advantage over check varieties. In addition, Swarna Samriddhi Dhan recorded average grain yield of 5.35 t/ha and showed yield advantage over check variety. Farmers of the demonstrated villages were very happy and satisfied with the performance of these climate resilient rice varieties in respect of early maturity, high yielding, grain qualities along with tolerance to drought &

diseases and insect pest characteristics. It is expected that large scale popularization of these varieties will help increasing farmers' income as well as production scenario of the targeting states.

Evaluation of Rice Genotypes for Submergence Tolerance

Twenty rice genotypes along with Swarna Sub 1, IR 64 *Sub1* and Sambha Mahsuri *Sub1* as tolerant and Swarna as susceptible checks were evaluated for submergence tolerance during *kharif* 2020 (Fig. 5.4). After ten days of transplanting, the crop was completely submerged with 1.0 to 1.25 m water depth for twenty one days and thereafter water was drained out of the field. The maximum survival percentage was recorded in IR 102796-14-77-2-1-2 (59.5%), followed by IR 96321-315-294-B-1-1-1 (46.3%) and IR 96321-558-563-B-2-1-1 (40.5%). Rice genotypes IR 102796-14-77-2-1-2 (1.22 t/ha), IR 94391-131-152-3-B-3-1-1 (0.78 t/ha), IR 96321-558-563-B-2-1-1 (0.73 t/ha), IR 96321-315-323-B-3-1-3 (0.71 t/ha), IR 96321-315-294-B-1-1-1 (0.70 t/ha), IR 102777-18-64-1-2-6 (0.69 t/ha), and IR 96321-558-209-B-6-1-1 (0.67 t/ha) performed better as compared to Swarna Sub 1 (0.42 t/ha), IR 64 Sub1 (0.22 t/ha), Sambha Mahsuri Sub 1 (0.18 t/ha). Further, higher spikelet fertility percentage (70-89%) were recorded in identified promising genotypes as compared to check varieties (59-61%). The lowest (11%) spikelet sterility was recorded in IR 102796-14-77-2-1-2 followed by IR 96321-315-323-B-3-1-3 (21%).

Fig. 5.4. Evaluation of rice genotypes under submergence condition.

Screening of rice genotypes for submergence tolerance

In another experiment, ten rice genotypes were screened for submergence tolerance along with Swarna *sub1*, IR64 *sub1* and Ciherang *sub1* as tolerant and Swarna as susceptible checks. Forty day old seedlings were transplanted in the submergence pond on 29th July 2020. After ten days of transplanting, the crop was completely submerged by filling water in the field. The crop was kept submerged under 1.0 m to 1.25 m water depth for 21 days by filing water and thereafter water was drained out of the pond. Even after de-submergence, water stagnation occurred in the pond due to intermittent rain prompting regular draining of water from the pond. The genotypes IR09L 342 (1.12 t/ha), IR10F365 (0.72 t/ha), TP30193-1 (0.55 t/ha) and IR11F195 (0.54 t/ha) performed better in comparison to Swarna *sub1* (0.25 t/ha), IR64 *sub1* (0.29 t/ha) and Ciherang *sub1* (0.27 t/ha). These genotypes have also shown significantly high level of survival under complete submergence for 21 days at early vegetative stage as compared to tolerant checks as presented in Table 5.1.

Table 5.1. Performance of rice genotypes under complete submergence at early vegetative stage

Genotypes	Survival (%)	Plant height (cm)	Panicle length (cm)	Panicles/ hill (No.)	Fertile grains/ Panicle (nos.)	Spikelet fertility (%)	100- Grain weight (g)	Grain yield (t/ha)
IR09L 342	51.3	92.3	24.8	12	104	67	2.08	1.12
IR10L 182	31.3	83.6	23.1	12	68	46	1.91	0.21
IR07L 342	30.7	83.9	23.7	13	91	62	2.03	0.27
IR09L 337	38.7	78.3	20.9	11	85	58	2.06	0.29
IR10F 365	49.0	96.4	25.6	12	68	45	2.18	0.72
IR11F 195	40.7	77.1	20.5	12	87	60	2.11	0.54
TP 30191	37.7	75.3	23.5	11	82	64	1.98	0.25
TP 30193	35.3	66.5	22.7	10	52	47	2.03	0.30
TP 30193-1	53.7	86.7	24.5	12	62	52	2.09	0.55
ST3	27.0	83.5	23.2	8	115	74	1.69	0.23
Ciherang *sub1*	39.7	76.1	23.2	10	76	56	2.18	0.27
IR64 *sub1*	24.0	60.9	23.5	10	54	47	2.19	0.29
Swarna *sub1*	26.3	60.1	20.6	12	28	22	1.77	0.25
Swarna	2.7	39.9	7.1	8	52	29	1.78	0.12
SEM	7.7	5.6	1.89	1.4	11.3	7.8	0.05	0.12

In order to assess their agronomic values, the same set of genotypes was evaluated under irrigated condition and observation on grain yield and yield attributes were recorded which are presented in Table 5.2.

Table 5.2. Performance of rice genotypes under favourable condition (irrigated)

Genotypes	Days to flowering	Plant height (cm)	Panicle length (cm)	Panicles/ m^2 (nos.)	Harvest index	Grain yield (t/ha)
IR09L342	98	130.0	25.5	343	48	5.09
IR10l 182	97	126.7	24.7	387	43	4.56
IR07L 342	96	127.8	25.7	372	47	5.40
IR09L 337	93	130.0	25.8	334	38	3.65
IR10F 365	96	127.2	27.8	363	41	4.61
IR11F 195	101	129.9	25.3	356	46	5.40
TP 30191	108	100.1	21.7	394	46	4.93
TP 30193	97	118.5	27.3	426	47	4.45
TP 30193-1	101	121.7	26.9	420	39	4.81
ST3	97	128.1	29.1	367	36	4.06
Ciherang *sub1*	98	114.8	25.8	363	47	4.67
IR64 *sub1*	91	104.9	27.3	367	48	4.53
Swarna *sub1*	118	95.8	23.4	404	44	4.73
Swarna	119	101.4	23.7	429	45	4.73
SEM	0.6	3.2	0.6	23	2.3	0.33

The genotypes IR11F 195 (5.40 t/ha) and IR09L 342 (5.09 t/ha) with 101 and 98 days to flowering, respectively, are significantly better than the best tolerant check Swarna *sub1* (4.73 t/ha) with 118 days to flowering under irrigated condition beside showing significantly better survival than Swarna *sub1* under 21 days complete submergence at early vegetative stage (Table 5.1). The other submergence tolerant genotypes like TP 30193-1 (4.81 t/ha) and IR10F 365 (4.61 t/ha) are at par with Swarna *sub1* and Swarna in terms of grain yield but duration was earlier by more than two weeks.

Evaluation of rice genotypes for shallow lowland

Shallow lowlands are favourable ecosystem for growing rice crop. These are free from flood and there is provision for supplementary irrigation during rainless period of crop growth. Eleven improved rice genotypes were evaluated along with Naveen (mid-early duration) and Rajendra Sweta and Swarna (late duration) as check during *kharif* 2020. Performance of these genotypes is presented in Table 5.3.

Table 5.3. Performance of rice genotypes under shallow lowland condition

Genotype	Days to flowering	Plant height (cm)	Panicle length (cm)	Panicles/ m^2 (nos)	Harvest index	Grain yield (t/ha)
RP5377-3	98	123.3	22.8	336.3	36.7	3.91
RP5535-8	110	121.4	25.1	329.7	34.1	4.46
RP5366-13	107	123.1	24.6	371.7	34.4	4.28
RP5535-22	107	121.1	25.4	413.3	38.1	4.95
RP5484-6	105	120.2	24.7	431.0	35.4	4.24
RP5377-19	109	130.4	27.1	318.7	21.7	2.52
RP5410-27	105	111.7	23.8	362.7	27.7	3.27
RP5504-39	116	133.1	25.5	347.0	34.1	4.08
RP5537-41	111	128.0	23.9	417.7	40.0	4.94
RP5423-62	101	120.1	26.2	406.7	40.2	4.86
RP5528-85	111	115.1	23.7	400.0	36.9	4.51
Naveen	99	123.7	26.9	431.0	28.9	2.73
Rajendra Sweta	121	90.5	21.9	362.7	21.1	3.66
Swarna	121	97.8	24.7	479.3	30.9	3.84
SEM	0.7	4.0	0.5	25.8	2.1	0.27

RP5535-22 (4.95 t/ha), RP5537-41 (4.94 t/ha), RP5423-62 (4.86 t/ha) and RP5528-85 (4.51 t/ha) were the top four elite genotypes with significantly higher grain yield than the best check variety Swarna (3.84 t/ha). Crop duration of these genotypes were 10 days earlier than Swarna and Rajendra Sweta. Therefore, these genotypes are required to be further evaluated through nomination to AICRIP.

Collection of popular rice landraces in flood-plains of eastern India

Twenty eight accessions of traditional rice germplasm have been collected from flood-prone areas in Madhubani and Darbhanga district in Bihar during *kharif* 2020. Flooding is a regular phenomenon in these areas with varying depth and duration of submergence. Occurrence of flood also varies from year to year. Rice crop may be subjected to flooding at any stage from seedling to ripening depending on the time of onset and depth and duration of flooding (Fig. 5.5). In low lying areas, rice fields remain inundated with water for prolonged period even after recession of flood. Modern high yielding semi-dwarf rice varieties and hybrids cannot sustain in such type of ecosystem. Therefore, in this ecosystem, farmers strategically grow traditional rice varieties (locally called *Agahnidhan*) which are characterized by their tall stature, high tillering ability under water stagnation, submergence tolerance, longer crop duration,

Fig. 5.5. Regenerated crop of IR09L 342 after de-submergence

photo period sensitivity and special grain qualities among others. Among the 28 collected accessions form such areas, 16 were short grain aromatic rice.

Performance of Different Rice Genotypes as Influenced by Different Doses of Nitrogen

A field experiment was conducted at the experimental farm of ICAR-RCER to evaluate the effect of different doses of nitrogen (N) and cultivar/ variety (V) on growth, yield, and N content of leaf at different growth stages of rice. For developing strategies on precision N management, an android based application has to be developed based on leaf colour, canopy development. For that purpose, at three growth stages (29, 43, 60 DAT), images of flag leaf as well as canopy were taken which will be analyzed further.

Chlorophyll content of flag leaf was determined at 59 DAT and it was found that chlorophyll b and total chlorophyll content varied considerably among the N treatments. N200 and N240 recorded significantly higher chlorophyll content than the rest of the treatments. Among the varieties, chlorophyll content was almost similar except Arize 6444 which showed higher chlorophyll content. Yield responses of Swarna Shreya, Swarna Samridhi, Swarna Shakti, Sahbhagi and Arize 6444 were 8, 8.5, 9.2, 10.3, 12.7 and 9.8 kg per kg applied N, respectively. Therefore, Arize 6444 was most responsive variety while Swarna Shreya was least responsive towards applied N (Fig. 5.6).

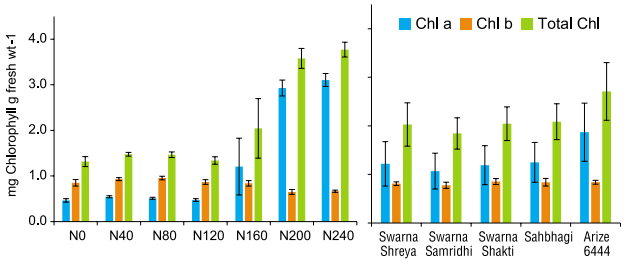


Fig. 5.6. Chlorophyll content of flag leaf as affected by different nitrogen doses and varieties in rice. Vertical bars represent standard error of the mean.

Response of Drought Tolerant Rice Cultivars to Iron and Zinc

A field experiment was conducted during *kharif* 2020 at the experimental farm of the institute under ICAR Window 3; a collaborative project of ICAR & IRRI, to study the response of iron and zinc foliar application on growth and yield of drought tolerant rice cultivars. The experiment was undertaken for 4 rice cultivars, i.e., Swarna Shreya, Swarna Shakti, Sahbhagi Dhan and DRR Dhan-42. The foliar application of $ZnSO_4$ and $FeSO_4$ was done with 1% $FeSO_4$ foliar spray, 1% $ZnSO_4$ foliar spray and in combination of 1% $FeSO_4$ +1% $ZnSO_4$ foliar spray. The effect was compared with control where no foliar spray was done. Experimental data analysis showed that the grain yield has been significantly affected by these treatments. The yield parameter of the selected cultivars and its interaction with foliar application of zinc and iron is depicted in Table 5.4. Foliar application of $ZnSO_4$ and $FeSO_4$ accounted for significantly higher test weight, harvest index, total chlorophyll and carotenoid content in all four rice varieties compared to control. The higher values of these attributes resulted in higher grain yield. The range of grain yield among different treatments varied from 4.31 t/ha to 6.12 t/ha. The highest and significantly more grain yield of 6.12 t/ha over yield of 5.61 t/ha without foliar spray was observed in cultivar Swarna Shreya with combined foliar spray of 1% $FeSO_4$ + 1% $ZnSO_4$.

Organization of Field Days under FLDs programme

Field days were organized by ICAR RCER, Patna at Phusbangla (Kawakol) village in Nawada district, Pandeypatti village in Buxar District and Darha (village), Barhat in Jamui district of Bihar on 16th, 20th and 22nd October, 2020, respectively with objective to see the performance of newly released aerobic rice variety Swarna Shreya at farmer's field grown under frontline demonstration (FLDs) programme (Fig. 5.7). Besides, field days were also organized at Barmasi village, Ramgarh (Jharkhand) and Garsanda (village), Barhat in Jamui (Bihar) on 22nd and 16th October, 2020 with objective to see the performance of newly released drought tolerant rice variety Swarna Shakti Dhan at farmer's field grown under FLDs programme. Moreover, a field day was also organized at Kaduatari (village), Barhat in Jamui (Bihar) on 17th October, 2020 with objective to see the performance of rice variety Swarna Samriddhi Dhan grown under FLDs programme. More than 300 farmers, scientific staff of Krishi Vigyan Kendra, and scientists of ICAR RCER participated in the field days progarmme.

Table 5.4. Yield parameters of rice as influenced by variety and foliar application of $ZnSO_4$ and $FeSO_4$

Treatments	Biological yield t/ha	Grain yield t/ha	Straw yield t/ha	HI (%)	Test weight (g)	Total no. of grains/ panicle	No. of chaffy grain/ Panicle	No. of filled grain/ panicle	Total chloro-phyll (mg g^{-1} fresh weight)	Carot-enoid (µg g^{-1} fresh weight)
Swarna Shreya (Control)	13.60	5.61	9.89	37.05	17.99	128.80	35.70	93.10	3.19	4.21
Swarna Shreya (1% $FeSO_4$)	15.00	5.82	9.18	39.73	21.60	174.00	57.40	116.60	4.30	4.70
Swarna Shreya (1% $ZnSO_4$)	14.75	5.92	8.84	40.22	21.25	167.50	49.90	117.60	3.63	4.00
Swarna Shreya (1%$FeSO_4$ + 1% $ZnSO_4$)	15.50	6.12	7.48	45.28	21.63	167.50	34.50	133.00	4.53	5.68
Swarna Shakti (Control)	14.75	4.61	11.99	28.54	21.83	145.90	33.90	112.00	3.90	4.37
Swarna Shakti (1% $FeSO_4$)	15.75	4.50	11.25	30.52	23.69	176.00	54.20	121.80	4.00	5.03
Swarna Shakti (1% $ZnSO_4$)	16.05	5.06	10.99	31.54	24.55	175.40	46.30	129.10	3.97	4.53
Swarna Shakti (1%$FeSO_4$ +1% $ZnSO_4$)	16.60	5.08	10.62	32.41	24.76	197.90	65.10	132.80	4.42	4.93
SahbhagiDhan (Control)	14.75	4.66	10.44	30.97	21.58	154.00	43.30	110.70	3.23	3.89
SahbhagiDhan(1% $FeSO_4$)	15.10	4.75	10.25	31.58	22.07	179.50	51.70	127.80	3.65	3.99
SahbhagiDhan(1% $ZnSO_4$)	15.00	4.85	10.90	31.19	21.87	182.60	60.60	122.00	3.37	3.93
SahbhagiDhan (1%$FeSO_4$ + 1% $ZnSO_4$)	15.75	5.00	9.75	33.86	22.83	191.80	54.00	137.80	4.61	5.45
DRR Dhan 42 (Control)	15.50	4.31	11.19	27.91	21.91	137.50	40.20	97.30	3.87	4.34
DRR Dhan 42 (1% $FeSO_4$)	16.60	4.87	11.73	29.36	23.27	168.00	35.20	132.80	4.51	5.16
DRR Dhan 42 (1% $ZnSO_4$)	16.50	5.05	11.45	31.01	22.66	170.20	54.00	116.20	3.93	4.38
DRR Dhan 42 (1%$FeSO_4$+ 1% $ZnSO_4$)	16.40	5.06	11.34	31.33	24.83	178.50	37.50	141.00	4.78	5.34
C.D.	NS	0.86	NS	7.45	2.80	26.45	14.02	NS	0.55	0.53
SE(m)	0.78	0.30	0.84	2.57	0.96	9.11	4.83	9.85	0.19	0.18

Fig. 5.7. Interaction with farmers during field day programme

All participants visited the demonstration plots and shared their experiences during field days. The farmers were highly impressed by the water stress tolerant characteristics of these rice varieties.

Breeder Seed Production of Rice Varieties

Breeder seeds of rice varieties Swarna Shreya (2.6 t), Swarna Shakti Dhan (1.3 t) and Swarna Samriddhi Dhan (1.8 t) were produced by ICAR RCER, Patna during *kharif* 2020. The representatives of National Seed Corporation (NSC), Patna, Bihar State Seed Certification Agency (BSSCA), Patna and scientific staff of ICAR RCER, Patna participated in monitoring of breeder seed production of these rice varieties. Besides, nucleus seeds (3.25 quintals) of rice varieties Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan were also produced during *kharif* 2020. Moreover, truthfully lebelled (TL) seed of rice varieties Swarna Shreya (1.7 t), Swarna Shakti Dhan (0.1 t) and Swarna Samriddhi Dhan (1.6 t) were produced during *kharif* 2020.

Seed Distribution of Rice Varieties

The seed of climate resilient high yielding rice varieties Swarna Shreya, Swarna Shakti Dhan and Swarna Samriddhi Dhan were distributed on foundation day of ICAR RCER, Patna to more than 100 farmers belonging to different districts of Bihar, Assam, Jharkhand, Odisha and West Bengal for on-farm testing during *kharif* 2020. Seed of these rice varieties were also distributed to more than 70 farmers belonging to Ramgarh district of Jharkhand and Jamui, Buxar, Gaya and Nawada districts of Bihar

for frontline demonstrations (FLDs) during *kharif* 2020. Besides, seeds of promising rice genotypes for drought tolerant and suitable for aerobic conditions were also distributed to the farmers of different districts of Bihar for on-farm evaluation during *kharif* 2020 (Fig. 5.8.).

Fig. 5.8. Seed distribution of rice varieties

Maintenance and generation advancement of rice breeding materials

One hundred ten rice genotypes comprises of advanced breeding lines and released varieties of different duration were grown, purified and maintained in rice cafeteria during *kharif* 2020 (Fig. 5.9). Besides, three F_4, thirteen F_5, five F_6 and eleven F_7 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 seeds of rice breeding materials have been retained for further evaluation and generation advancement.

Fig. 5.9. Different rice genotypes in cafeteria

Wheat

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

Sixteen wheat genotypes were evaluated during *rabi* season of 2019-20 at institute experimental farm and KVK Buxar under timely sown (27 November, 2019) and late sown conditions (28 December, 2019) in order to study the effect of water deficit and heat stress on physiological traits and yield attributes. The maximum temperature at the time of anthesis to grain filling for timely sown crop ranged from 22 to 28°C while maximum temperature ranges at anthesis for late sown crop was 21.4-34.8°C, indicating vulnerability of late sown crop to moderate heat stress during anthesis. Study showed that the duration of crop was significantly reduced under late sown condition (TS = 120 Days, LS = 105 days for Patna and TS = 122 Days, LS = 117 days for Buxar region), which in turn lead to lower biomass accumulation. The grain yield (kg/ha) was significantly declined by 18.8% for Patna and 25% in Buxar from timely to late sown condition. Apart from this, biological yield, test weight, ear length also declined under late sown condition in both the growing areas (Table 5.5).

Physiological traits like relative water content (RWC) and Chlorophyll content were also declined from timely sown to late sown condition. The maximum reduction in RWC (5.9%) and Chl (16.3%) were observed under combined stress condition (terminal drought and heat). Biochemical traits like TBARS content (indicating lipid peroxidation) and Proline level (indicating water deficit stress) were higher under both stress conditions, indicating the negative effect of stresses on wheat genotypes. Overall, negative effect of combined stress was more pronounced as compared to normal sown and individual stress. Further, when drought combined with heat, the effect was significantly severe. At genotypic level, varieties WH 730, NW1014, HD3118, 3010 and HD2967 were performing better under late sown stress condition (Fig. 5.10).

Studies on Weed and Seed Bank Dynamics in Different Cropping Systems in the Middle Indo Gangetic Plains (IGP)

The present study was conducted at the institute farm with an objective to study (i) the weed flora shift in different cropping systems, (ii) the impact of different cropping systems on weed seed bank dynamics

Table 5.5. Effect of water deficit and heat stress on yield and yield attributes of wheat genotypes grown under different experimental conditions

	Timely sown			Mean	Late sown			Mean	% reduction TSC to LSC	%reduction TSC to LSRD
	TSC	TSVD	TSRD		LSC	LSVD	LSRD			
Yield and yield attributes										
GY (t/ha)	4.18	3.35	3.72	3.75	3.51	2.81	3.13	3.15	16%	25%
BY (t/ha)	10.31	8.84	9.31	9.49	8.77	7.49	7.82	8.03	15%	24%
TGW (g)	38.0	36.5	37.2	37.2	37.2	35.7	36.5	36.5	2%	3.9%
EL (cm)	10.5	9.7	10.0	10.1	10.0	9.2	9.5	9.6	4.8%	9.5%
Tillers/ m^2	610	560	582	584	569	535	550	551	6.7%	9.8%
HI (%)	40.6	37.9	40.0	39.5	40.3	38.4	39.7	39.5	0.7%	5.4%
Factors										
LSD (P=0.05): TS (T X V) BY: 0.485;GY: 0.0877;TGW: 0.2332 Tiller: 24.561;EL: 0.9607;HI: 1.865					LSD (P=0.05): LS (T X V) BY: 0.7902;GY: 0.0896;TGW: 0.2336 Tiller: 70.701;EL: 0.9172;HI: 6.8337					

TSVC – timely sown vegetative stage control condition, TSVD – timely sown vegetative stage drought condition, TSRC – timely sown reproductive stage control condition, TSRD – timely sown reproductive stage drought condition, LSVC – late sown vegetative stage control condition

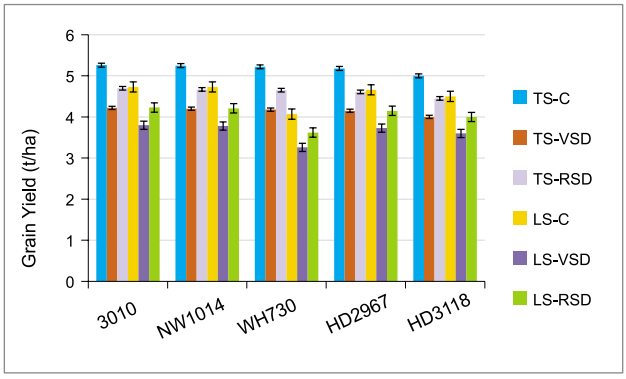


Fig.5.10. Grain yield of top 5 promising wheat genotypes under timely and late sown conditions.
TS-C: timely sown control condition, TSVSD – timely sown vegetative stage drought condition
TSRSD: timely sown reproductive stage drought condition; LS-C: late sown control;
LS-VSD: late sown vegetative stage drought; LS-RSD: late sown reproductive stage drought

and iii) to devise suitable weed management strategy. Out of which, first objective was undertaken in the year 2019-20. From the study it was observed that weeds of Poaceae family dominated in most of the cropping systems taken under the study followed by Amaranthaceae and Papilionaceae.

Further, frequency, dominance and abundance of weed species *viz. Cyperus rotundus* (1.0, 24.0,24.0), *Chenopodium album* (1.0, 10.0, 10.0), *Anagallis arvensis* (1.0,11.67, 11.67), *Solanum nigrum* (1.0. 42.0,42.0), *Cichorium intybus* (1.0, 15.0,15.0/1.0, 21.33, 21.33/1.0,99.67,99.67/1.0, 91.67,97.67) *Alternanthera paronychioides (1.0, 23.0, 23.0), Cynodon dactylon (1.0,7.33,7.33) and Leptochloa chinensis (0.67, 7.33, 11.0) were found higher in* rice- wheat, rice- maize, rice- lentil-moong, guava-turmeric, okra-cauliflower-onion, rice- cauliflower-vegetable, onion-moong, jowar-chickpea-fallow, lemon- turmeric and cowpea-tomato-okra cropping systems, respectively.

Fig. 5.11. Study on weed seed bank

6. Pulses

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

Evaluation of long duration pigeon pea germplasm

Based on four years of selection, the pigeon pea lines IC 611683, IC 611232, IPA-203 and type-7 were found suitable for cultivation under eastern plateau and hill region. Among them, highest yield was obtained in IPA-203 (Table 6.1). IPA-203 and Type-7 were long duration genotypes and IC 611683 and IC 611232 were of medium duration which could be harvested during December.

Table 6.1. Performance of promising genotypes of pigeon pea (long duration)

Genotype	Days to 50% flowering	Yield (q/ha)	100 seed weight (g)
IPA-203	145	21.77	9.37
Type-7	155	14.02	13.65
IC 611683	117	12.20	10.86
IC 611232	116	15.50	10.16

Evaluation of short duration pigeon pea germplasm

Seven short duration genotypes collected from ICRISAT, Hyderabad *viz*., ICPL-92047, ICPL-81-3, ICPL-88034, ICPL-11318, ICPL-11303, ICPL-20327 and ICPL-20325 were evaluated in a replicated trial (Table 6.2). ICPL-92047, ICPL-81-3, ICPL-88034 and ICPL-20325 were found promising among the short duration group with respect to yield attributes and yield.

Chickpea

Two station trials each comprising the same set of 12 treatments including 2 check varieties (released for north east plains) were conducted both under normal irrigated and rainfed conditions (during the 3rd week of November 2019) following randomized complete block design (RCBD) in three replications to select the promising genotypes for the north east plains zone (NEPZ) at ICAR RCER, Patna. The test entry 'DBGC 3' (2209 kg/ha), with test weight of 26 g and maturity period of 144 days showed an yield advantage over the best check 'Pusa 1103' (1920 kg/ha) by more than 15% under irrigated condition (Table 6.3). In rainfed trial, the same entry 'DBGC 3' performed best and yielded 2234 kg with 100 seed wt and maturity duration of 26 g and 141 days, respectively. During the year 2019-20, there was adequate and well distributed rainfall during crop growing season, resulting in almost comparable yield realization in irrigated as well as rainfed condition.

Table 6.2. Evaluation of promising genotypes of pigeon pea (short duration)

Genotype	Days to 50% flowering	Plant height (m)	Yield (q/ha)	100 seed weight (g)	Shelling %
ICPL-92047	82.5	2.5	15.28	7.66	75
ICPL-81-3	92.0	2.5	12.00	7.03	64
ICPL-88034	91.0	2.8	12.17	9.91	75
ICPL-11318	55.0	1.9	6.11	8.08	79
ICPL-11303	67.5	2.1	7.64	8.86	75
ICPL-20327	65.0	2.0	9.33	8.01	75
ICPL-20325	73.0	2.1	12.55	8.10	78
C.D (0.05)	6.44	0.16	2.67	0.68	10.45
C.V	5.02	5.54	31.61	16.93	8.90

Table 6.3. Mean performance of promising chickpea genotypes in irrigated and rainfed situations under normal sown conditions

Genotypes	Irrigated condition			Rainfed condition		
	Yield (kg/ha)	100 seed wt (g)	Maturity period (days)	Yield (kg/ha)	100 seed wt (g)	Maturity period (days)
DBGC 1	2040	31	144	1979	31	140
DBGC 2	1843	32	142	1884	31	141
DBGC 3	2209	26	144	2234	26	141
DBGC 4	1627	30	145	1991	28	141
Pusa 372	1800	15	143	1831	14	140
Pusa 1103	1920	25	144	1769	25	141
Pusa 3043	1725	22	142	1843	22	139
LSD (0.05)	198	2.12	1.32	189	1.61	0.45

Heat stress studies in chickpea

Two trials each with the same set of 12 genotypes each in RCBD with three replications were sown on January 02, 2020 to assess their performance for heat and drought stress tolerance. In one trial was given irrigation at branching stage. Due to intermittent rain during seed-filling period, the second irrigation was not provided. The second trial was kept completely rainfed in order to observe the cumulative effects of both heat and drought stress. Due to well distributed rainfall and optimum cardinal growth temperatures from mid of February to till first week of April, individual and cumulative effects of heat and drought stress were not realized in terms of reduction in yield and its component traits. The performance of the test genotype 'DBGC 4' and the released cultivar 'Pusa 3043' were comparable under heat stress and heat + drought stress conditions (Table 6.4).

Table 6.4. Mean performance of promising chickpea genotypes under heat stress condition

Genotypes	Irrigated condition			Rainfed condition		
	Yield (kg/ha)	100 seed wt (g)	Maturity period (days)	Yield (kg/ha)	100 seed wt (g)	Maturity period (days)
DBGC 1	1652	26	108	1545	27	106
DBGC 2	1655	27	107	1098	31	106
DBGC 3	1552	24	106	1514	26	105
DBGC 4	1683	27	109	1879	28	108
Pusa 372	1661	16	106	1187	15	108
Pusa 1103	1761	24	106	1547	26	105
Pusa 3043	1894	22	106	1659	23	105
LSD (0.05)	189	2.02	1.12	179	1.55	0.65

Screening of Chickpea genotypes against phyllody disease under irrigated and rainfed conditions with heat stress

Thirteen chickpea genotypes were screened against chickpea phyllody under irrigated and rainfed conditions with heat stress. Genotypes varied in their response against the disease (Table 6.5). Most of the genotypes *viz.* Pusa 256, Pusa 547, Pusa 372, DBGC 3, Pusa 1103, Pusa 3043, DBGC4 and GNG1581 were showing resistance under irrigated as well as rainfed conditions, however genotypes ICC 4958 and JG 14 were highly resistant to phyllody under both the conditions. DBGC 1, DBGC 2 and KWR 108 were moderately susceptible under irrigated conditions (Fig. 6.1).

Table 6.5. Response of chickpea genotypes to phyllody under different conditions

Genotypes	Disease reaction under different conditions	
	Irrigated	Rainfed
Pusa 256	Resistant	Resistant
Pusa 547	Resistant	Resistant
DBGC 1	Moderately Susceptible	Resistant
Pusa 3043	Resistant	Resistant
DBGC 2	Moderately susceptible	Resistant
Pusa 372	Resistant	Resistant
DBGC 3	Resistant	Resistant
Pusa 1103	Resistant	Resistant
DBGC 4	Resistant	Resistant
KWR 108	Moderately susceptible	Resistant
GNG 1581	Resistant	Resistant
ICC 4958	Highly resistant	Highly resistant
JG 14	Highly resistant	Highly resistant

Fig. 6.1. Phyllody symptoms in chickpea genotype DBGC 1

Performance of advance breeding lines in AICRP/State trials

In chickpea, one entry each for timely sown condition (DBGC 1) and rainfed condition (DBGC 4) were put to IVT of AICRP on chickpea during 2019-20. One entry 'DBGC 1' has been promoted to AVT-I for East Central Zone. One entry each in lentil (DBGL 105) and chickpea (DBGC 2) was put in the state varietal trial during 2019-20.

Donor Registered

A pigeonpea "cleisto" genotype 'RCEA 14-5' (IPA 203 × ICPL 87154) which have shown zero percent natural crossing with yield at par with 'IPA 203' has been registered with National Bureau of Plant Genetic Resources, New Delhi. The genotype 'RCEA 14-5' has been assigned the registration number *INGR 20024*.

Performance of Advance Breeding Lines in Wilt Sick Nursery

Four genotypes of chickpea (DBGC 1, DBGC 2, DBGC 3 and DBGC 4) and three genotypes of lentil (DBGL 62, DBGL 105 and DBGL 135) were put to pathological trials for assessment of wilt reaction at Tirhut College of Agriculture, Dholi (Muzaffarpur). The data showed that all the genotypes of chickpea and two genotypes of lentil appeared resistant to moderately resistant against chickpea wilt and lentil wilt, respectively (Table 6.6 & 6.7).

Table 6.6. Wilt reaction of chickpea genotypes at TCA, Dholi (2019-20)

Test genotypes of chickpea	Mean wilting (%)	Wilt reaction
DBGC 1	7.56	R
DBGC 2	0.00	R
DBGC 3	10.99	MR
DBGC 4	0.00	R
JG 62 (S-check)	90.38	S

R: resistant; S: susceptible

Table 6.7. Wilt reaction of lentil genotypes at TCA, Dholi (2019-20)

Test genotypes of lentil	Mean wilting (%)	Wilt reaction
DBGL 62	21.25	MR
DBGL 105	13.83	MR
DBGL 135	38.73	S
Seohore 70-3 (S-check)	61.45	S

R: Resistant; S: Susceptible

Lentil

Two station trials, each comprising of 12 treatments were conducted under normal sown condition (3rd week of November 2019) following randomized complete block design (RCBD) in three replications to select the productive lentil genotypes/varieties for the north east plains zone (NEPZ) of Bihar. In the first trial, three test entries, 'RCEL 16-4' (1830 kg/ha), 'RCEL 16-5' (1717 kg/ha) and 'RCEL 16-2' (1561 kg/ha) excelled the best check 'HUL 57' (1249 kg/ha). In the second trial, the variety 'HUL 57' (1945 kg/ha) followed by 'DPL 62' (1884 kg/ha), 'KLS 218' (1864 kg/ha) and 'IPL 220' (1844 kg/ha) excelled all other lentil varieties (Table 6.8).

Heat stress studies in Lentil

Two trials each with the same set of 13 released cultivars each in RCBD with three replications were sown on January 03, 2020 to assess their performance for heat stress tolerance. Other variables were almost same as in chickpea. The performance of two cultivars, namely 'IPL 406' and 'IPL 220' were rated good under the conditions of individual heat stress and cumulative heat and drought stress. The details are mentioned in the Table 6.9.

Table 6.9. Mean performance of promising lentil cultivars under heat stress condition

Genotypes	Irrigated condition			Rainfed condition		
	Yield (kg/ha)	100 seed wt (g)	Maturity period (days)	Yield (kg/ha)	100 seed wt (g)	Maturity period (days)
IPL 406	945	3.38	99	1072	3.47	100
KLS 218	928	2.03	96	663	2.19	96
IPL 220	917	2.13	97	892	2.03	97
IPL 316	767	2.67	98	595	2.60	97
DPL 62	700	2.97	99	871	3.17	100
Arun	639	2.49	96	650	2.48	95
DPL 15	613	2.56	96	389	2.36	97
LSD (0.05)	109	0.12	0.72	99	0.15	0.75

Screening of lentil genotypes for resistance to stemphyllum blight and rust

Twelve lentil genotypes were screened for disease resistance to Stemphyllum blight (*Stemphylium botryosum Walr.*) and rust (*Uromyces viciae-fabae*) (Table

Table 6.8. Mean performance of promising genotypes and released cultivars of lentil under normal sown condition

Genotypes	Yield (kg/ha)	100 seed wt (g)	Maturity period (days)	Genotypes	Yield (kg/ha)	100 seed wt (g)	Maturity period (days)
RCEL 16-2	1561	2.33	118	IPL 220	1844	2.45	118
RCEL 16-3	940	2.19	119	HUL 57	1945	2.10	116
RCEL 16-4	1830	2.39	117	IPL 316	1681	2.68	117
RCEL 16-5	1717	2.20	117	KLS 218	1864	2.18	117
HUL 57	1249	2.16	118	DPL 62	1885	3.01	120
IPL 220	1060	2.02	118	DPL 15	1671	2.77	117
Pusa Vaibhav	1065	1.97	121	Pusa Masoor-5	1609	2.04	116
LSD (0.05)	157	0.11	1.12	LSD (0.05)	136	0.13	1.02

6.10). Out of twelve genotypes, nine genotypes (RCEL 16-2, RCEL 16-3, RCEL 16-4, RCEL 16-5, DBGL 62, DBGL 105, IPL220, HUL 57 and Pusa Vaibhav) were resistant to Stemphyllum blight, however, DBGL 135 was found susceptible. Two genotypes *viz.*, RCEL 16-6 and RCEL 16-7 expressed highly susceptible reaction to stemphyllum blight.Varible disease reactions were observed against rust. IPL220 and Pusa Vaibhav were resistant however RCEL 16-6 and RCEL 16-7 were highly susceptible to rust disease (Fig. 6.2). Detail of disease reaction of different lentil genotypes against rust is given in Table 6.10.

Table 6.10. Response of lentil genotypes to stemphyllum blight and rust

Genotypes	Stemphyllum blight (Scale 1-9)		Rust (Scale 1-9)	
	Disease score	Disease reaction	Disease score	Disease reaction
RCEL 16-2	2	R	4	MR
RCEL 16-3	2	R	4	MR
RCEL 16-4	1	R	2	R
RCEL 16-5	1	R	4	MR
RCEL 16-6	9	HS	7	HS
RCEL 16-7	9	HS	7	HS
DBGL 62	2	R	4	MR
DBGL 105	2	R	4	MR
DBGL 135	5	S	4	MR
IPL220	2	R	1	R
HUL 57	2	R	4	MR
Pusa Vaibhav	2	R	2	R

0: Highly resistant (HR), 1-2: resistant (R), 3-4: moderately resistant (MR), 5-6: susceptible, ≥ 7: Highly susceptible

Fig. 6.2. (a) Symptom of Stemphyllum blight and rust on susceptible genotype of lentil; (b) Field view of Stemphyllum blight resistant and susceptible genotypes of lentil.

Evaluation of lentil genotypes for resistance to stemphyllum blight and rust

Twelve lentil genotypes were screened for resistance against Stemphyllum blight and rust in varietal trail. Most of the genotypes (DPL 15, DPL 62, HUL 57, IPL 220, IPL 316, IPL 406, KLS 218 and Pusa Vaibhav) were resistant to Stemphyllum blight. Rest of the genotypes showed variable disease reaction like K 75 and Arun (moderately resistant); Pusa Masoor 5 (susceptible) and Ranjan (highly susceptible). Except three genotypes (HUL 57, Arun and Ranjan), all the tested genotypes were resistant to rust under field conditions. Details of Stemphyllum blight and rust reaction to different lentil genotypes are given in Table 6.11.

Table 6.11. Response of lentil genotypes to Stemphyllum blight and rust in varietal trial

Genotypes	Stemphyllum blight (Scale 1-9)		Rust (Scale 1-9)	
	Disease score	Disease reaction	Disease score	Disease reaction
DPL 15	2	Resistant	2	Resistant
DPL 62	2	Resistant	2	Resistant
HUL 57	2	Resistant	3	Moderately Resistant
IPL220	2	Resistant	2	Resistant
IPL 316	2	Resistant	2	Resistant
IPL 406	2	Resistant	2	Resistant
KLS 218	2	Resistant	2	Resistant
K 75	3	Moderately Resistant	2	Resistant
Arun	3	Moderately Resistant	3	Moderately Resistant
Pusa Masoor 5	5	Susceptible	2	Resistant
Pusa Vaibhav	2	Resistant	2	Resistant
Ranjan	9	Highly susceptible	5	susceptible

0: Highly resistant (HR), 1-2: resistant (R), 3-4: moderately resistant (MR), 5-6: susceptible, ≥ 7: Highly susceptible

Response of lentil genotypes to stemphyllum blight under heat stress conditions

Two experiments, one each in irrigated and rainfed conditions were conducted to screen the thirteen lentil genotypes against Stemphyllum blight. Genotypes were categorized on 0-9 scale. DPL 15, DPL 62, IPL220, IPL 406 showed resistant reaction under both the conditions (irrigated and rainfed), however, IPL 316, KLS 218 and Pusa Vaibhav were moderately resistant. HUL 57 was moderately resistant in rainfed conditions but moderately susceptible under irrigated conditions. DBGL 135 and Ranjan showed highly susceptible reaction under irrigated as well as rainfed conditions. Details of Stemphyllum blight reaction to different lentil genotypes are given in Table 6.12.

Table 6.12. Lentil genotypes and disease reaction in response to stemphyllum blight

Genotypes	Heat stress			
	Irrigated		Rainfed	
	Disease score	Disease reaction	Disease score	Disease reaction
DBGL 135	9	HS	7	HS
DPL 15	2	R	2	R
DPL 62	2	R	2	R
HUL 57	5	MS	3	MR
IPL220	2	R	1	R
IPL 316	3	MR	3	MR
IPL 406	2	R	1	R
KLS 218	3	MR	3	MR
K 75	5	MS	5	MS
Arun	5	MS	5	MS
Pusa Masoor 5	5	MS	5	MS
Pusa Vaibhav	3	MR	3	MR
Ranjan	9	HS	9	HS

0: Highly resistant (HR), 1-2: resistant (R), 3-4: moderately resistant (MR), 5-6: susceptible, ≥ 7: Highly susceptible

Field Evaluation of *Trichoderma* Isolates against Wilt Complex in Chickpea and Lentil

Nineteen *Trichoderma spp* were isolated from soil collected from root zone of different crops/plants from different locations in Patna and adjoining areas. Based on radial growth, siderophore production ability and dual plate culture against *Fusarium spp*, *Rhizoctonia solani* and *Sarocladium oryzae*, four isolates (T16, T17, T18 and T19) have been found most efficient *in vitro*. Futher efficacy of these four isolates were tested under field conditions in lentil (Var: Sehore Local and HUL 57) and chickpea (Var: JG 62 and L550) against wilt complex diseases. Seed treatment was done with *Trichoderma* @ 10 g/kg seeds before sowing of crops. To compare efficacy, seeds treated with Iprovalicarb 5.5% +Propineb 25% @ 0.2% and untreated seeds (control) were also sown and disease incidence (mortality %) was recorded at 30 DAS, 50 DAS and 70 DAS (Table 6.13). Isolates T18 and T19 were found most effective where disease incidence was significantly lower as compared to control. However their efficacy was lesser than chemical fungicide (Iprovalicarb 5.5% +Propineb 25%).

ICARDA Nursery (2019-20)

Under the project "Development of nutrient rich lines of pulse legumes for eastern India", a total of 72 breeding lines in chickpea and 50 breeding lines in lentil were procured from ICARDA through its regional Centre, Bhopal during 2019-20. These advance breeding lines were grown as per design and layout provided by ICARDA. During the year, a total of 18 promising lines of chickpea (Table 6.14) and 16 lines of lentil (Table 6.15) were selected based on yield and yield attributes (days to flowering, maturity period and seed size). Seeds of these genotypes were also analyzed for micronutrient contents.

Table 6.13. Field evaluation of *Trichoderma* isolates against wilt complex in chickpea and lentil

Lentil				Chickpea			
Treatments	Mortality (%) due to wilt complex diseases			Treatments	Mortality (%) due to wilt complex diseases		
	30 DAS	50 DAS	70 DAS		30 DAS	50 DAS	70 DAS
Variety: Sehore local				Variety: JG 62 (Desi type)			
T 16	4.70^{ab}	18.17^{d}	24.23^{d}	T 16	5.22^{bc}	9.29^{b}	13.72^{c}
T 17	5.14^{b}	17.53^{d}	22.00^{c}	T 17	4.96^{bc}	7.25^{ab}	11.79^{b}
T 18	4.18^{ab}	14.51^{c}	19.13^{b}	T 18	3.70^{ab}	5.55^{a}	10.32^{b}
T 19	4.19^{ab}	12.34^{b}	17.50^{b}	T 19	3.60^{ab}	5.21^{a}	10.05^{ab}
Iprovalicarb 5.5% + Propineb 25%	3.31^{a}	9.90^{a}	12.10^{a}	Iprovalicarb 5.5% + Propineb 25%	2.95^{a}	5.14^{a}	8.40^{a}
Control	7.63^{c}	25.39^{e}	39.65^{e}	Control	6.50^{c}	12.69^{c}	20.11^{d}
Variety: HUL-57				Variety: L 550 (Kabuli type)			
T 16	6.91^{c}	16.04^{c}	20.51^{c}	T 16	$5.14b^{c}$	9.20^{b}	15.69^{b}
T 17	7.00^{c}	14.96^{c}	17.62^{b}	T 17	$4.84b^{c}$	8.97^{b}	15.28^{b}
T 18	6.59^{bc}	13.19^{b}	17.67^{b}	T 18	4.60^{bc}	8.32^{ab}	14.61^{b}
T 19	5.53^{ab}	12.44^{b}	15.59^{b}	T 19	3.61^{ab}	7.89^{ab}	13.60^{b}
Iprovalicarb 5.5% +Propineb 25%	5.12^{a}	9.87^{a}	11.14^{a}	Iprovalicarb 5.5% + Propineb 25%	2.56^{a}	6.08^{a}	8.33^{a}
Control	8.83^{d}	21.44^{d}	30.01^{d}	Control	6.13^{c}	13.79^{c}	22.59^{c}

DAS: Days after sowing; T16, T17, T18 & T19 are *Trichoderma* isolates

Table 6.14. Promising lines of chickpea selected from ICARDA nursery

Designation of genotypes	Grain yield (kg/ha)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
FLIP13-353C (13122)	1167	64	7	89	8
ILC482 (13125)	1677	49	26	57	7
FLIP13-82C (13126)	1750	48	31	19	17
FLIP13-233C (13127)	1333	34	12	54	10
FLIP13-138C (13128)	1228	45	8	85	2
FLIP13-171C (13131)	1222	47	34	28	12
FLIP13-292C (13132)	1483	39	23	52	12
FLIP13-273C (13134)	1117	57	35	65	11
FLIP13-246C (13135)	1472	31	3	75	14
FLIP13-352C (13222)	1861	32	31	44	3
FLIP 82-150C (13225)	1439	31	30	41	12
FLIP13-265C (13226)	1445	33	34	15	10
FLIP88-85C (13227)	1711	63	9	68	2
FLIP13-243C (13228)	1672	62	48	79	21
FLIP13-187C (13231)	1445	35	13	54	6
FLIP13-233C (13232)	1617	52	31	61	17
FLIP13-254C (13234)	1639	51	33	62	14
FLIP13-288C (13235)	1783	56	3	88	10

*Figures in parentheses indicate ICARDA plot number.

Breeding Materials and Germplasm Maintained during 2019-20

The advance breeding lines (DBGC 1, DBGC 2, DBGC 3, DBGC 4, RCECK 15-1, RCECK 15-2, RCECK 15-3 and RCECK 15-4), ICRISAT germplasm line (ICC 4958) and released *Desi* germplasm (Pusa 256, Pusa 372, Pusa 547, Pusa 1103, Pusa 3043, KWR 108, JG 14, JG 16, GNG 1581 and GNG 2299) and Kabuli (IPCK 2002-29 and Pusa 1003) of chickpea varieties were grown and maintained. In addition, 3 advance breeding lines (each selected from a separate F_8 bulk received from IARI, New Delhi) were also grown.

In lentil, 18 advance breeding lines and 17 released varieties were grown, purified and maintained. A "super early" advance breeding line 'RCEL 16-1' (ILWL 118 × DPL 58) that started flowering from 40 days after sowing and matured in about 90 days was grown and multiplied for further evaluation in station trial in *rabi* season of 2020-21. This super early line has also shown field resistance to *Stemphyllum* blight that infected most of the early lentil genotypes including an earliest maturing lentil cultivar 'Ranjan' during 2019-20. Besides, three individual plant progenies from a local land race 'Gopalpur Local' were also grown, purified and maintained.

Table 6.15. Promising lines of lentil selected from ICARDA Nursery

Designation of genotypes	Grain yield (kg/ha)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
LIRL-21-50-1-1-1/DPL 62/10-1 (59001)	947	60	16	107	7
7978/ILWL 118/1-2 (59016)	840	88	15	44	14
8114/10956/11-4 (59017)	667	88	20	59	9
×2013_166 _ 8 (59021)	693	70	16	67	16
ILL4605 (59023)	813	67	20	57	2
6002/LIRL-21-50-1-1-1/17-7 (59024)	1073	59	25	100	16
99/209/LIRL-22-107/4-4 (59025)	987	99	24	104	6
LIRL-21-50-1-1-1/DPL 62/10-1 (59034)	1020	8	10	90	2
8114/10956/24-7 (59036)	993	82	33	69	30
6002/LIRL-21-50-1-1-1/24-1 (59037)	680	89	27	62	13
6994/10141/4-1 (59042)	740	82	16	102	17
10848/DPL 62/15-3 (59043)	1813	70	33	106	21
7978/ILWL 118/1-2 (59045)	800	74	15	54	1
6002/LIRL-21-50-1-1-1/17-7 (59047)	773	72	6	23	6
6002/LIRL-21-50-1-1-1/17-5 (59049)	887	99	31	81	10
LIRL-21-50-1-1-1/DPL 62/7 (59050)	767	44	20	92	4

*Figures in parentheses indicate ICARDA plot number.

In grass pea, three low ODAP (≤ 0.15%) released cultivars (Ratan, Prateek and Mahateora), eight advance breeding lines including one low ODAP line 'RCEGP 16-1' and three local land races were grown, purified and rejuvenated. Among low ODAP cultivars, 'Ratan' appeared to be more competitive and high yielding than the remaining two cultivars 'Prateek' and 'Mahateora' under field condition. However, local land races appeared more competitive, and were relatively less affected by powdery mildew and showed less aphid infestation under field condition.

Pulse Seed Hub

Under the aegis of NFSM funded Mega Project on "Creation of seed hubs for increasing indigenous production of pulses in India", breeder seed production of pigeonpea (IPA 203) and chickpea (Pusa 3043)

was taken up at ICAR RCER, Patna and KVK, Buxar, respectively. Quality seeds of other category (F/S, C/S and T/L) were also produced for selected varieties in lentil, chickpea, mungbean, urdbean and pigeonpea. Details of quality seeds produced are mentioned in the Table 6.16. During the year, newly constructed seed processing hall cum seed storage godown was inaugurated by Dr Punjab Singh, Hon'ble Chancellor of RLBCAU, Jhansi, Uttar Pradesh.

Table 6.16. Quality seeds of pulses produced under Pulse Seed Hubs during the

Crop	Variety	Class of seed	Quantity (tonnes)
Lentil	HUL 57	C/S, T/L	5.50
	PL 8	T/L	1.00
	IPL 220	Nucleus, T/L	0.30
Chickpea	Pusa 3043	Nucleus	0.10
	Pusa 3043	B/S	0.15
	Pusa 3043	T/L	1.60
	RVG 202	F/S	7.00
	Shubhra	Nucleus, T/L	0.15
Pigeonpea	IPA 203	Nucleus	0.02
		B/S	2.00
Mungbean	Samrat	T/L	0.60
	IPM 02-14	T/L	0.05
Urdbean	Uttara	T/L	0.01
	IPU 02-11	Nucleus	0.01
Total			18.49

B/S: Breeder seed; F/S: Foundation seed; CS: Certified seed; T/L: Truthfully labelled seed

7. Fruits

Performance of Small Seeded Litchi Selection CHL-8 under Eastern Plateau and Hill Region

A superior small seeded litchi selection CHL-8 was evaluated under rainfed condition for its quality and yield. The fruit weight (21.23g) was found significantly higher in CHL-8 than the litchi cultivar Bedana. The fruit length, peel percentage, seed percentage, average seed weight and pulp percentage were found similar in both the varieties. The juice percentage was significantly higher in CHL-8 (44.14 %) than Bedana (39.98 %). Moderately resistance to fruit borer was found to be the major advantage of CHL-8 over Bedana which is susceptible to fruit borer. The fruit yield of CHL-8 was 20-22 kg/plant as against 16-18 kg/plant in Bedana (Table 7.1 & Fig. 7.1).

Table 7.1. Comparison of CHL-8 and Bedana variety of litchi.

Characters	Bedana (Control) (mean ± SD)	CHL-8 (mean±SD)
Fruit weight (g)	18.15^{b}±2.21	21.23^{a}±1.30
Fruit length (mm)	30.31^{a}±1.46	31.22^{a}±0.98
Fruit diameter (mm)	32.94^{b}±1.27	34.63^{a}±0.99
Peel %	19.63^{a}±1.92	17.55^{a}±1.38
Seed %	7.66^{a}±2.43	7.30^{a}±2.61
Average seed weight (g)	1.38^{a}±0.44	1.56^{a}±0.57
Pulp %	72.71^{a}±3.61	75.15^{a}±3.46
Juice %	39.98^{b}±0.88	44.14^{a}±1.81
TSS (°B)	17.2^{a}±0.07	17.8^{a}±0.05
Fruit borer	Susceptible	Mod. resistant
Yield (kg/plant)	16-18	20-22

Improving Bearing Potential of Litchi Through Girdling of Primary Branches

Irregular bearing is a major constraint of China group of Litchi. Occurrence of late vegetative flushing in autumn or winter, with insufficient degree of dormancy has been attributed to this problem. The investigation was undertaken with objectives to study the effect of different girdling size on inducing regular bearing, improving the bearing potential and increase in yield and quality of litchi fruits in litchi

Fig. 7.1. Fruits of CHL-8 and Bedana of small seeded litchi

cultivar China. Based on the result of four years of study (2015 to 2019), girdling at 4 mm width on 50% primary branches during 1st week of September or after appearance of second vegetative flushes, produced regular flowering and fruiting without affecting the fruit quality in litchi (Fig. 7.2). The highest flowering (41.66%), fruit yield (50.30 kg/tree) and B:C ratio (2.91) were obtained with Girdling of 50% of primary branches with a width of 4mm (Table 7.2). Based on the performance of four years, the technology was recommended for farmers by ICAR-AICRP on Fruits.

Bagging of litchi bunches for quality fruits

Fruit cracking, sun burning and borer infestation are the major problem in litchi production in all litchi growing regions. The present investigation was undertaken during 2017 to 2019 on litchi cv. Shahi with objective to study the effect of bagging on fruit cracking, sun burning and borer infestation. Pooled analysis of three years of data indicated that bunch

Fig. 7.2. Flowering in girdled tree and new flush in non-girdled litchi tree

Table 7.2. Effect of girdling on yield and B:C ratio of litchi cv. China at Ranchi

Treatments	2015 (ON year)	2017 (OFF year)	2018 (ON year)	2019 (OFF year)	Pooled yield (kg/plant)	Pooled yield (t/ha)	B:C ratio	Healing period (days)
T1 (25% PB + 2mm G)	45.52	7.89	43.67	15.40	28.12	2.81	1.63	40-45
T2 (50% PB + 2mm G)	48.74	25.43	46.29	22.31	35.69	3.57	2.06	40-45
T3 (25% PB + 4mm G)	52.46	11.98	55.94	17.51	34.47	3.45	1.99	110-125
T4 (50% PB + 4mm G)	65.23	33.80	70.40	31.77	50.30	5.03	2.91	110-125
T5 (25% PB + 6mm G)	40.82	11.66	44.98	16.89	28.59	2.86	1.65	150-160
T6 (50% PB + 6mm G)	53.53	24.92	58.76	25.40	40.65	4.07	2.35	150-160
T7 (control)	38.35	4.09	42.27	12.27	24.25	2.42	1.44	-
CD at 5 %	4.24	3.98	5.16	2.12	4.51	0.45	-	-
SEm±	3.56	1.28	1.66	0.68	1.84	0.18	-	-

bagging with polypropylene bags (pink coloured) 25 days after fruit set resulted in significantly higher fruit weight (21.82g), fruit yield (46.78 kg/tree) and B:C ratio (3.26) (Table 7.3). Incidence of sunburn, borer infestation and cracking were significantly lower in all bagging treatments in comparison to control. During all the three years of study, highest sunburn were recorded in control. The total anthocyanin content of litchi peel was higher in all the bagging treatments with pink coloured polypropylene bags than that in white coloured bags (Fig. 7.3). Based on the three years of performance the technology was released by ICAR-AICRP on Fruits.

Fig. 7.3. Bagged bunches on litchi tree

Evaluation of subtropical peach varieties under Eastern Plateau and Hill Region

Five subtropical peach varieties were evaluated under rainfed condition of eastern plateau and hill for yield and quality parameters. The highest fruit weight, length, diameter were obtained in Early Grand variety. The fruit pulp (93.44%), TSS (12.5°B) and yield (31.25kg/plant) were found higher in the variety Florida Prince. Based on fruit yield and quality, variety Florida Prince and Early Grand performed better than other varieties (Table 7.4 & Fig. 7.4).

Table 7.4. Performance of subtropical peach varieties for yield and quality parameters

Varieties	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Pulp %	TSS (°B)	Yield (kg/plant)
Early Grand	93.23	57.20	56.10	91.77	13.3	27.50
Prabhat	62.82	48.80	47.80	93.02	14.2	17.63
Florida Prince	80.49	53.40	52.60	93.44	12.5	**31.25**
Pratap	69.99	53.90	49.60	90.56	11.7	14.75
N-22	90.75	55.10	55.50	93.20	12.5	8.90
SEm ±	1.50	0.95	0.79	1.61	0.22	2.06
CD at 5%	4.98	2.72	2.27	NS	0.73	6.42

Table 7.3. Effect of bunch bagging on fruit quality and yield at Ranchi

Treatment	Fruit cracking (%)	Fruit sunburn (%)	Fruit borer infestation (%)	Fruit weight (g)	Yield (kg/tree)	Pericarp anthocyanin content (mg/100g)	B:C ratio
T1 (PPW + 15 DAFS)	4.93	3.66	1.00	19.52	39.08	62.99	2.65
T2 (PPW + 25 DAFS)	6.11	4.64	0.67	19.93	46.55	61.58	3.24
T3 (PPW + 30 DAFS)	6.61	5.44	0.67	17.89	38.24	61.18	2.57
T4 (PPP + 15 DAFS)	3.54	2.79	1.17	21.60	43.78	73.48	3.05
T5 (PPP + 25 DAFS)	4.67	3.92	1.00	21.82	46.78	75.80	3.26
T6 (PPP + 30 DAFS)	5.16	4.32	0.33	20.25	44.37	74.02	3.09
Control	21.45	19.51	15.70	16.87	30.32	74.19	2.11
CD (5 %)	3.11	2.89	1.64	2.25	3.87	4.53	2.65
PPW: Polypropylene white, PPP: Polypropylene pink, DAFS: Days after fruit set							

8. Vegetables

Collection, Evaluation and Development of Bacterial Wilt Resistant (BWR) Germplasm of Brinjal

Evaluation of BWR germplasm

Four promising genotypes of brinjal found promising during the previous year were evaluated for yield and yield characters (Table 8.1). The highest fruit yield was recorded in HAB-915 and based on the performance, HAB-915 (RCBR-22) was submitted under Round Varietal trial of IET ICAR-AICRP(VC) 2019. Individual plant selection of F_8 and F_9 generations of Swarna Shyamali x Swarna Pratibha was carried out for wilt resistance and non spiny fruit character.

Table 8.1. Evaluation of promising genotypes of brinjal

Genotype	Yield (t/ha)	Days to 50% flowering	Fruit shape and colour
IC 545901	44.90	46.50	Long purple, green calyx
IC 545901-1	39.75	45.50	Long dark purple
IC 261786	40.56	41.50	Long green, green calyx
HAB-915	49.66	43.25	Round green stripes, green calyx
CV	14.93	7.75	

Evaluation of BWR F_1s

Best performing five F_1 hybrids i.e., Swarna Abhilamb x IC-545901, IC-261786 x IC-545901, HAB-906 x IC-545901, HAB-905 x IC-545901 and HABR-6 x IC-545901 selected from previous experiments were evaluated for yield, fruit characters and bacterial wilt resistance in field conditions (Table 8.2). The highest yield was recorded in IC 261786 x IC-545901 and the F_1 hybrid IC 261786 x IC-545901 (RCBLH-21/ Long Hybrid) was submitted under IET ICAR-AICRP(VC) 2020 for multi-location testing.

Genetic Enhancement of Tomato for Nematode and Bacterial Wilt Resistance through Molecular Markers

Evaluation of promising BWR F_1s

Promising bacterial wilt resistant and nematode tolerant crosses of tomato *viz.*, Swarna Lalima x HAT-311 (RCDTH-15/ Determinate Hybrid) (Fig. 8.1) under IET ICAR-AICRP(VC) 2019, HAT-296 x HAT-310 (RCDTH-21/ Determinate Hybrid) and HAT-296 x HAT-311 (RCDTH-11/ Determinate Hybrid) under IET AICRP(VC) 2020 (Table 8.3) were submitted for multilocation testing. Among six promising germplasm tested for yield and bacterial wilt resistance, RCDT 1608 (49.43 t/ha) was submitted for multilocation testing under AICRP(VC) 2019-2020 in Determinate Varietal trial

Table 8.2. Performance of promising F_1 hybrids of brinjal

Genotype	Yield (t/ha)	Days to 50% flowering	Fruit shape and colour
Swarna Abhilamb x IC 545901	58.00	43.75	Long purple, green calyx
IC 261786 x IC 545901	56.00	43.50	Long purple, green calyx
HAB-906 x IC 545901	51.28	44.0	Long purple, green calyx
HABR-905 x IC 545901	51.13	44.25	Long dark purple
HABR-6 x IC 545901	63.28	43.50	Oblong purple
C.V.	8.60	6.59	
F test	S	NS	

Fig. 8.1. Swarna Lalima x HAT-311

Table 8.3. Performance of promising F_1 hybrids of tomato

Crosses	Yield (t/ha)
HAT-296x HAT-310	45.79
Swarna Lalima x HAT-311	55.02
HAT-296 x HAT-311	63.37

Garden pea

Under the garden pea (Early) AVT-I trial of ICAR AICRP (VC), out of seven entries tested, the entries 2018/PEVAR-5 (16.69 t/ha) and 2018/PEVAR-3 (13.72 t/ha) were found promising in respect of marketable green pod yield. Under the AVT-II, out of six entries tested, the entries 2017/PEVAR-5 (16.40 t/ha) and 2017/PEVAR-6 (16.04 t/ha) were found promising in respect of marketable green pod yield.

Out of eight entries tested under garden pea (Mid) AVT-I, the entries 2018/PMVAR-6 (18.12 t/ha) and 2018/PMVAR-7 (15.00 t/ha) were found promising in respect of marketable green pod yield, while out of seven entries tested under AVT II, 2017/PMVAR-5 (18.57 t/ha) and 2017/PMVAR-6 (15.82 t/ha) were found promising in respect of marketable green pod yield.

Under the garden pea (Edible pod) AVT-I, out of seven entries tested, 2018/PEDVAR-1 (23.32 t/ha) and 2017/PEDVAR-2 (18.17 t/ha) were found promising in respect of marketable edible green pod yield.

French bean

Under the French bean (Pole) AVT-II, out of seven entries tested, 2017/FBPVAR-7 (20.57 t/ha), 2017/FBPVAR-2 (19.43 t/ha) and 2017/FBPVAR-5 (18.73 t/ha) were found promising in respect of marketable green pod yield.

Dolichus bean

Out of seven entries tested under Dolichos bean (Bush) AVT-II, 2017/DOLBVAR-2 (35.69 t/ha) and 2017/DOLBVAR-5 (35.66 t/ha) were found promising in respect of marketable green pod yield whereas under AVT I, out of the three entries tested, 2018/DOLBVAR-2 (39.67 t/ha) and 2018/DOLBVAR-4 (30.12 t/ha) were found promising in respect of marketable fresh pod yield.

Under the Dolichos bean (Pole) AVT-I, out of eight entries tested, 2018/DOLPVAR-8 (38.59 t/ha) performed the best in respect of marketable fresh pod yield, while under AVT-II, out of four entries tested, 2017/DOLPVAR-5 (28.36 t/ha) and 2017/DOLPVAR-3 (27.19 t/ha) were found promising in respect of marketable fresh pod yield.

Genetic Resource Management in Vegetable Crops

Nucleus seed production of 15 released and 16 pre-released varieties of leafy, underutilized and legume vegetables

Nucleus seeds of released varieties of garden pea Swarna Amar (36 kg) and Swarna Mukti (7 kg), snow pea Swarna Tripti (27 kg), bush type French bean Swarna Priya (18 kg), pole type French bean Swarna Lata (10 kg), pole type vegetable cowpea Swarna Sweta (0.5 kg), Swarna Harita (5.5 kg) and Swarna Suphala (1.5 kg), bush type vegetable cowpea Swarna Mukut (4 kg), pole type photosensitive lablab/dolichos bean Swarna Utkrisht (2.5 kg), pole type photo-insensitive lablab bean Swarna Rituvar (2.5 kg), vegetable soybean Swarna Vasundhara (47 kg), pole type lima bean Swarna Poshan (15 kg), vegetable Faba/winter bean Swarna Safal (27 kg) and leaf amaranth Swarna Raktim (2.6 kg) were produced for maintenance. Nucleus seeds of pre-released varieties of vegetable cowpea HACP-3 (1 kg), HACP-24 (2 kg), HACP-30 (1.2 kg), HACP-56 (1.5 kg), HACP-57 (2.5 kg) and HACP-65 (2 kg), early peas HAEP-1 (12 kg) and HAEP-2 (8 kg), bush type pencil bean HAFB-7 (30 kg), pole type photo-insensitive lablab/dolichos bean HADB-32 (15 kg) and HADB-119 (3 kg), leaf amaranth HAMTH-13 (4.2 kg) and HAMTH-21 (1.3 kg), Faba bean HAVFB-37 (37 kg), Basmatic vegetable soybean AGS-458 (78 kg) and pole type French bean HAPB-5 (10 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 pigeon pea (7) and yam bean (2) were maintained.

Enhancing Nutritional Security of Rural Households through Vegetable Based Nutri Garden in Bihar

Nutri-garden models of 100 m^2 (no. of family members-4) and 200 m^2 (no. of family members-8) area were developed and established at institute during *rabi* 2019-20. During standardization and validation of the model, ICMR recommendations of vegetable intake (200g fruit vegetables, 50g leafy vegetables and 50g root vegetables) was considered. Four *rabi* season leafy vegetables (palak, mustard green, coriander and methi), three *kharif* leafy vegetables (green Amaranth, red amaranth and Crotolaria), four fruit vegetables (tomato, brinjal, sem, pea) and three cole crops (cabbage, cauliflower, broccoli) in *rabi* season and ten fruit vegetable (Okra, cowpea, bottle gourd, bitter gourd, ridge gourd, sponge gourd,

chilli, brinjal, tomato and satputia) in *kharif* season and three root vegetables (radish, carrot, beet) in *rabi* season and one (sweet potato) in *kharif* season were included in both the model. In *rabi* season (duration 120 days), from 100m^2 model 195.02 g fruit vegetables and cole crops, 330.79 g leafy vegetables and 172.95 g root vegetables could be obtained per head per day for a family size of four members while from 200m^2 model 219.94 g fruit vegetables and cole crops, 131.59 g leafy vegetables and 204.81 g root vegetables could be obtained per head per day for family size of 8 member. Similarly in *kharif* season 287.74 g fruit vegetables and 42 g leafy vegetables were produced per head per day from 100 m^2 model and 310.65 g fruit vegetables 53.45 g 42 g leafy vegetables were produced per head per day from 200 m^2 model. The Nutri-garden models could provide a significant percentage of the recommended dietary allowance (RDA) for protein (55%), essential fat (25%), micronutrients like iron (46%), calcium (20%) and essential vitamin like vitamin A (138%), vitamin C (411%) and folate (100%) and niacin (14%).

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

The experiments were conducted at Ranchi, Patna and Ramgarh to understand the seasonal dynamics and management options of insect pests of cabbage and cauliflower. Diamondback moth, *Plutella xylostella (L.)* was recorded as major pest on main season cauliflower & cabbage. Painted bugs and *Spodoptera litura* were major insect pests in early summer season grown cauliflower (Fig. 8.2).

Weather parameters had significant effect on insect pest population build up in cauliflower and cabbage crop during year 2020. The minimum temperature showed significant negative correlation (-0.75; p≤0.1) with *Plutella xylostella* infestation while *S. litura* showed positive correlation with temperatures.

Fig. 8.2. Infestation of *Spodoptera litura* on early summer cauliflower

For the pest management strategies in cabbage and cauliflower, 12 treatments including rotation of insecticides were tested in randomized block design at experimental farm. Strategy of rotational and mixture (profenophos+cypermethrin @2.0ml) of insecticides followed by Flubendiamide 20% WG @ 0.4gm/L, spinosad 2.5% SC @ 0.3ml/L and Indoxacarb 14.5 SC @ 1.0 ml/l and cypermethrin 25 EC @2.0ml/L were found to be effective against *P. xylostella* and *S. litura* in both early summer and main season grown cabbage and cauliflower.

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

Based on surveys conducted in nearby forest and local markets of Ranchi, two types of naturally grown wild edible mushrooms were collected from Sal forest and identified as Tecnus (*Termitomyces* spp.) and Rugda (*Scleroderma* spp.). These wild edible mushrooms play an important role in improvement of rural livelihood. Among the wild edible mushroom, *Termitomyces* spp. is sold at a premium price @ Rs. 700-800/kg in the local market of Ranchi. This mushroom is known for its delicacy and taste.

Fig. 8.3. Wild edible mushroom collected from the local market and neighboring forest of Ranchi

Advance varietal trial of high yielding varieties/ strains of Oyster Mushroom (*Pleurotus* spp) on paddy straw substrates

Seven high yielding strains of *Pleurotus* species (PL-19-01 to PL-19-07) were evaluated to see their yield performance in term of biological efficiency under Ranchi condition during October 2019 to January 2020. Among the evaluated strains of *Pleurotus* species, highest biological efficiency was recorded in PL-19-04 (73.87%) followed by PL-19-07 (68.97%), PL-19-05 (67.83%), PL-19-02 (66.20%). Moreover, highest weight of fruiting body was recorded in PL-19-04 (12.10 g). Performance evaluation during July to September, 2020 also resulted in highest biological efficiency of the strain PL-19-04 (72.4%) followed by PL-19-07 (70.0%), PL-19-05 (69.0%), PL-19-02 (67.0%). Moreover, highest weight of fruiting body was recorded in PL-19-01, PL-19-04 and PL-19-07 (12.28, 12.27 and 12.19 g, respectively).

9. Makhana

Effect of Secondary and Micronutrients on Yield and Quality of Makhana

Impact of secondary and micronutrient was evaluated on yield and quality of makhana fruit. A field experiment was conducted wherein makhana was grown with seven treatment combinations [T_1 Control (no fertilization); T_2-100% NPK @100, 60 and 40 kg as N, P_2O_5 and K_2O/ha; T_3-NPK+Mg applied foliarly as 2.5% $MgSO_4$ solution; T_4-NPK+Zn @5kg/ha (applied as $ZnSO_4$ solution) T_5-NPK+Cu applied foliarly as 0.1% $CuSO_4$ solution; T_6-NPK+B @1.0kg/ha applied as Borax solution; T_7-NPK+Mg,Zn,Cu,B), laid out in randomized complete block design with each treatment replicated thrice (Fig. 9.1). Substantial yield improvement (26%) over control was observed by the application of recommended NPK dose. Sole application of any among the Mg, Zn and B in combination with NPK led to a further improvement of 16-17% in makhana yield over T_2. Interestingly, the treatments involving Cu spray resulted in the highest yield improvement in the study. Copper spray in combination with recommended NPK led to over 28% yield enhancement while copper spray in combination with NPK, Zn, Mg and B resulted in highest yield advantage (43%) over sole NPK application. Quality parameters including test weight of makhana seeds and nutrient contents also improved with application of secondary and micronutrients. The positive impacts of secondary and micronutrients, particularly Cu, can be attributed to increased numbers of fruits/plant, seeds/fruit and test weight of seeds along with general improvement in crop growth and health.

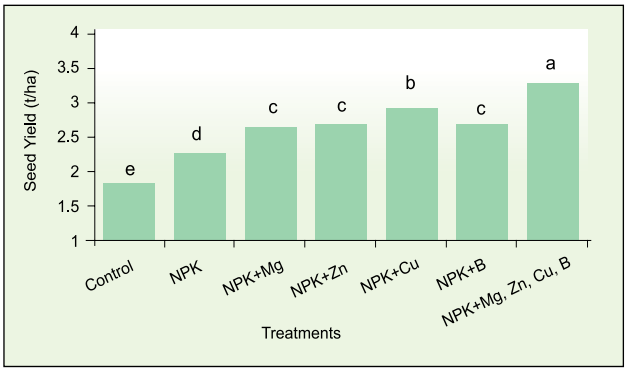


Fig. 9.1. Effect of secondary and micronutrients on seed yield of Makhana

Effect of Seed Size on Productivity of Makhana

The makhana seed of 8-10 mm diameter had the major share (by number) among different sizes of makhana seeds. The seeds sizes in between 8 to 10 mm diameter dominated among all seeds found in one fruit. There was some peculiarity in length of roots and shoots of the plant. The roots and shoots were recorded to be of almost equal length. No linear and consistent relationship could be recorded between the size of roots and amount of biomass produced. The number of seed development in individual fruit was inversely proportional to the size of seeds (Table 9.1 & 9.2, Fig. 9.2).

Table 9.1. Effect of seed size on initial morphological observations on root and shoot growth

Seed diameter (mm)	Length of shoot (cm)	Length of root (cm)	No. of leaves emergence	Germination (%)
< 8	30	33	03	40
8-10	27	28	03	60
10-12	35	35	03	40
12-14	25	26	03	35
14-16	28	30	03	35
16-18	-	-	-	-

Table 9.2. Effect of seed size on growth and yield potential of plant

Seed diameter (mm)	F.W. of 100 seeds (g)	F.W. of biomass (kg)	Avg. no. of seed / fruit	Avg. no. of fruit / plant	Avg. yield / plant (g)
< 8	65	8	35	10	210
8-10	80	10	60	12	691
10-12	98	7	40	08	320
12-14	110	6.5	25	06	168
14-16	113	7.1	20	06	118
16-18	-	-	-	-	-

Response of Nutrients on Soil Fertility Status and Productivity Potential of Water Chestnut

Five different NPK treatments *viz.*, NPK @ 40:20:20, NPK @ 60:30:30, NPK @ 80:40:40, NPK @

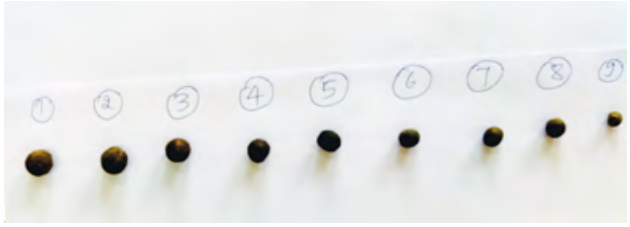


Fig. 9.2. Nine grades (sizes) of Makhana seed

100:50:50 and NPK @ 120:60:60 were applied to assess their effects on fertility status of soil and productivity potential of water chestnut plants. The treatment NPK @ 120:60:60 significantly recorded the highest organic carbon (OC), available N, P and K. The treatment of NPK @120:60:60 and 100:50:50 were found at par in improving the status of OC, available N, P and K content. The treatment effect was not evident in case of available micronutrients content. The yield potential of water chestnut was recorded to be almost equal in three NPK treatments like NPK @ 80:40:40, NPK @ 100:50:50 and NPK @120:60:60. The highest fruit yield was observed with 120:60:60 NPK treatments (21.5 t/ha) (Table 9.3-9.5).

Nutritional Analysis of Kernels of Water Chestnut

The nutritional properties of kernels of both local cultivar and germplasm brought from Madhya Pradesh were analysed at CFTRI, Mysore. The data revealed that thornless Red Jabalpur -2 germplasm performed better in respect of nutrients content [protein (8.8%), P (310 mg/100 g), K (771.2 mg/100 g), Na (105.2 mg/100 g), Ca (278.3 mg/100g), Mg (134 mg/100 g), Fe (5.9 mg/100 g), Mn (9.0 mg/kg), Cu (3.5 mg/kg) and Zn (28.9 mg/kg)] as compared to the local cultivar. (Fig. 9.3).

The amino acid profile study showed that the germplasm was superior in respect of different essential and non-essential amino acids.

Fig. 9.3. Freshly harvested water chestnut fruits

Table 9.3. The physical properties of soil under different NPK treatments

Treatments	Bulk density (Mg m-3)	Particle density (Mg m-3)	Water holding capacity at field capacity (%)	Water holding capacity at wilting point (%)
Control	1.35	2.48	36	18
NPK (@ 40:20:20)	1.33	2.50	36	19
NPK (@ 60:30:30)	1.30	2.47	38	20
NPK (@ 80:40:40)	1.24	2.44	42	24
NPK (@ 100:50:50)	1.22	2.40	41	25
NPK (@ 120:60:60)	1.22	2.40	44	25

Table 9.4. Effect of different doses of NPK on soil fertility status

Treatments	pH	EC (dS/m)	Org. C (%)	Av. N (kg/ha)	Av. P (kg/ha)	Av. K (kg/ha)	Yield (t/ha)
Control	7.1	0.20	0.54	218	28	225	16.5
NPK (@ 40:20:20)	7.0	0.28	0.56	240	29	228	16.4
NPK (@ 60:30:30)	7.3	0.26	0.67	241	30	237	19.0
NPK (@ 80:40:40)	7.2	0.34	0.67	253	31	238	21.0
NPK (@ 100:50:50)	6.0	0.35	0.78	264	34	240	21.0
NPK (@ 120:60:60)	6.0	0.34	0.81	265	37	242	21.5

Table 9.5. The status of available micronutrient status of soil under different NPK treatments

Treatments	Fe (mg/kg)	Mn (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
Control	24	16	1.21	0.24
NPK (@ 40:20:20)	28	17	1.21	0.23
NPK (@ 60:30:30)	27	18	1.32	0.33
NPK (@ 80:40:40)	28	19	1.35	0.33
NPK (@ 100:50:50)	30	20	1.36	0.37
NPK (@ 120:60:60)	30	20	1.37	0.37

Biology of *Singhara* Beetle *Galerucella birmanica* Jacoby on Water chestnut

Water chestnut (*Trapa natans* Linn.), belongs to the Trapaceae family and commonly known as '*Singhara*' or '*Paniphal*' in India. It is an aquatic, annual plant found in stagnant water in ponds, lakes, wetlands and tanks. In India, Water chestnut is mainly cultivated in the states, where high rainfall occurs, i.e., Bihar, Madhya Pradesh, Uttar Pradesh, Odisha, Assam, West Bengal and Tripura. It is mainly grown for human consumption either in the form of vegetable or in the form of flour to prepare chapatti or to prepare sweet dishes of many kinds. The fruits of the water chestnut are crispy in texture with remarkable nutritional and medicinal properties.

Water chestnut was observed to be severely affected by Singhara beetle *Galerucella birmanica* Jacoby (Chrysomelidae: Coleoptera), where both adult and grubs scraped the upper surface of green leaves causing severe defoliation. The life cycle of Singhara beetle, *G. birmanica* was observed to be 33- 46 days under laboratory conditions.

Egg

Gravid females laid eggs on upper surface of the leaves in small batches of 5-13 eggs. female could lay eggs up to 110-115 in her life. Egg viability ranged from 53-64 per cent. The freshly laid eggs were small, round in shape, light yellow in colour which gradually turned to reddish brown in colour before hatching. The incubation period varied from 3.5 to 5.5 days.

Grub

The neonate grubs were light brown in colour and gradually turned to dark brown with age. Immediately after hatching, they remained passive for a while and then gradually moved to different directions on the leaf and started biting on the upper epidermis of the leaf. Larvae had three instars to become pupa. Duration of the total larval period ranged from 12 to 14 days. Full grown larvae stopped its feeding and became sedentary by settling itself on leaf surface through a gummy secretion from its anus.

Pupa

The pupa was exarate, bright orange yellow in colour. The pupal period ranged from 3-5 days. The adult beetles were bright yellow in colour immediately after emergence and gradually turned to greyish brown. It was also observed that adult beetles were sluggish in nature and could fly occasionally.

To control this pest farmers are using synthetic insecticides which may lead to resistance to insecticides, resurgence of target pest, residues in food, contamination of groundwater, adverse effect on human health and mortality of non-target organisms. Bio control agents such as *Metarhizium anisopliae* IIVR strain (1 x 1010 cfu/ g) + Neem oil 1% or *Beauveria bassiana* IIVR strain (1 x 1010 cfu/ g) was found effective for controlling Singhara beetle. (Fig. 9.4-9.5)

Fig. 9.4. Eggs of Singhara beetle

Fig. 9.5. Water chestnut growing under field condition

10. Medicinal and Aromatic Plants

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

Collection and conservation of germplasm

Three medicinal plant species *viz*. *Psoralea corylifolia*, *Abrus precatorius*, *Desmodium gangeticum* were collected from NAU, Gujarat. Four plant species viz. *Curcuma aromatica, C. zedoaria, Justicia adhatoda* and *Phlogacanthus thyrsiformis* were collected from Kakching district Manipur. All plants belong to clade angiosperm in which two are monocots and five are dicot. The crops belong to three families and three orders. The family with a higher number of species is *Fabaceae*. All the collected plants were maintained in an herbal garden situated at institute farm, Patna.

Adaptability studies of newly collected medicinal and aromatic plants

All the newly collected plants were established at the institute for their adaptability study. The germination rate of Gokhru (*Pedalium murex)* and Sarpagandha (*Rauvolfia tetraphylla*) were 90% and 80%, respectively. The rest of the seven species were propagated asexually either through slips or cuttings or bulb. High field survival was observed in most of the plants except for vetiver and palmarosa, in which the survival percentage were 25% and 40%, respectively. The most severe insect species was termite which destroyed guggal and basil. Aphid was common for Madhunasini, Antamul and Aswagandha. Like the previous year, root rot disease was observed in Safed Musli, and blight in *Hemigraphis sp.* Jumping spider was observed in the basil plant from July end to October last week, 2020 (Fig. 10.1).

Evaluation of Kawach for bioactive compounds and bioactivity

Among various medicinal plants, *Mucuna pruniens* was selected for detailed profiling of the phenolic compounds using ultra-performance liquid chromatography with quadrupole time of flight mass spectrometry. More than thirty phenolic compounds were putatively identified in seeds and pods of mucuna. The total phenol content in the Mucuna pod was 337.5 mg GAE /100g. However, the total phenol content of the seed was approximately 1.6 times higher as compared to the pod. Flavonoids content of pod and seed was 165.7 mg/100g and 172.5mg/100g, respectively. Antioxidant activity measured by FRAP assay was 114.83 μmol TE/g for seed, which was approximately two times higher than pod i.e. 55.41 μmol TE/g. A similar trend was also observed for all other assays (CUPRAC, DPPH, and TEAC), however, CUPRAC method was proven superior amongst all. Both seed and pod showed prominent anti-diabetic potentiality as measured by alpha-glucosidase inhibition assay and alpha-amylase inhibition assay. Both seed and pod showed strong antimicrobial activities. Ethanolic extract of the pod was able to inhibit the growth of *E. coli*, *S.aureus*, *P.aeruginosa* both in ATCC and clinical strain.

Fig. 10.1. Jumping spider in basil found at medicinal garden

11. Farming System Research

Two Acre IFS Model

An experiment based on integrated farming system model in two-acre area comprising of field crops + horticultural crops + dairy + fishery was conducted at research farm of the institute. Three cropping seasons at the site, which include *kharif* season (June-Oct.), *rabi* season (Nov.-Feb.) and summer season (March- May) were undertaken for the study in sandy loam soil. The field experiment was set up to estimate the energy input-output, energy use efficiency, net energy gain and other energy indices for the different agricultural component in an integrated farming model. The crops grown under the two acre IFS model were field crops (rice, wheat, maize, gram and mustard), vegetable crops (okra, tomato and cabbage), fruit crops (lemon, guava and banana) and fodder crops (sorghum, cowpea, berseem, oat and maize). The IFS model also included cattle (2 milking cows); ducks (30 nos.) and vermicompost unit (Table 11.1). The model also possessed a pond of size 25 m x 40 m in which fishes were stocked of fingerling size at the rate of ten thousand per hectare and polycarp culture was practiced comprising of *Catla catla, Labeo rohita* and *Cirrhinus mrigala*. Thirty number of ducks (Khaki Campbell) were also reared in integration especially with fish pond. Inputs such as labour, fossil fuel, electricity, feed, seed, organic and inorganic fertilizers, machineries, water etc. and yield as grain, fruit, vegetables, meat, milk, manure, eggs and other products and byproducts were taken into consideration to calculate total energy input and output. The energy output for the fodder crops was estimated based on the dry matter of the green fodder grown under IFS model.

During the study, it was observed that total energy input required for the cattle rearing was estimated to be 90.30 GJ/m^2 milking cows/year. Majority of energy was consumed through feed intake and resulted energy efficiency ratio (EER) as 0.13. The least EER in dairy could be because of the energy stored in their body in the form of muscles, tissues or bones and their calves were not accounted in the analysis, but still, balanced ration is needed to enhance the milk production. The total energy input in field crops was estimated to be 14.53 GJ and duckery required 13.79 GJ energy. However, energy efficiency ratio (EER) was obtained to be highest in fodder crops (13.38) followed by field crops, vegetables, fruits, fish, cattle and duck, *viz.*, 7.91, 2.70, 2.03, 0.64, 0.16 and 0.13, respectively (Table 11.2). It is to mention that the energy efficiency ratio for the main output was highest in fodder crops i.e. 13.38 as it has not produced any by-product, while field crops, fruits, vegetable, fishery, duckery and dairy units have resulted in EER as 3.97, 0.54, 0.45, 0.64, 0.10 and 0.09, respectively. The integrated model can be adopted in the irrigated ecologies of eastern region of the country. Furthermore, the results have

Table 11.1. Details about the one-acre IFS model

Integration	Area (m^2)	Component	Output Main (kg)	Byproducts (kg)
Field crops	4000	Rice	2280.0	2530.0
		Wheat	400.0	580.0
		Maize	640.0	760.0
		Gram	230.0	290.0
		Mustard	220.0	380.0
Vegetables	500	Okra	450.0	410.0
		Tomato	700.0	315.0
		Cabbage	650.0	250.0
Fruit crops	500	Lemon	112.0	30.0
		Guava	250.0	50.0
		Banana	312.0	350.0
Fodder crop	1500	Sorghum	1400.0	nil
		Cowpea	550.0	nil
		Berseem	835.0	nil
		Oat	615.0	nil
		Maize	1140.0	nil
Fish	1000	Catla, Rohu, Mrigal	545.0	nil
Duck	30 Nos.	Meat Eggs (kg)	72.0 2150.0	1080.0 manure
Cattle	2 Nos.	Milk (L)	2573.0	4250.0 manure + 6500.0 L. of urine
Vermi-compost	100	Vermicompost	1600 .0	0

Table 11.2. Energy indices for one-acre IFS model

Energy indices	Field crop	Vegetables	Fruit	Fodder	Fish	Duck	Cattle	Vermi-compost
TEi (GJ)	14.53	4.32	3.32	6.11	3.94	13.79	90.30	2.93
TEo (GJ)	114.96	11.69	6.72	81.72	2.51	1.65	11.59	0.80
TEo main (GJ)	57.69	1.94	1.78	81.72	2.51	1.32	8.10	0.80
EER	7.91	2.70	2.03	13.38	0.64	0.12	0.13	0.27
EERm (main output)	3.97	0.45	0.54	13.38	0.64	0.10	0.09	0.27
NEG (GJ)	100.44	7.36	3.40	75.61	-1.42	-12.14	-78.71	-2.13
EP (GJ)	6.91	1.70	1.03	12.38	-0.36	-0.88	-0.87	-0.73
DE (GJ)	4.89	1.44	0.67	2.23	1.34	1.15	1.85	0.49
IE (GJ)	9.63	2.89	2.65	3.87	2.60	12.65	88.45	2.44
RE (GJ)	1.98	0.91	0.97	1.03	0.96	13.19	89.71	2.93
NRE (GJ)	12.55	3.41	2.35	5.07	2.98	0.60	0.59	0.01
HEP (GJ GJ^{-1})	63.75	14.06	11.59	78.97	5.13	2.63	8.85	1.63
WEP (GJ GJ^{-1})	83.49	14.32	19.38	47.13	1.23	-	-	-

Note: - TEi: Total input energy; TEo: Total output energy; EER: Energy efficiency ratio; NEG: Net energy gain; EP: Energy profitability; DE: Direct energy; IE: Indirect energy; RE: Renewable energy; NRE: Non- renewable energy; HEP: Human energy profitability; WEP: Water energy profitability.

revealed that individual manner farming of fish, duck and cattle is not sustainable in terms of energy gain and energy utilization whereas two-acre integrated farming system has resulted energy efficiency ratio as 1.66. Hence, integrated farming system is more energy efficient which can be promoted and adopted rather than cultivation of livestock and fish in isolation. The net energy gain (NEG) was estimated maximum in field crops, followed by fodder crops, vegetables, fruit crops, while, dairy, fishery, duckery and vermi-composting have resulted negative trends in terms of net energy mileage (Fig. 11.1). The energy profitability (EP) was found to be pre-eminence in fodder crops that is equal to 12.38 followed by field crops, vegetables and fruit crops, respectively. The overall, total energy input in this two-acre integrated farming model was estimated to be 139.23 GJ while total energy output obtained was 231.64 GJ and energy efficiency ratio as 1.66.

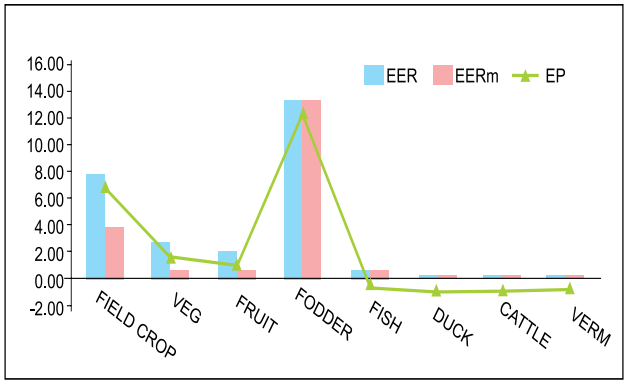


Fig. 11.1. Energy efficiency ratio and energy profitability of various IFS components under two-acre IFS model

Development of Climate Resilient Farming System Models for Livelihood Improvement

To improve productivity, profitability and sustainability of smallholder farmers by providing critical inputs with technological backstopping, the project has been implemented for the last four years in four adopted villages of East Champaran district of Bihar. The following activities and demonstrations were carried out during *rabi* 2019-20 and *kharif* 2020.

Performance of Moong

The performance of moong during the summer of 2020 (April-May) was satisfactory with the introduction of Virat and IPM02 and yielded 17% higher than the 'local' variety (6.0 q/ha). This increase in production resulted in net income of Rs. 22542/- per ha which was 53.4% higher over control (Table 11.3). Among the four villages, where these varieties were grown, the maximum yield was recorded in Chintamanpur followed by Jasaulipatti and minimum in Khairimal Jamunia. Low yield can be attributed to poor crop management by the farmers where the input cost was 80% less than those villages where yields were high.

Performance of paddy

Two improved varieties of paddy (CR 909 and Swarna Shreya) were introduced in the project area, two years ago and have become highly popular. While the farmer variety is a long duration crop and prefers water logged situations and yields long white scented grains, the latter is a short duration crop and

Table 11.3. Performance of moong in the adopted villages

Village name	Category of farmers	Variety	Yield (q/ha)	Input cost (Rs/ha)	Net income* (Rs/ha)
Chandrahiya	Beneficiary	Virat	6.67	18750	21315
		IPM02	6.97	18750	23090
	Non-beneficiary	Local	4.63	18750	9040
Khairimal Jamunia	Beneficiary	Virat	4.83	12218	17091
		IPM02	4.88	12431	16567
	Non-beneficiary	Local	4.30	11794	14025
Chintamanpur	Beneficiary	Virat	8.70	21958	30241
		IPM02	7.43	22666	21913
	Non-beneficiary	Local	7.28	22666	21013
Jasauli Patti	Beneficiary	Virat	7.80	25500	21345
		IPM02	8.33	25500	28775
	Non-beneficiary	Local	Not sown		

*Price was calculated @ Rs.6000/- per quintal

yields satisfactorily. Seeds of these two varieties were also provided this year to selected beneficiaries. Performance of the crop was compared with other varieties, like Rajendra Bhagwati, JK 2082, Basmati and 30P37. Overall, the yield of Swarna Shreya was 36.5% higher than the local varieties combined together (Table 11.4). Yields of CR 909 were lower by 28% over the improved varieties grown by non-beneficiaries farmers.

Table 11.4. Performance of paddy in the adopted villages

Variety	Yields (t/ha)	Input cost (Rs./ha)	Net income* (Rs./ha)
Swarna Shreya	4.27	35281	33215
CR 909	3.70	40120	19038
Local	3.56	32662	24336
Assorted	3.46	36035	19366

*Calculated @ Rs.16000/t

Performance of sugarcane

This year no sugarcane planting material was provided and most farmers arranged the planting material from their own resources or used from previous planting materials, which was provided them under the project. The performance of Co 238 was the best and yielded 22.1% higher in case of beneficiaries than non-beneficiaries and this can be attributed to timely application of fertilizer and irrigation. Consequently net income from Co238 was increased by 11.4 % in beneficiary farmers than non-beneficiary (Table 11.5).

Table 11.5. Performance of sugarcane in the adopted villages

	Variety	Yields (t/ha)	Input cost (Rs /ha)	Net income* (Rs/ha)
Beneficiary	Co 238	77.19	101582	143050
Non-beneficiary	Co 238	63.21	73876	128395
	Co 110	55.25	118575	58225

*Calculated @ Rs.3200/- per tonnes

Performance of potato

During the year 2020, potato was grown extensively in the project area and three popular varieties *viz*., Kufri Pukhraj, Kufri Sindoori and Kufri Khyati were raised. A new hybrid variety (Aruna Gold) recently introduced in the market, was also grown by non-beneficiary farmers. The highest yields were obtained from variety K. Pukhraj, followed by that from K. Khyati and then by K. Sindoori (Table 11.6). Higher yields was due to improved crop management practices. Although farmers were not willing to apply irrigation to the potato crop, but regularly carried out earthing up operations and disease (potato blight) control.

Table 11.6. Performance of potato in the adopted villages

Category	Variety	Yields (t/ha)	Input cost (Rs./ha)	Net income* (Rs./ha)
Beneficiary	Kufri Pukhraj	19.26	55477	163538
	K. Sindoori	17.57	40307	143886
	K. Khyati	19.13	68998	160501
Non-beneficiary	Aruna Gold	15.27	63823	108019
	K. Sindoori	17.00	74800	103700

*Calculated @ Rs.10500/- per tonnes

Performance of wheat

This year seeds of variety HD 2967 were distributed to 228 farmers in the project area, while variety HD 2733 was sown by farmers from their own resources. Some farmers also sowed other varieties like Sriram 303, Sriram 502 and an old but popular variety UP 61. The summarized result of crop yields is presented in Table 11.7. As indicated in the table, the differences in the yields obtained from the varieties are not significant, but increase in monetary gain was of about 12% from HD 2967 when income from control yields was calculated, while there was yield decline of 5.81% in case of HD 2733.

Table 11.7. Performance of wheat in the adopted villages

Category	Variety	Yields (t/ha)	Input cost (Rs./ ha)	Net income* (Rs./ha)
Beneficiary	HD 2967	3.81	40527	24226
	HD 2733	3.48	39707	20456
Non-beneficiary	Sriram 303	3.55	39421	23518
	Sriram 502	3.83	42122	23375
	UP 61	3.28	37734	18042

*Calculated @ Rs.170000/- per tonnes

Integrated Fish Farming Model for Livelihood Improvement

A total of six fish ponds were developed as integrated fish-duck farming models at four different villages, i.e., 26°.29'33.75" N, 84°52'56.48" E (Jasauli Patti); 26°.28'06.04" N, 84°53'05.44" E (Jasauli Patti), 26°.35'19.44" N, 84°54'16.04" E (Chandrahiya), 26^0.35'11.92" N, 84°54'02.87" E (Chandrahiya), 26°.30'35.98" N, 84°58'31.88" E (Chintamanpur) and 26°.33'21.71" N, 85°00'15.26" E (Khairimal Jamunia) of East Champaran district of Bihar, in which fingerlings of Indian major carps (IMCs) and exotic major carps (EMCs) were stocked @4000/acre with an average body weight about 30 ± 2g, and integrated with 150 numbers of Khaki Campbell ducks. About a month prior to the fish stocking, fertilization of the ponds was done by applying cow dung, urea, DAP and MOP at the rate of 1000 kg, 45 kg, 15 kg and 10 kg per acre, respectively, for the development of plankton, i.e., natural food of fishes. Thereafter, the duck excreta and supplementary feed were supplied to the fish ponds. The fish stocking was done based on the adaptation to the ecological niches of different species such as surface feeder, catla and silver carp (40%), column feeder, rohu and grass carp (30%) and bottom feeder, mrigal and common carp (30%). Supplementary feed, i.e., mixture of mustard oil cake and rice bran in 1:1 ratio was supplied to the fish pond @ 1.0% of the fish biomass on daily basis. Khaki Campbell ducks of @150 numbers per acre having average body weight of 620 ± 12.5 g were kept inside a low cost shed constructed over pond dyke and fed supplementary feed (mixture of wheat bran, paddy and maize) at the rate of 50-60 g per day per duck, and rest of the feed they obtained from foraging in the pond. Water parameters like pH, dissolved oxygen, temperature and conductivity were analyzed throughout the culture period and annual average pH, dissolved oxygen, temperature and conductivity were found to be 7.8 ± 0.42, 5.74 ± 0.5 ppm, 26.16 ± 3.2^{0}C and 1.04 ± 0.12 mS/cm, respectively (Fig. 11.5). The average growth rate of fishes was recorded from 27 g per month of mrigal to 31.7 g per month of grass carp. After a culture period of one year, the average body weight was found to be minimum (465.2 g) for mrigal and maximum (823.2 g) for grass carp (Fig. 11.6). The fish yield was estimated to be 22.5 quintals per acre per year while ducks and eggs were the additional produce (Fig. 11.7). The number of eggs was estimated from a flock of 150 ducks (males 10% and females 90%, with 90% survival rate till the end of culture period). The energy use efficiency ratio of

Fig. 11.2. Moong crop (Virat) in a beneficiary farmers' field

Fig. 11.3. Paddy crop (CR 909) in a beneficiary farmers' field

Fig. 11.4. Wheat crop (HD 2967) in a beneficiary farmers' field

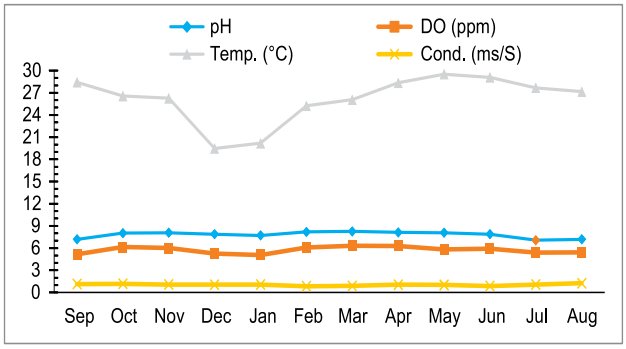


Fig. 11.5. Month-wise average pH, dissolved oxygen (ppm) and temperature (°C) of pond water

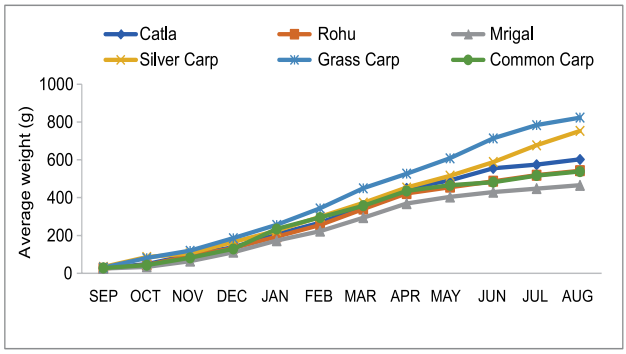


Fig. 11.6. Monthly average body weight (g) of stocked fish species

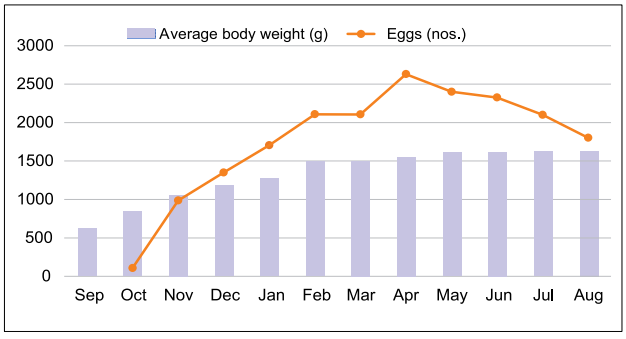


Fig. 11.7. Average body weight (g) of ducks, and number of eggs produced (from 150 ducks)

the fish-duck farming systems was estimated to be 0.19 and net income earned was calculated to be Rs. 2,34,393/- per acre per year.

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

A 0.75 Acre IFS model (Crop + Horticulture + Dairy) has been developed with the objective to ensure food security of a farm family under rainfed ecosystem. In the model, livestock (1 cow + 3 calves),

Fig. 11.8. Procurement of fish seed before transportation and stocking

Fig. 11.9. Integrated fish farming models developed

fruits (Guava and Badhal) have been integrated with cereals, pulses and oilseeds. During 2020, the total guava yield was 220.5 kg which is sufficient for fulfilling the daily dietary requirement of 1.5 families. Total milk production was 842.85 litres from one cow which is sufficient for the 1.44 families. So, the milk and fruit production were in surplus in the IFS. The cereals (440 kg) obtained from IFS was sufficient for fulfilling the daily dietary requirement of one family. The total pulses and oilseed production was deficit and could fulfill the daily requirement of 0.24 and 0.57 family, respectively. Vegetable production from tuber and leafy crops (170 kg) was sufficient for fulfilling the daily dietary requirement of 0.39 family. The total manure production was recorded as 3.4 t/year and cow urine production as recorded as 2920 litres/year from one cow and three calves. The total green fodder production was 4.5 t/year.

Evaluation of Zero Budget Natural Farming (ZBNF) for Eastern Plateau and Hill Region (EPHR)

The experiment was initiated during the year 2020 to evaluate the performance of Zero Budget

Natural Farming module for different cropping systems in EPHR in terms of crop productivity, soil fertility, plant protection, nutritional quality, system productivity and economic viability. The cropping patterns of paddy- lentil, black gram-niger, finger millet- mustard & cow pea- tomato were considered under the study. The open pollinated varieties of lentil, mustard, nizer & tomato were taken under the experiment. The four principles of ZBNF, i.e., Seed treatment by *Beejamrita*, use of *Ghan Jeevamrita*, *Jeevamrita*, paddy straw as mulch to suppress weeds and *Whaapasa* for moisture conservation technique were applied. For plant protection measure, application of Neemastra was undertaken for aphid control.

The Initial Soil status of ZBNF & Conventional Plots

The conventional plots recorded soil pH range of 4.67 to 4.99 in 0-15 cm soil depth whereas 15-30 cm of soil depth recorded pH range of 4.55 to 4.83. Similarly, the organic carbon showed the range of 0.28 -0.46 %, available N 204.4 -227.1 kg/ha, available P 21.4 – 29.60 kg/ha and K 138.9 – 213.9 kg/ha in soil depth of 0-15 cm, whereas soil depth of 15-30 cm recorded organic carbon of range 0.34 – 0.40 %, available N 180.0 - 197.4 kg/ha, available P 23.71 – 37.81 kg/ha and K 129.9 – 217.3 kg/ha. The ZBNF plots recorded soil pH range of 4.48 to 4.59 in 0-15 cm soil depth whereas 15-30 cm of soil depth recorded pH range of 4.27 to 4.62. Similarly, the organic carbon showed the range of 0.34 -0.53 %, available N 152.0 -214.9 kg/ha, available P 22.4 – 26.40 kg/ha and K 181.4 – 218.4 kg/ha in soil depth of 0-15 cm, whereas soil depth of 15-30 cm recorded organic carbon of range 0.29 – 0.56 %, available N 180.0 - 216.7 kg/ha, available P 16.18 – 29.30 kg/ha and K 175.8 – 213.9 kg/ha. Analysis of chemical properties of Jeevamrit showed pH - 4.1, EC- 1.5, N- 625 ppm, P- 160 ppm & K- 231 ppm whereas Bijamrit showed pH -9.5, EC- 1.43, N- 40 ppm, P- 155.4 ppm & K- 285.5 ppm. Analysis of microbial population indicated higher values of bacterial population in Beejamrit (Table 11.8).

Table 11.8. Microbial Count of ZBNF Ingredients

Sample	Fungal colony (cfu/g of soil) x 105	Bacterial colony (cfu/g of soil) x108
Soil	2.13±0.31	8.67±0.76
Beejamrit	0.90±0.20	24.17±1.04

Performance of different crops under conventional and ZBNF methods

During *rabi* season, the performance of ZBNF was tested with niger, lentil, mustard, tomato. The conventional method sown crops yielded better in first year of experiment in comparison to ZBNF. In conventional method, the plant height of niger, lentil tomato and mustard were 60.43 cm, 25.33 cm, 48.63 cm and 152.70 cm whereas in ZBNF it were 52.25 cm, 18.65, 35.30 and 117.33 cm respectively. The yield of niger, lentil, mustard and tomato under conventional method were 0.74 q/ha, 2.30 q/ha, 12.57q/ha and 208.95 q/ha, respectively while under ZBNF the yields were 1.29 q/ha, 0.58 q/ha, 5.65 q/ha and 125.30 q/ha, respectively (Table 11.9).

Table 11.9. Growth & yield parameters of different crops of CF & ZBNF

Treatments	Plant height (cm)	Canopy spread (cm^2) 90 DAS	Yield (q/ha)
Main Treatment means			
ZBNF	223.53	3481.36	132.82
CF	287.08	6657.06	225.57
CD 5%	11.09	583.18	11.92
Sub Treatment means			
Niger	225.35	3512.12	6.07
Lentil	87.95	413.13	5.75
Tomato	167.85	8453.90	668.50
Mustard	540.05	7897.68	36.45
CD 5%	6.38	748.05	10.37
Treatment means (Main x Sub)			
ZBNF x Niger	52.25	744.12	1.29
ZBNF x Lentil	18.65	63.00	0.58
ZBNF x Tomato	35.30	1080.49	125.30
ZBNF x Mustard	117.33	1593.75	5.65
CF x Niger	60.43	1011.94	1.74
CF x Lentil	25.33	143.57	2.30
CF x Tomato	48.63	3146.46	208.95
CF x Mustard	152.70	2355.09	12.57
CD 5%	9.03	1057.90	14.67

The qualitative parameters of ZBNF grown tomato showed higher ascorbic acid, TSS & acidity in comparison to conventional methods of tomato. However, the acidity (%) was found at par in conventional and ZBNF.

During *kharif*, the performance of paddy, cowpea, black gram and finger millet were evaluated. The zero budget natural farming resulted in comparatively higher yield of cowpea (6.6 t/ha) and finger millet (1.94 t/ha) than the conventional farming (5.2 t/ha and 0.89 t/ha respectively). However, the yield of Paddy (2.2 t/ha) and black gram (1.1 t/ha) was recorded higher in conventional farming in comparison to the zero budget natural farming (1.30 t/ha and 0.70 t/ha, respectively).

Jivamrita application in ZBNF Paddy | Field view of Conventional plots | Field view of ZBNF plots

Fig. 11.10. Field view of different crops under ZBNF

Evaluation and Optimization of Integrated Farming System

An information system on integrated farming system (IFS) was developed using SQL, PHP, Java and HTML with the objective to optimize the land allocation and crop options so as to get maximum profit. This information system was tested for appropriate land allocation among various components of IFS. Through this system cost of production, gross profit, net profit, family food requirement of size (2+2) etc. can be calculated. This information system is based on user login and password (Fig. 11.11). Data for 1 acre and 2 acre IFS models at farmer's field of Anantpur village at Chandi block in Nalanda district, Bihar, were collected, evaluated and optimized for gross income by employing LINPROG optimization solver. The main components of 2 acre IFS model at Anantpur village were crop in 1.25 acre, horticulture crop in 0.47 acre, livestock (2 cows and 2 calves) in 0.03 acre and fish in 0.25 acre. The gross income was Rs. 3.1 lakh but when the land allocation was optimized and reallocated as 1.0 acre in crop, 0.47 acre in horticulture crop, 0.02 acre in livestock and 0.51 acre for fish then the gross return was Rs. 3.5 lakh from this model. Income was increased by Rs. 40000 because the fish component provides more income than crop. So, in general the income may be increased by 12-15 % if the land allocation is optimized. Gross

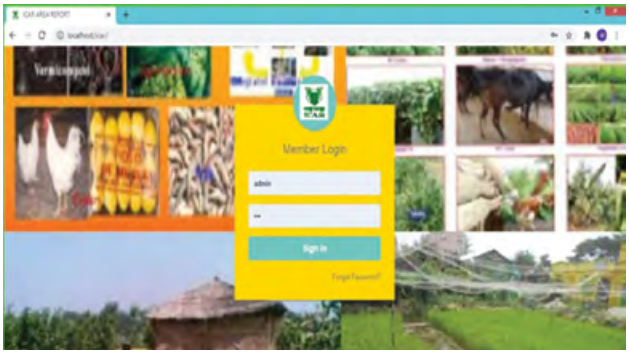


Fig. 11.11. User login, password and main menu screen

return was also calculated from this information system after entering required data into database of 1 Acre and 2 Acre IFS model (Fig. 11.12).

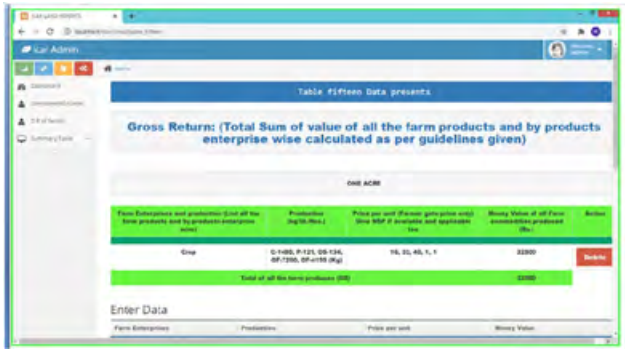


Fig. 11.12. GUI (Graphic User Interface) gross return from crop component of 1 Acre and 2 Acre IFS model

12. Crop Diversification

Evaluation of Establishment Methods for Improving the Productivity of Rice Fallows

A long-term study was initiated during the kharif season of 2016 at the ICAR-RCER Patna to find out the most suitable rice–winter crop rotation; following appropriate crop establishment methods and residue management practices in rice–fallow production system in eastern India. The treatment comprised of six levels of crop establishment methods and residue management (CERM) practices: zero–till direct seeded rice (ZTDSR), conventional-till-DSR (CTDSR), puddle transplanted rice (PTR), ZTDSR with rice residue retention (ZTDSRR+), CTDSR with rice residue retention (CTDSRR+), PTR with rice residue retention (PTRR+) 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. In general, rice yields were higher after pulse crops in comparison to oilseeds. Rice productivity was 28.1 and 19% higher in PTR (4.66 t/ha) compared to ZTDSR (3.64 t/ha) and CTDSR (3.92 t/ha) irrespective of residue management (Table 12.1).

Table 12.1. Rice yields as influenced by establishment methods and residues management practices and succeeding crops

CERM	Rice grain yield (t/ha)					Mean
	Chick-pea	Lentil	Saf-flower	Lin-seed	Mus-tard	
[ZTDSR-ZT] R-	3.22^{D}	3.55^{E}	3.86^{A}	3.77^{C}	2.99^{E}	3.48
[ZTDSR-ZT] R+	3.49^{D}	4.01^{D}	4.19^{A}	4.11^{B}	3.19^{DE}	3.80
[CTDSR-ZT] R-	3.87^{C}	3.99^{D}	3.84^{A}	3.53^{C}	3.41^{D}	3.73
[CTDSR-ZT] R+	4.19^{C}	4.55^{C}	4.17^{A}	3.73^{C}	3.89^{C}	4.11
[TPR-ZT] R-	4.83^{B}	4.91^{B}	3.96^{A}	4.17^{B}	4.42^{B}	4.46
[TPR-ZT] R+	5.21^{A}	5.35^{A}	4.22^{A}	4.51^{A}	5.02^{A}	4.86
Mean	4.14	4.39	4.04	3.97	3.82	

Standardization of Agro-techniques in Nutri-cereals for Enhancing the Productivity in Eastern India

A long-term field experiment was initiated during *kharif* 2020 at the institute farm (25°30′N, 85°15′E, 52 m above mean sea levels) with an objective of designing the most productive, profitable and sustainable climate resilient cropping system for the eastern India. Six nutri-cereals including 2-major (jowar and bajra) and 4-minor nutri-cereals (ragi, barnyard millet, foxtail millet and kodo millet) were grown under 3-different planting windows, i.e., starting with onset of monsoon and later on at 10-days intervals (26 June, 6 July and 16 July 2020). Soil of the experimental site was loamy in texture (50.4, 35.0 and 14.6% sand, silt and clay) (Typic Haplustept, Fluvisol), with pH of 7.5, EC of 0.12 dS m^{-1}, soil organic carbon content of 6.0 g/kg, $KMnO_4$ oxidizable N of 64.6 mg/kg, Olsen phosphorus of 23.9 mg/kg, NH_4OAc exchangeable potassium of 78.3 mg /kg and DTPA-extractable zinc of 0.66 mg/kg (0-15 cm soil). Results revealed that 1st planting window (26.6.2020) performed better as compared to II & III planting windows (06.7.2020 & 16.7.2020) in terms of grain yield (Table 12.2 and Fig. 12.1). Among the nutri-cereals, jowar (2750 kg/ha) as major and barnyard millets (1735 kg/ha) as minor nutri-cereals were found more productive when planted with onset of monsoon.

Table 12.2. Yields of nutri-cereals under different planting windows

Nutri-cereals	Grain yield (kg/ha)		
	I planting (26 June 2020)	II planting (06 July 2020)	III plant-ing (16 July 2020)
Jowar (CSV-15)	2750	2500	2270
Bajra (Dhanshakti)	1960	1800	1670
Ragi (GPU-67)	1750	1560	1470
Barnyard millet (VL-207)	1735	1488	1346
Foxtail millet (S/A-3085)	1211	1016	970
Kodo millet (JK-41)	1367	1311	1278

Diversification of Rice-Wheat Cropping System with Vegetables

An experiment was conducted to identify the most suitable diversified rice based cropping system for silty clay loam soil at institute farm. Two rice varieties (medium: Swarna Shreya and long duration-Swarna) were cultivated as *kharif* crop followed by vegetables and wheat as *rabi* crops and greengram as

Fig. 12.1. Performance of nutri-cereals under different planting windows

summer crop. Six cropping systems *viz*. rice-wheat-green gram, rice-potato- greengram, rice-tomato-greengram, rice-cauliflower- greengram, rice-broccoli-greengram and rice-garden pea- greengram were studied with medium and long duration rice varieties (Fig. 12.2). Among six cropping systems, rice-wheat cropping system was treated as control and other diversified cropping systems were compared with the control treatment. Rice crop duration significantly influenced the yield of *rabi* crops and system productivity as a whole. Rice variety Swarna Shreya attained maturity in 120 days while variety Swarna (MTU 7029) took 28 more days than Swarna Shreya. *Rabi* crops grown after medium duration rice produced significantly higher yield with better quality than those grown after long duration rice variety. During *kharif* season Swarna produced 48% higher yield than Swarna Shreya (5.29 t/ha) but yield of *rabi* and summer crop were significantly lower than those grown after Swarna (Table 12.3). Crop diversification also showed significant differences among different cropping systems with respect to yield. The system productivity of rice-cauliflower- greengram (25.87 t/ha) was significantly higher over other cropping systems except rice-broccoli-greengram (24.62 t/ha). Cauliflower and broccoli grown after Swarna Shreya provided an opportunity to introduce one more crop in the system before sowing of greengram. Hence, spring onion and spinach were sown after cauliflower

Table 12.3. Effect of rice varieties and cropping systems on yield and rice equivalent yield (REY) (t/ha)

Treatments	Rice yield (t/ha)	*Rabi* yield (t/ha)	Green-gram yield (t/ha)	REY of *rabi* crop (t/ha)	REY of green-gram (t/ha)	System REY (t/ha)
Rice variety						
Swarna Shreya (Medium duration)	5.29	26.30	0.99	15.92	2.82	24.15
Swarna (Long duration)	7.61	11.54	0.67	7.56	1.73	17.15
C.D (P= 0.05)	0.34	1.86	0.06	0.36	0.29	0.36
Cropping System						
R-W-GG	6.56	3.98	0.79	4.45	1.20	13.36
R-P-GG	6.50	22.56	0.84	8.73	3.22	17.73
R-T-GG	6.28	24.82	0.77	16.01	1.49	24.62
R-CF-GG	6.65	30.98	0.85	19.9	1.84	29.16
R-Br-GG	6.37	26.52	0.84	18.26	3.49	26.98
R-GP-GG	6.34	4.65	0.90	3.00	2.40	12.04
C.D (P=0.05)	NS	2.47	0.07	1.48	0.66	1.53

and broccoli, respectively which further enhanced the system productivity. Significant differences were also observed within the system due to duration of rice crop. Nutrient status of different cropping system varied from each other but no significant differences were found due to variation in rice crop duration. Rice-garden pea-greengram showed highest available nitrogen (184.2 kg/ha) and organic carbon (0.53%) in soils.

Further, economics of different cropping systems was also affected due to diversification of cropping system as well as variation in rice crop duration (Table 12.4). Rice-cauliflower-spring onion-green gram produced significantly higher rice equivalent yield (36.91 t/ha), net return (Rs. 262950) and benefit : cost ratio (2.90) among all cropping systems followed by rice-broccoli-spinach-greengram (net return: Rs. 325000 & B:C : 2.74) and rice-tomato-greengram (net return: Rs. 231314 & B:C : 2.6).

Fig. 12.2. Diversification of rice-wheat system with vegetables

Table 12.4. Rice equivalent yield and economics as influenced by cropping system and rice duration

Cropping Systems	REY (t/ha)	Gross income (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	B:C ratio
Medium duration rice					
Rice-Wheat-Greengram	13.85	207750	127336	80414	1.63
Rice- Potato -Greengram	19.39	290850	164584	126266	1.77
Rice- Tomato -Greengram	28.49	427350	162860	231314	2.60
Rice-C.F-Spring onion -GG	36.91	553650	190700	362950	2.90
Rice-Broccoli-Spinach -GG	34.10	511500	186500	325000	2.74
Rice-Pea-Greengram	12.16	182400	115667	66733	1.58
Long duration rice					
Rice-Wheat-Greengram	12.87	193050	139400	53650	1.38
Rice-Tomato-Greengram	16.08	241200	169500	71700	1.42
Rice-Potato-Greengram	20.75	311250	187912	123338	1.66
Rice-C.F-Spring onion -GG	21.40	321000	191558	129442	1.68
Rice-Broccoli-Spinach -GG	19.87	298050	190347	107703	1.57
Rice-Pea-Greengram	11.92	178800	126500	52300	1.41

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

Under rainfed upland condition of eastern plateau and hill region, the trial on diversification of direct sown upland rice area was conducted with ten treatments during kharif season of 2019. The treatments were T1 (sole crop of rice cv. BVD-109), T2 (sole crop of finger millet cv. BBM-10), T3 (sole crop of black gram cv. Uttara), T4 (sole crop of horse gram cv. Birsa Kulthi-1), T5 (sole crop of pigeon pea cv. UPAS-120), T6 (sole crop of vegetable cowpea cv. Swarna Mukut), T7 (Rice + Black gram in area ratio of 1:1), T8 (Rice + Horse gram in area ratio of 1:1), T9 (Finger millet + Black gram in area ratio of 1:1) and T10 (Finger millet + Horse gram in area ratio of 1:1) (Table 12.5). The plot size of each treatment was 3mx2m (6 m^2). The grain yield/plot was recorded in all the crops except vegetable cowpea whose green pod yield/plot was recorded. The sale prices of rice, finger millet, black gram, horse gram, pigeon pea and vegetable cowpea were Rs.18.15, Rs.31.5, Rs.57, Rs.50, Rs.58 and Rs.20 per kg, respectively. The sole crop of vegetable cowpea recorded the maximum rice equivalent yield of 10.42 t/ha followed by that of pigeon pea (8.71 t/ha), black gram (5.00 t/ha), horse gram (4.95 t/ha) and finger millet (4.09 t/ha). The rice equivalent yield of black gram and horse gram were at par with each other. Among the combination treatments, T10 recorded maximum rice equivalent yield (5.77 t/ha) followed by T9 (4.91 t/ha), T7 (4.32 t/ha) and T8 (3.99 t/ha). T9 and T7 were at par with each other. Also, T7 and T8 were at par with each other in respect of rice equivalent yield. The yield of sole crop of rice was 1.29 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. The B:C ratio of finger millet + horse gram in area ratio of 1:1(3.67) was maximum followed by that of finger millet + black gram in area ratio of 1:1(3.09) and vegetable cowpea (3.05). The cultivation of rainfed upland rice solely was found to be non-remunerative (BC ratio 0.44).

Table 12.5. Rice equivalent yields under diversified cropping system

Treatments	Rice equivalent yield (t/ha)
T-1 (Rice)	1.29
T-2 (Finger millet)	4.09
T-3 (Black gram)	5.00
T-4 (Horse gram)	4.95
T-5 (Vegetable cowpea)	10.42
T-6 (Pigeon pea)	8.71
T-7 (Rice + Black gram)(1:1)	4.32
T-8 (Rice + Horse gram)(1:1)	3.99
T-9 (Finger millet + Black gram)(1:1)	4.91
T-10 (Finger millet + Horse gram)(3 m^2 + 3 m^2)	5.77
CD at 5%	0.71

Fig. 12.3. Crop diversification in rainfed uplands in eastern plateau and hill region

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

The project is being undertaken to develop multitier system for rainfed uplands of eastern plateau and hills. The intercrop yield was monitored under different five-year-old multitier cropping systems. The highest paddy equivalent yield was recorded under Mango+ Mahogany + Peach + Rice (12.9 t/ha) followed by in Mango + Mahogany + Peach + Ragi system (11.5 t/ha). The mango yield varied from 6.33 kg/plant to 6.99 kg/plant under different systems. The filler crop peach yield (45.48 kg/ha) was found higher under Mango + Mahogany + Peach + Rice system (Fig. 12.4).

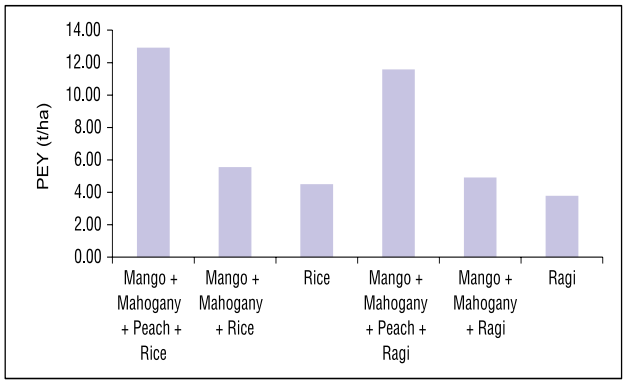


Fig. 12.4. Paddy equivalent yield under different multitier systems

Rehabilitation of Coal Mine Affected Areas through Agroforestry Interventions

A model of Agri-horti-silvi-pastural system was developed in the year 2015 at coal mine affected area of Phusri village, Near Charhi, Mandu, Ramgarh, Jharkhand. In this model, agroforestry species *viz.*, Bael (*Aegle marmelos*), Jackfruit (*Artocarpus heterophyllus*), *Citrus lemon*, Kalashisham (*Dalbergia latifolia*), Mango (*Mangifera indica*), Bakain (*Melia azedarach*), Karanj (*Pongamia pinnata*), Guava (*Psidium guajava*), Pomegranate (*Punica granatum*), Mahogony (*Swietenia mahogany*) and Teak (*Tectona grandis*) had been planted. After five years of plantation, the maximum plant height (7.28 m) and trunk diameter (10.11 cm) was recorded in Bakain compared to other multipurpose trees (MPTs). Among the fruit crops, maximum plant height (3.27 m) and plant spread were recorded in Bael. A total of 938.43 kg green fodder was harvested from Kans grass (*Saccharum spontaneum*), *Melia azedarach* and Bhoomi sudha (*Tephrosia candida*). Apart from this, the farmer could obtain a net return of approximately Rs. 24000/- by growing intercrops like Tomato, Cucurbits, Chilli, lady's finger, paddy nursery, *etc.* during the *kharif* season and mustard, groundnut, chickpea, pigeon pea, cabbage, cauliflower, potato, *etc.* during *rabi* season. Due to the intervention, the vegetable intake of family (4 members) increased by 16.67% and fruit intake increased by 77.66% during the year 2020.

Another model of Agri-horti-silvi-pastural system was developed at new extended coal mine affected area (i.e., Keribanda, Mandu, Ramgarh, Jharkhand) in the year 2020. The species like Guava, Custard apple (*Annona reticulata*), Jackfruit, Mango, Bael, Teak, Karanj, Kalashisham, Mahogony, Malabar neem (*Melia dubia*) and *Tephrosia candida* were introduced. Among all the plants, 100% survival was observed during December in case of Jackfruit, Mango, Teak, Karanj, Malabar neem and Kalashisham while high mortality was recorded in case of Bael (30%), Guava (22.50%) and Custard apple (17%), due to high moisture stress during November and December (Fig. 12.5).

Development of Multipurpose Trees (MPT) and Medicinal Plants Based Agroforestry Models for Eastern Plateau and Hill Region

The project was initiated during 2020 to develop MPT + medicinal plant based agroforestry system.

Field view of Phusri coal mine affected area during summer

Paddy nursery in the alleys of Bakain plantation

Field view of Phusri coal mine affected area during monsoon

Fig. 12.5. Field view of coal mine affected areas

During the first year of the project, screening of 21 different medicinal plants *viz.,* Kalmegh (*Andrographis paniculata*), Ashwagandha (*Withania somnifera*), Bhringraj (*Eclipta prostrate*), Vasaka (*Adhatoda vasica*), Giloe (*Tinospora cordifolia*), Sarpagandha (*Rauvolfia serpentina*), Shatavari (*Asparagus racemosus*), Van tulsi (*Ocimum gratissimum*), Bryophyllum (*Kalanchoe pinnata*), Sadabahar (*Catharanthus roseus*), Hadjod (*Cissus quadrangularis*), Aparajita (*Clitoria ternatea*), Insulin (*Costus igneus*), Gandha Prasarini (*Paederia foetida*), Anantmool (*Hemidesmus indicus*), Spearmint (*Mentha spicata*), Punarnava (*Boerhavia Diffusa*), Hathikan (*Leea macrophylla*), Van dhania (*Peucedanum dhana*), Van Kapas (*Urena sinuate*) and Vidanga (*Embelia ribes*) were conducted under two different agroforestry systems (i.e., Teak+Karanj and Mahogony+Karanj). Among all the medicinal plants, species like Giloe, Van tulsi, Bhringraj, Bryophyllum, Sadabahar, Hadjor, Aparajita, Shatavari and Vasaka performed satisfactorily under rainfed condition (100% survival). However, high mortality of 100%, 92%, 84% and 62% were observed in case of species like Kalmegh, Van dhania, Ashwagandha and Insulin, respectively, due to moisture stress (Fig. 12.6-12.7).

Fig. 12.6. Giloe *(Tinospora cordifolia)*

Fig. 12.7. Aparajita (*Clitoria ternatea)*

Diversification of Existing Upland Production Systems with Tuber Crops in Eastern Plateau and Hill Region

The objectives of the project were to multiply planting materials of food and nutrition rich promising genotypes of selected potential tuber crops and to diversify rainfed upland rice and millet production system through these selected tuber crops. To conduct the experiment on diversification, generation of planting material was done during 2020 through multiplication of identified promising genotypes of five tuber crops namely taro/colocasia ACC-60 (158 kg) (Fig. 12.8), aerial/potato yam ACC-28 (85 kg) (Fig. 12.9), greater yam ACC-34 (318 kg) (Fig. 12.10), cassava ACC-139 (50 plants) (Fig. 12.11) and sweet potato ACC-161 (150 plants) (Fig. 12.12). The planting material will be utilized during 2021 to layout the trials on crop diversification.

Fig. 12.8. Planting materials of Taro genotype ACC-60

Fig. 12.9. Planting materials of Potato yam genotype ACC-28

Fig. 12.10. Planting materials of greater yam ACC-34

Fig. 12.11. Planting materials of cassava ACC-139

Fig. 12.12. Planting materials of sweet potato ACC-161

BIODIVERSITY CONSERVATION

Natural Occurrence of Lac Insect, *Kerria lacca* Kerr in Various Agro-climatic Zones of Bihar

Extensive surveys were conducted in twenty eight districts of Bihar for occurrence of natural population of lac insect, *Kerria lacca* Kerr (Hemiptera: Tachardiidae) and availability of its host plants for conservation and future promotion of lac cultivation in the region. Naturally occurring lac insect was observed in 18 districts in varied proportion mostly on *Ficus religiosa*, *Ficus benghalensis* and rarely on *Ziziphus mauritiana and Butea monosperma* (Fig. 12.13-12.14). Majority of insects were found dead, but at a few places good live population was noticed. Out of 17 districts of south Bihar falling under zone III of agro-climatic region, ten districts showed rich diversity in naturally surviving lac insects (Fig. 12.15). The major districts where lac insects were abundant were Bhagalpur, Banka, Sheikhpura, Munger, Lakhisarai, Arwal, Nawada and Patna. Lac insects in scattered manner were also observed in many other districts of north Bihar, but their occurrence and population densities were very low. Survey revealed that the 59% districts of zone III of Bihar harbor plenty of

Fig. 12.13. Natural occurrence of lac on *F. benghalensis*

Fig. 12.14. Natural occurrence of lac on *F. religiosa*

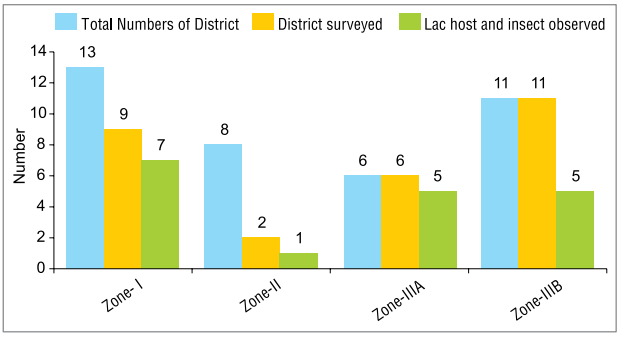


Fig. 12.15. Natural occurrence of lac insect in different agro-climatic zones of Bihar

lac hosts and natural population of lac insects. This observation opens a new window for introduction of lac cultivation in these areas for livelihood support to resource poor farmers during off-agricultural season.

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

For improving rice – vegetable pea-summer maize system productivity through efficient water management practices, an experiment was undertaken in *rabi* season, 2019-20. In this experiment, 03 genotypes of pea along with 04 irrigation application levels (irrigation at IW: CPE) were tested under cropping system mode. Performance of individual crops in cropping system is reported below:

Performance of *kharif* season crop

During *kharif* 2020, three genotypes of rice (namely V_1 = CR Dhan 40, V_2 = Rajendra Shweta and V_3 = Swarna Shreya) along with 04 irrigation application levels, i.e., W_1 (IW: CPE=0.4), W_2 (IW: CPE=0.6), W_3 (IW: CPE=0.8) and W_4 (IW: CPE=1.0), with one irrigation depth 20 mm, were tested under rice – vegetable pea-summer maize system in split plot design keeping irrigation application in main plots and genotypes in sub plots at institute experimental farm. Results revealed that irrigation applied at W_4 level produced significantly higher grain (5.41 t/ha) compared to other tested levels of water management (Table 12.6). It is noted that yield advantage was recorded with enhancement up to the highest tested level. Similarly, the genotype Swarna Shreya produced significantly higher rice yield (5.03 t/ha) as compared to other tested rice genotypes. Similar trend was seen in case of biological yield with both the tested factors, i.e., water management and genotypes. Maximum biological yield (16.38 t/ha) was recorded when irrigation was applied at W_4 and minimum (11.22 t/ha) with W_1. In case of genotype,

the maximum biomass (14.79 t/ha) was produced by Swarna Shreya and minimum by CR Dhan 40 (12.88 t/ha). None of treatments has significantly influenced harvest index (HI). In case of water productivity, maximum water productivity (1.40 kg/m^3) was achieved when rice was irrigated at W_1 and minimum water productivity (1.17 kg/m^3) was achieved in case of irrigation applied at W_4. In case of genotype, the Swarna Shreya recorded maximum water productivity (1.90 kg/m^3).

Table 12.6. Rice performance as influenced by water and genotypes

Treatments	Grain Yield (t/ha)	Biological Yield (t/ha)	Harvest Index	IWP (kg/ha)
W_1 = (IW: CPE=0.4)	3.93	11.22	0.35	1.40
W_2 = (IW: CPE=0.6)	4.47	13.14	0.34	1.24
W_3 =(IW: CPE=0.8)	4.93	14.50	0.34	1.23
W_4 = (IW: CPE=1.0)	5.41	16.38	0.33	1.17
CD (±5%)	1.7	2.93	NS	0.26
V_1 = CR Dhan 40	4.38	12.88	0.34	1.65
V_2 = Rajendra Shweta	4.64	13.65	0.34	1.75
V_3 = Swarna Shreya	5.03	14.79	0.34	1.90
CD (±5%)	0.79	2.51	NS	0.19

Performance of *rabi* season crop

During *rabi* season, 03 vegetable pea genotypes namely V_1=Annapurna, V_2=Haribhajan and V_3= SPL-VS 10 were tested under 04 irrigation application levels, i.e., W_1 (IW: CPE=0.4), W_2 (IW: CPE=0.6), W_3 (IW: CPE=0.8) and W_4 (IW: CPE=1.0). Results are given in Table 12.7. The highest green pod yield (7.95 t/ha) was recorded in the plots where irrigation application level was W_3. In case of genotypes, Haribhajan produced significantly higher green pod (7.80 t/ha) than other tested varieties. In case of water productivity, the maximum water productivity (10.93 kg/m^3) was achieved when pea was irrigated at W_1, and the lowest (6.51 kg/m^3) was found in case of irrigation applied at W_4. The Genotype Haribhajan recorded maximum water productivity (8.57 kg/m^3).

Table 12.7. Yield attributes and yields of vegetable pea influenced by genotypes and water management treatments

Treatments	Green pea yield (t/ha)	WP (kg/m^3)
W_1 (IW:CPE=0.4)	6.67	10.93
W_2 (IW:CPE=0.6)	7.71	9.52
W_3 (IW:CPE=0.8)	7.95	7.87
W_4 (IW:CPE=1.0)	7.88	6.51
CD (P=0.05)	0.49	1.41
V_1=Annapurna	7.32	8.04
V_2=Haribhajan	7.80	8.57
V_3= SPL-VS 10	7.55	8.30
CD(P=0.05)	0.52	2.17

Performance of summer / *Zaid* season crop

Three summer maize genotypes namely V_1= S-999, V_2= Visal and V_3= S-585, were tested under 04 irrigation application levels, i.e., W_1 (IW: CPE=0.4), W_2 (IW: CPE=0.8), W_3 (IW: CPE=1.0) and W_4 (IW: CPE=1.2). Results revealed that in case of irrigation application level treatments, significantly highest green cob yield (18.41 t/ha) was recorded in plots at irrigation application level W_4 and minimum (9.94 t/ha) green cob yield at irrigation application level W_1. Genotype, S-585 produced significantly higher green cob yield (15.89 t/ha) as compared to other tested genotypes (Table 12.8). In case of water productivity maximum water productivity (6.25 kg/m^3) was achieved when pea was irrigated at W_2, corresponding lowest (3.84 kg/m^3) was noticed in case of water supplied with W_4. In case of genotype, maximum water productivity (5.30 kg/m^3) was obtained by S-585 variety.

Table 12.8. Green cob yield (t/ha) as influenced by genotypes and water management treatments

Treatments	Green cob yield (t/ha)	WP (kg/m^3)
W_1 (IW:CPE=0.4)	9.94	6.21
W_2 (IW:CPE=0.8)	15.01	6.25
W_3 (IW:CPE=1.0)	16.78	5.24
W_4 (IW:CPE=1.2)	18.41	3.84
CD (P=0.05)	2.17	0.21
V_1=S-999	14.15	4.72
V_2=Visal	15.06	5.02
V_3= S-585	15.89	5.30
CD (P=0.05)	0.82	0.17

13. Carbon Sequestration and Nutrient Dynamics

Assessment of Leaf Litter Decomposition Pattern of Different Agroforestry Species

The leaf litter decomposition pattern of different agroforestry species *viz. Tectona grandis* (Teak), *Butea monosperma* (Palas), *Terminalia arjuna* (Arjun), *Schleichera oleosa* (Kusum) and *Gmelina arborea* (Gamhar) were studied through litter bag techniques using the nylon netting bags measuring 30 × 30 cm. The average mass loss in Teak, Palas, Arjun, Kusum, and Gamhar leaf litter was 12, 10.6, 13.0, 13.5 and 23.6%, during the entire period of 15th, 15th, 14th, 14th and 8th months of decomposition, respectively. The annual decomposition rate constant (k) for dry matter followed the order Gamhar (-2.44) > Teak (-1.39) > Kusum (-1.26) > Arjun (-1.09) > Palas (-0.89). Among the leaf litter, Palas had the slow decomposition rate and resulted in highest value of T_{50}, T_{99} as 0.78, 5.61 year, respectively (Table 13.1). The decomposition rate of Gamhar leaf litter was highest and accordingly the value of T_{99} period was lowest (2.05 year). The climatic variables *viz.,* soil temperature and rainfall significantly influenced the leaf litter decomposition and the order of influence was rainfall > soil temperature > soil moisture > air temperature.

The highest N-decomposition rate constant was -3.20 in Gamhar leaf litter with lowest T_{99} period of 1.56 years, while Palas leaf litter had lowest decomposition rate constant of -1.49 with highest T_{99} period of 3.35 years. The P-decomposition rate constant was highest in Gamhar (-3.08) followed by Teak (-1.77). Among the different leaf litter, Gamhar has the lowest T_{99} period of 1.62 years and Palas had the highest T_{99} period of 4.75 years. The Gamhar leaf litter had the highest K-decomposition rate constant of -4.32 with least T_{99} period of 1.16 years. Among the leaf litter, Palas had the lowest K-decomposition rate constant of -1.90 with highest T_{99} period of 2.63 years (Table 13.2). Thus, the mineralization of N, P and K from leaf

Table 13.1. Annual decomposition constant (k), decay for 50 and 99% of mass and nutrients for leaf litter of agroforestry species.

Tree species	Parameter	Exponential regression equation	k	T_{50}	T_{99}	R^2
Tectona grandis	D.m	$y = 74.3e^{-1.39x}$	-1.39	0.50	3.59	0.55
	N	$y = 103.9e^{-2.22x}$	-2.22	0.31	2.26	0.76
	P	$y = 89.04e^{-1.77x}$	-1.77	0.39	2.83	0.60
	K	$y = 30.961e^{-2.49x}$	-2.49	0.28	2.01	0.63
Butea monosperma	D.m	$y = 61.7e^{-0.89x}$	-0.89	0.78	5.61	0.56
	N	$y = 65.2e^{-1.49x}$	-1.49	0.46	3.35	0.82
	P	$y = 52.3e^{-1.05x}$	-1.05	0.66	4.75	0.58
	K	$y = 16.6e^{-1.90x}$	-1.90	0.36	2.63	0.57
Terminalia arjuna	D.m	$y = 59.4e^{-1.09x}$	-1.09	0.64	4.60	0.54
	N	$y = 84.2e^{-1.72x}$	-1.72	0.40	2.90	0.65
	P	$y = 89e^{-1.51x}$	-1.51	0.46	3.32	0.62
	K	$y = 20.5e^{-2.07x}$	-2.07	0.33	2.42	0.55
Schleichera oleosa	D.m	$y = 66.2e^{-1.26x}$	-1.26	0.55	3.97	0.68
	N	$y = 95.6e^{-1.95x}$	-1.95	0.36	2.57	0.73
	P	$y = 53.3e^{-1.69x}$	-1.69	0.41	2.96	0.66
	K	$y = 21.543e^{-2.39x}$	-2.39	0.29	2.09	0.65
Gmelina arborea	D.m	$y = 41.757e^{-2.44x}$	-2.44	0.28	2.05	0.56
	N	$y = 55.5e^{-3.2x}$	-3.20	0.22	1.56	0.81
	P	$y = 46.1e^{-3.08x}$	-3.08	0.22	1.62	0.56
	K	$y = 11.9e^{-4.32x}$	-4.32	0.16	1.16	0.50

D.m = Dry matter

Table 13.2. Leaf litter decomposition rate (% wt-loss/month) as influenced by climatic variables.

Tree species	Variable	Regression equation	R^2
Tectona grandis	Soil moisture (%)	y = 1.1761x - 7.77	0.460
	Soil temp. (°C)	y = 1.8201x - 19.36	0.583
	Rainfall (mm)	y = 0.1291x + 8.20	0.756
	Air temp. (°C)	y = 1.8974x - 33.56	0.234
Butea monosperma	Soil moisture (%)	y = 0.8051x - 1.82	0.297
	Soil temp. (°C)	y = 0.9807x - 4.83	0.473
	Rainfall (mm)	y = 0.0628x + 10.25	0.438
	Air temp. (°C)	y = 0.8572x - 7.76	0.124
Terminalia arjuna	Soil moisture (%)	y = 1.5225x - 7.98	0.330
	Soil temp. (°C)	y = 1.8428x - 18.03	0.537
	Rainfall (mm)	y = 0.1267x + 9.31	0.664
	Air temp. (°C)	y = 1.9637x -34.29	0.229
Schleichera oleosa	Soil moisture (%)	y = 1.9055x - 9.56	0.379
	Soil temp. (°C)	y = 2.3641x -28.68	0.411
	Rainfall (mm)	y = 0.1996x + 5.55	0.835
	Air temp. (°C)	y = 2.3531x - 44.09	0.153
Gmelina arborea	Soil moisture (%)	y = 3.8808x - 38.63	0.302
	Soil temp. (°C)	y = 2.5907x - 26.75	0.471
	Rainfall (mm)	y = 0.2024x + 12.0	0.794
	Air temp. (°C)	y = 3.007x - 55.63	0.228

litter was faster in Gamhar leaf and least in Palas. The nutrient release pattern shows the order as, K > N > P irrespective of leaf litter species.

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

Leaching loss of nutrients in summer okra and green gram

The leaching loss of nutrients was evaluated under different treatments comprised of T1: N0P0K0 (Control), T2: 100% recommended NPK as inorganic fertilizer; T3: 100% recommended NPK as organic manure; T4: 50% recommended NPK as inorganic fertilizer + 50% Recommended NPK as organic manure on summer crop of okra and green gram. The irrigations were applied to all the plots by flood irrigations as per farmer's practice as and when required. The water leached out from each plot was collected through PVC pipe at the bottom of each plot into a 200 litre plastic drum. Periodically leachates were collected from all the plots and were analysed for nutrient losses.

In okra crop, the highest leaching loss of N was 11.22 kg/ha in the treatment receiving 100% recommended NPK as inorganic fertilizer (T_2) with loss of 8% N from the applied fertilizer. The lowest leaching loss of N was 3.36 kg/ha which corresponds to loss of 1.4% N from applied fertilizer in the treatment receiving 100% recommended NPK as farmyard manure (T_3). The leaching loss of P was very low which varied from 0.53 to 7.4 g/ha and was found non-significant among the different treatments. The leaching loss of K varied significantly among the different treatments. The highest K loss of 6.51 kg/ha was recorded in the treatment receiving 100% recommended NPK as inorganic fertilizer (T_2) with a corresponding loss of 9.24% K from the applied fertilizer. The lowest K loss was 3.17 kg/ha in T_3 treatments with a corresponding loss of 2.54% K from the applied fertilizer (Table 13.3). The leaching loss of calcium varied from 9.5 to 15.1 kg/ha, while the loss of magnesium varied from 4.6 to 9.0 kg/ha among the different treatments (Fig. 13.1). The leaching loss of S, Fe, Mn, Zn and Cu were in negligible amount in all the treatments.

In green gram crop, the highest leaching loss of N was 5.35 kg/ha in the treatments receiving 100% recommended NPK as inorganic with a corresponding 10.5% N loss from the applied fertilizer. The leaching loss of P among the treatments was very low and varied from 0.8 to 9.25 g/ha. The leaching loss of K varied significantly among the treatments

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

Treatments	Loss of N (kg/ha)	Loss of P (g/ha)	Loss of K (kg/ha)
T1: N0P0K0 (Control)	1.62	0.53	1.90
T2: 100% RDF as inorganic	11.22 (8.0)	7.40 (0.027)	6.51 (9.24)
T3: 100% RDF as organic	3.36 (1.4)	0.66 (0.001)	3.17 (2.54)
T4: 50% RDF as inorganic +50% RDF as organic	7.92 (5.2)	3.71 (0.013)	4.59 (5.39)
LSD (p≤0.05)	2.9	1.23	1.53

*RDF: 120:25:50 kg N: P: K/ha
*Figures in parenthesis indicate % nutrient loss from applied fertilizer

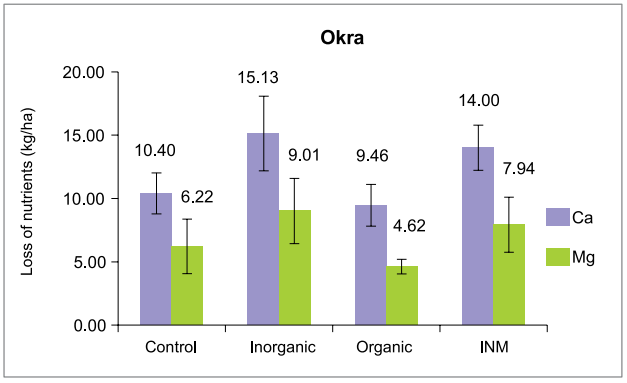


Fig. 13.1. Leaching loss of calcium and magnesium in okra under different nutrient management practices.

and highest K loss was 4.3 kg/ha in T_2 treatment with a corresponding 10.43% K loss from the applied fertilizer (Table 13.4). The leaching loss of Ca varied from 8.64 to 18.72 kg/ha while Mg loss varied from 4.04 to 11.21 kg/ha among the treatments (Fig. 13.2). The leaching loss of S, Fe, Mn, Zn and Cu are in trace and negligible amount in all the treatments.

Table 13.4. Leaching loss of N, P and K in green gram under different nutrient management practices in summer season.

Treatments	Loss of N (kg/ha)	Loss of P (g/ha)	Loss of K (kg/ha)
T1: N0P0K0 (Control)	2.72	0.79	1.69
T2: 100% RDF as Inorganic	5.35 (10.53)	9.25 (0.017)	4.30 (10.43)
T3: 100% RDF as organic	3.53 (3.26)	3.56 (0.005)	2.05 (1.42)
T4: 50% RDF as inorganic +50% RDF as organic	4.30 (6.34)	8.26 (0.015)	3.39 (6.77)
LSD (p≤0.05)	1.6	2.87	1.3

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

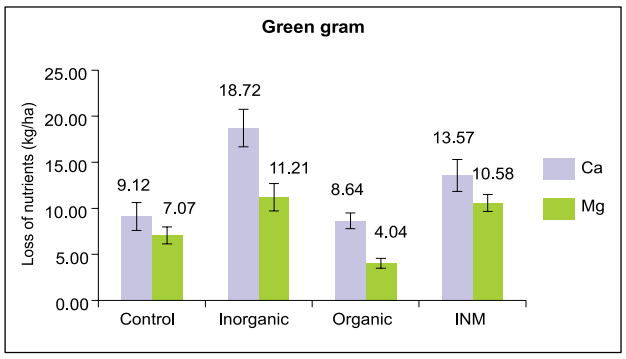


Fig. 13.2. Leaching loss of calcium and magnesium in green gram under different nutrient management practices.

Leaching loss of nutrients in *kharif* rice and finger millet

In *kharif* rice crop, the leaching loss of nitrogen varied from 9.6-19.0 kg/ha among the treatments. The highest nitrogen loss of 19.0 kg/ha was recorded in the treatment receiving 100% recommended NPK as inorganic fertilizer (T_2) with loss of 23.5% N from the applied fertilizer. The lowest N-leaching loss of 11.5 kg/ha which corresponds to loss of 4.8% N from applied fertilizer was recorded in the treatment receiving 100% recommended NPK as farmyard manure (T_3) recorded. The P-leaching loss was very low varied from 0.05-0.1 kg/ha among the different treatments. The K-leaching loss varied significantly among the different treatments. The highest K loss was 10.5 kg/ha recorded in the treatment receiving 100% recommended NPK as inorganic fertilizer (T_2) with a corresponding loss of 26.3% K from the applied fertilizer. The lowest K loss was 7.2 kg/ha in T_3 treatments with a corresponding loss of 9.8% K from the applied fertilizer (Table 13.5).

Table 13.5. Leaching loss of N, P and K in rice under different nutrient management practices in *kharif* season.

Treatments	Loss of N (kg/ha)	Loss of P (kg/ha)	Loss of K (kg/ha)
T1: N0P0K0 (Control)	9.6	0.051	5.3
T2: 100% RDF as Inorganic	19.0 (23.5)	0.100 (0.25)	10.5 (26.3)
T3: 100% RDF as organic	11.5 (4.8)	0.067 (0.08)	7.2 (9.8)
T4: 50% RDF as inorganic +50% RDF as organic	15.9 (15.7)	0.080 (0.15)	8.3 (15.2)
LSD (p≤0.05)	2.5	0.57	3.09

*RDF: 40: 20:20 kg N: P: K/ha
*Figures in parenthesis indicate % nutrient loss from applied fertilizer

In finger millet, the N-leaching loss varied from 9.6-13.6 kg/ha among the different treatments. The treatments receiving 100% recommended NPK as inorganic fertilizer (T_2) registered highest N loss of 13.6 kg/ha with a corresponding 12.2% N loss from the applied fertilizer. The leaching loss of P was very low & varied from 0.061-0.078 kg/ha among the treatments. The leaching loss of K varied significantly among the treatments and highest K loss was 6.73 kg/ha in T_2 treatment with a corresponding 17.4% K loss from the applied fertilizer (Table 13.6). The leaching loss of S, Fe, Mn, Zn and Cu are in trace and negligible amount in all the treatments.

Table 13.6. Leaching loss of N, P and K in finger millet under different nutrient management practices in *kharif* season.

Treatments	Loss of N (kg/ha)	Loss of P (kg/ha)	Loss of K (kg/ha)
T1: N0P0K0 (Control)	9.6	0.061	3.77
T2: 100% RDF as Inorganic	13.6 (12.2)	0.078 (0.13)	6.73 (17.4)
T3: 100% RDF as organic	10.5 (2.7)	0.061 (0.00)	4.40 (3.7)
T4: 50% RDF as inorganic +50% RDF as organic	11.7 (6.4)	0.069 (0.065)	6.05 (13.4)
LSD (p≤0.05)	2.6	NS	1.92

*RDF: 33:13:17kg N: P: K/ha
*Figures in parenthesis indicate % nutrient loss from applied fertilizer

Water balance in summer okra and green gram

The total water applied through flood irrigation and rainfall in okra and green gram was 350 mm. The total evaporation in the crop growth period of okra and green gram was 166.6 and 140.2 mm, respectively. There is negative soil water storage of -26.4 and -7.5 mm, respectively in both crops of okra and green gram. The total deep percolation during the entire crop growth period was 52.3 and 50.6 mm, which corresponds to 23.5 and 22.5% of applied water, respectively in okra and green gram (Table 13.7).

Table 13.7. Water balance parameters in okra and green gram under different organic and inorganic nutrient management

Parameter (in mm)	Okra	Green Gram
Irrigation + Rainfall	350.0	350.0
Evaporation	166.6	140.2
Root water uptake	159.1	165.8
Change in soil storage	-26.4	-7.5
Deep percolation, predicted	50.7 (22.7%)	51.4 (22.8%)
Deep percolation, observed	52.3 (23.5%)	50.6 (22.5%)

Water balance in *kharif* rice and finger millet

The total water applied through flood irrigation and rainfall in rice and finger millet was 868.0 mm while the total evaporation in rice and finger millet was 118.0 and 130.8 mm, respectively. There was negative soil water storage of -4.6 mm, in finger millet. The total deep percolation during the entire crop growth period was 301.0 and 297.0 mm, which corresponds to 34.7 and 34.2% of applied water, respectively in rice and finger millet (Table 13.8).

Table 13.8. Water balance parameters in rice and finger millet under different organic and inorganic nutrient management

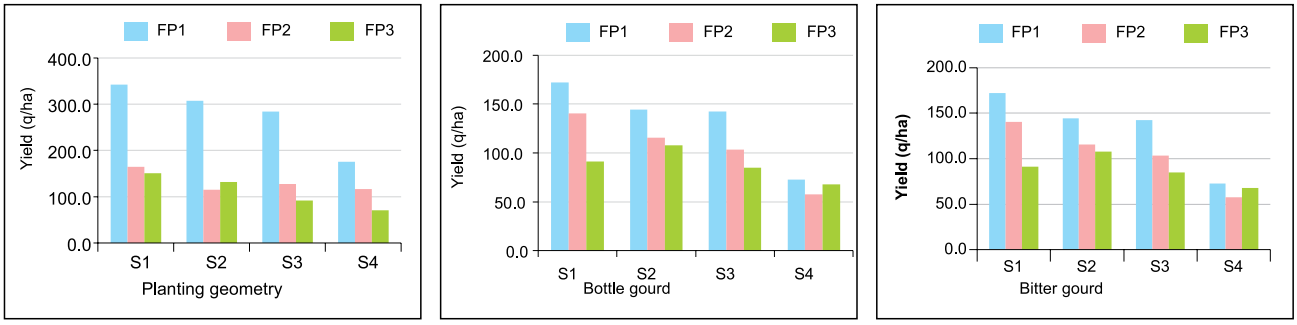
Parameter (mm)	Rice	Finger millet
Irrigation + rainfall	868.0	868.0
Evaporation	118.0	130.8
Root water uptake	228.4	214.5
Runoff	199.8	205.2
Change in soil storage	27.5	-4.6
Deep percolation, predicted	294.3 (33.9)	322.1 (37.1)
Deep percolation, observed	301.0 (34.7%)	297.2 (34.2%)

Study on Growth Stage Based Fertigation Patterns and Crop Geometry in Cucurbitaceous Crops in Eastern Hill Plateau Region Condition

The experiment was conducted to evaluate the efficacy of different growth stage based fertigation and crop geometry on yield potential of Cucurbitaceous crops *viz.*, Bottle gourd, Bitter gourd & Cucumber. The experiment comprised of three growth stage based fertigation level (F_1, F_2 &F_3) and four crop geometry (S_1, S_2, S_3 & S_4) in twelve treatment combination. In cucumber (summer season), highest yield (342.0 q/ha),WP (26.1 kg/m^3) & Economic Water Productivity (EWP) (Rs 260.6 m^3) were recorded with the planting geometry S_1 (80 x 80 cm, square with one row per lateral of 1525 plant/ha) and fertigation pattern FP_1 (constant fertilizer dose throughout the cropping season). In bottle gourd, the same treatment, i.e., S_1 x FP_1 resulted in highest yield (172.4 q/ha),WP (13.1 kg/m^3) & EWP (Rs. 131.4/m^3). Similarly in bitter gourd, the treatment FP_1 x S_1 also resulted in highest yield (148.9 q/ha),WP (10.3 kg/m^3) & EWP (Rs. 154.1/m3). Hence, the initial trend revealed the closely spaced crop geometry (80 x 80 cm) and uniform fertilizer dose throughout the cropping season was better in terms of yield, WP & EWP in Bitter gourd, Bottle gourd & Cucumber (Fig. 13.3).

Structure and Functioning of Agroforestry Systems in the Middle IGP

Selection and identification of agroforestry system was carried out following a preliminary reconnaissance survey in the Vaishali district. In general, two types of agroforestry systems *viz.*, agri-silvicultural and agri-horticultural are widely practiced by farmers of this region. Teak (*Tectona grandis*) + agricultural crops, Poplar (*Populus* spp) + agricultural crops and Sissoo (*Dalbergia sissoo*) + agricultural crops represented agri-silvicultural system while Mango (*Mangifera indica*) + agricultural crops denoted the agri-horticultural system (Table 13.9). Apart from these systems, patches of bamboo (*Dendroclamus strictus*) are maintained in common lands or in corners of fields due to their versatile use in rural areas. Under the Teak based agroforestry system (TB-AFS), farmers of this region generally grow mustard (*Brassica* spp*)* and rice (*Oryza sativa)*. Wheat (*Triticum aestivum*) and rice are commonly used as intercrop in poplar-based agroforestry system (PB-AFS). Similarly, under the Sissoo based agroforestry system (SB-AFS) farmers favor the cultivation of mustard, potato (*Solanum tuberosum)*, maize (*Zea mays*) etc., while mustard, moong (*Phaseolus vulgaris)* and potato are commonly cultivated under mango based agroforestry system (MB-AFS) (Fig. 13.4).



Cucumber Bottle gourd Bitter gourd

Fig. 13.3. Yield of different vegetables under different crop geometry and fertigation pattern

(a) Teak based AFS

(b) Poplar based AFS

(c) Sissoo based AFS

(d) Mango based AFS

Fig. 13.4. Different agroforestry systems in Vaishali district

Table 13.9. Details of agroforestry systems prevailing in Vaishali district

Agroforestry system (AFS)	Mean DBH (cm)	Mean height (m)	Spacing (m)	Age of tree (years)
Teak based AFS	12.64	7.80	4m ×4m boundary plantation)	8-10
Poplar based AFS	24.96	18.15	5m ×5m boundary plantation)	5-6
Sissoo based AFS	6.74	3.15	4m×4m	5-6
Mango based AFS	6.02	4.55	8m×8m	5-6

Distribution of Different Carbon Fractions

The effect of different AFS on the distribution of different carbon fractions is presented in Table 13.10. In all the AFS, the higher amounts of carbon fractions of different oxidisability were recorded in the surface soil. Different forms of carbon fractions in all the AFS ranged from 1.19 to 1.35 Mg C/ha, 0.89 to 1.16 Mg C/ha, 0.63 to 0.77 Mg C/ha and 2.93 to 3.52 Mg C/ha for very labile (fraction I), labile (fraction II), less labile (fraction III) and non- labile (fraction IV), respectively. The soil of polar based-AFS had consistently contained the highest carbon fractions than the rest of the AFS. On the other hand, the MB-AFS had the lowest carbon fractions of different oxidisability. Across all the AFS, non- labile form of fraction (fraction IV) contributed the maximum amount of carbon followed by very labile fraction (fraction I) with the order being (in decreasing order) fraction IV > fraction I > fraction II > fraction III.

Table 13.10. Soil organic carbon fractions (Mg C/ha) at three depths in different agroforestry systems

Parameters	Depths (cm)	TB-AFS	PB-AFS	SB-AFS	MB-AFS	Mean
F_1 (Very labile carbon)	0-15	2.13^{a}	2.28^{a}	2.06^{a}	1.94^{a}	2.10^{A}
	15-30	1.16^{b}	1.24^{b}	1.09^{b}	1.04^{b}	1.13^{B}
	30-45	0.90^{c}	0.79^{c}	0.81^{c}	0.83^{c}	0.83^{C}
	Mean	1.40^{AB}	1.44^{A}	1.32^{BC}	1.27^{c}	
F_2 (Labile carbon)	0-15	1.40^{a}	1.69^{a}	1.52^{a}	1.13^{a}	1.44^{A}
	15-30	1.30^{a}	1.26^{b}	1.31^{b}	1.04^{a}	$1.23.^{B}$
	30-45	0.91^{b}	0.79^{c}	0.90^{c}	0.75^{b}	0.84^{C}
	Mean	1.20^{A}	1.25^{A}	1.24^{A}	0.97^{B}	
F_3 (Less labile carbon)	0-15	1.44^{a}	1.48^{a}	1.39^{a}	1.25^{a}	1.39^{A}
	15-30	1.25^{b}	1.15^{b}	1.24^{b}	1.12^{ab}	1.19^{B}
	30-45	1.11^{c}	1.15^{b}	1.06^{c}	1.03^{b}	1.09^{C}
	Mean	1.27^{A}	1.26^{A}	1.73^{A}	1.13^{B}	
F_4 (Non-labile carbon)	0-15	3.46^{a}	3.79^{a}	3.11^{a}	3.04^{a}	3.35^{A}
	15-30	2.88^{b}	3.07^{b}	2.64^{b}	2.50^{a}	2.77^{B}
	30-45	2.04^{c}	2.21^{c}	1.87^{c}	1.74^{b}	1.97^{C}
	Mean	2.79^{B}	3.02^{A}	2.54^{C}	2.43^{C}	

Different small letters denote significant difference ($p \leq 0.05$) among the soil depths within the agroforestry system. Different capital letters denote significant difference ($p \leq 0.05$) between the agroforestry systems.

14. Water Quality and Productivity

Optimization of Cropping Pattern to Maximize Water Productivity

A study was conducted in the command of Paliganj distributary and Nalanda corridor (ground water irrigated area) to find out optimum crop plan that enhances water productivity. Data on inputs applied (like seeds, fertilizer, insecticides/ pesticides, land preparation, farm implements, water and labour) outputs produced (like main product and by-product) along with cost were collected through developed questionnaire from representative farmers. Water productivity maximization problem was formulated and constraints were decided after interaction with farmers for both the project sites. Objective function is common but constraints are different and given below.

Objective function:

Maximization of Water Productivity (Z_{WP})

$$\text{Max } Z_{WP} = \left[\sum_{i=1}^{3} \sum_{j=1}^{6} \frac{1}{IA_{ij}} [A_{ij} (Y_{ij} P_{ij} + YB_{ij} PB_{ij} - CP_{ij}) - \sum_{i=1}^{3} PCW_i \times A_i - PGW \times NH] \right]$$

Where Z_{WP} is Net annual return from all the crops of command per unit of irrigation water applied (Rs.-ha/m^3); i = Index for crop season (i = 1 for monsoon or *kharif* season, 2 for non-monsoon or *rabi* season and 3 for summer season); J = index for crop name; A_{ij} = Area to be allocated (ha) in season i for crop j; IA_{ij} = Irrigation applied in season i for crop j (m^3); Y_{ij} = Yield of crop j grown in season i (kg/ha); P_{ij} = Current market price of crop j in season i (Rs./kg); YB_{ij} = Yield of by-product of crop j grown in season i (kg/ha); PB_{ij} = Current market price of by-product of crop j in season i (Rs./kg); CP_{ij} = Cost of production (excluding irrigation water price) of crop j grown in season i (Rs./ha); PCW_i = Price for canal water paid (Rs./ha); A_i is area covered by crops during monsoon, non-monsoon and summer season; PGW = Price paid for ground water applied (Rs./hr); NH = Number of hours of operation in providing irrigation.

Constraints for Paliganj site:

Crop area constraints

1. $A_R + A_{MK} \leq 3410$ ha
2. $A_W + A_L + A_{KH} + A_G + A_{MR} + A_P \leq 3410$ ha
3. $A_O + A_{GG} \leq 1705$ ha
4. $A_R \geq 1705$ ha
5. $A_W \geq 1023$ ha

Canal and Ground water availability constraints

6. $0.734\ A_R + 0.225\ A_{MK} \leq 1498.94$ ha-m
7. $0.225A_W + 0.1A_L + 0.1A_{KH} + 0.1A_G + 0.375A_{MR} + 0.135\ A_P + 0.4A_o + 0.075\ A_{GG} \leq 323.64$ ha-m

Man-days requirement constraints

8. $196\ A_R + 40\ A_{MK} + 120\ A_W + 40\ A_L + 40\ A_{KH} + 45\ A_G + 40A_{MR} + 56A_P + 70A_O + 40\ A_{GG} \leq 500000$ man-days

Where, A_R, A_{MK}, A_W, A_L, A_{KH}, A_G, A_{MR}, A_P, A_O and A_{GG} are the areas to be allocated under rice, kharif maize, wheat, lentil, khesari, gram, maize rabi, potato, onion and green gram crops , respectively.

The value of water productivity considering existing area under different crops and optimum water productivity after revising the allocation of area under different crops employing simplex linear programming technique are given below in Table 14.1.

Table 14.1. Existing and optimum water productivity computed at Paliganj site

Crop	Existing area (ha)	Optimum area allocation (ha)
Rice	3083	1705
Maize *(kharif)*	10	107
Wheat	1100	1023
Lentil	1200	0
Khesari	700	0
Gram	300	0
Maize *(rabi)*	30	0
Potato	80	692
Onion	90	0
Green Gram	100	0
Total area	6693	3527
Water Productivity (Rs/m^3)	198197/6693 = 29.61	115069/3527 = 32.62

It is concluded from above that water productivity can be enhanced from existing 29.61 Rs./m^3 from 6693 ha area to 32.62 Rs./m^3 from 3527 ha area only if area under different crops is reallocated and

constraints of ground water availability and other prevailing constraints in the project area are considered.

For Nalanda corridor site following constraints were formulated

Crop area constraints

1. $A_R \leq 400$ ha
2. $A_W \geq 200$ ha
3. $A_B \geq 6$ ha
4. $A_{MP} \geq 6$ ha
5. $A_W + A_L + A_G + A_P + A_{MU} + A_C + A_B \leq 400$ ha
6. $A_{MA} + A_{GG} + A_{MP} \leq 300$ ha

Ground water availability constraints

7. $0.225\ A_R \leq 81$ ha-m
8. $0.175A_W + 0.05A_L + 0.05A_G + 0.135A_P + 0.1A_{MU} + 0.75\ A_C + 0.5A_B \leq 54$ ha-m
9. $0.35A_{MA} + 0.15A_{GG} + 0.5A_{MP} \leq 27$ ha-m

Man-days requirement constraints

10. $118\ A_R + 75A_W + 42\ A_L + 30A_G + 66A_P + 40A_{MU} + 24A_C + 25A_B + 64A_{MA} + 60A_{GG} + 25A_{MP} \leq 500000$ man-days

Here A_R, A_W, A_L, A_G, A_P, A_{MU}, A_C, A_B, A_{MA}, A_{GG}, A_{MP} are the areas to be allocated under rice, wheat, lentil, gram, pea, mustard, coriander, berseam, maize, green gram and MP chari, respectively.

The value of water productivity considering existing area under different crops and optimum water productivity after revising the allocation of area under different crops employing simplex linear programming method at Nalanda Corridor site is given below in Table 14.2.

Table 14.2. Existing and optimum water productivity computed at Nalanda corridor site

Crop	Existing area (ha)	Optimum area allocation (ha)
Rice	400	360
Wheat	280	200
Lentil	10	194
Gram	10	0
Pea	4	0
Mustard	80	0
Coriander	10	0
Berseem	6	6
Maize	60	0
Green gram	80	0
MP Chari	6	6
Total area	946	766
Water Productivity (Rs/m^3)	17289.08/9416 = 18.28	17440.8/766 = 22.77

It is concluded from above that water productivity at Nalanda Corridor site can be enhanced from existing 18.28 Rs./m^3 from 946 ha area to 22.77 Rs./m^3 from 766 ha if area under different crops is reallocated and constraints of ground water availability and other prevailing constraints in the project area are considered.

Studies on Irrigation Water Pricing and Influencing Factors

Thirty farmers representing I, II and III reach of Paliganj distributary and thirty farmers from Nalanda Corridor site were interviewed and questionnaires were filled up. Irrigation water price was assessed by considering canal and ground water applied by farmers at Paliganj distributary command and only ground water applied at Nalanda Corridor site. Results of the study are given below in Table 14.3 and 14.4 for Nalanda Corridor site and Table 14.5 and 14.6 for Paliganj distributary site.

Table 14.3. Input output ratio of rice-wheat-moong cropping system farmers from Nalanda Corridor site

Particulars of Inputs/ outputs	Area 1 ha		
	Rice	Wheat	Moong
Input cost (including seed, organic matter, fertilizer, insecticide, pesticide etc. but excluding water) (Rs.)	6352	5652	6220
Labour cost involved in ploughing/ rotavator/ tilling/ harrowing/ sowing/ dibbling/ planting/transplanting/ weeding/ harvesting/ threshing etc.(Rs.)	11300	6400	6000
Fixed cost including rental value of land, depreciation cost of farm building and implements and interest on fixed cost (Rs.)	43180	20160	12750
Total cost of cultivation (Rs.)	60832	32212	24970
Yield of main products (T)	4.5	3.5	0.7
Sale price (Rs./T)	15000	19000	55000
Yield of bi-products (T)	4.5	3.5	0
Sale price (Rs./T)	5000	5000	0
Output from main products and bi-products (Rs.)	90000	84000	38500
Output – Input (Rs.)	29168	51788	13530

Table 14.4. Irrigation water price computation based on water applied

Source of water	Volume of water applied (m^3)		
	Area 1 ha		
	Rice	Wheat	Moong
Canal	0	0	0
Tubewell	2250	1750	1500
Total irrigation applied	2250	1750	1500
Profit (Rs.)	29168	51788	13530
Irrigation water price (Rs./m^3)	12.96	29.59	9.02

Table 14.5. Input output ratio rice and wheat in farmers from I, II, and III reach of Paliganj distributary

Particulars of inputs/ outputs	Reach I Area 1.13 ha		Reach II Area 1 ha		Reach III Area 1 ha	
	Rice	Wheat	Rice	Wheat	Rice	Wheat
Input cost (including seed, organic matter, fertilizer, insecticide, pesticide etc. But excluding water) (Rs.)	11680	16605	9930	14170	10010	15550
Labour cost involved in ploughing/ rotavator/ tilling/ harrowing/ sowing/ dibbling/ planting/transplanting/ weeding/ harvesting/ threshing etc. (Rs.)	27100	23100	22500	19000	22500	19000
Fixed cost including rental value of land, depreciation cost of farm building and implements and interest on fixed cost (Rs.)	48000	23820	44500	25408	43100	20160
Total cost of cultivation (Rs.)	86780 (76796/ha)	63525 (56217/ha)	76930	58578	75610	54710
Yield of main products (T)	6.0	3.5	5.5	3.2	5.3	3.0
Sale price (Rs./T)	17500	18400	17500	18400	17500	18400
Yield of bi-products (T)	3.0	3.0	3.0	2.5	3.0	2.4
Sale price (Rs./T)	5000	5000	5000	5000	5000	5000
Output from main products and bi-products (Rs.)	120000 (106195/ha)	79400 (70265/ha)	111250	71380	107750	67200
Output – Input (Rs.)	33220 (29398/ha)	15875 (14048/ha)	34320	12802	32140	12490

Table 14.6. Irrigation water price computation based on irrigation water applied

Source of water	Volume of water applied (m^3)					
	Reach I Area 1.13 ha		Reach II Area 1 ha		Reach III Area 1 ha	
	Rice	Wheat	Rice	Wheat	Rice	Wheat
Canal	5835	1160	5160	1060	4950	-
Tubewell	1190	1670	1450	1525	1750	2000
Total irrigation applied	7025	2830	6610	2585	6700	2000
Profit (Rs.)	33220	15875	34320	12802	32140	12490
Irrigation water price (Rs./m^3)	4.73	5.61	5.19	4.95	4.80	6.24

It may be observed from Table 14.6 that irrigation water price considering irrigation water applied through canal and tube well in Reach I, II and III of Paliganj distributary for rice crop was 4.73, 5.19 and 4.80 Rs./m^3 and for wheat crop was 5.61, 4.95 and 6.24 Rs./m^3. It may also be observed from Table 14.6 that in Reach III, canal water could not be available to irrigate wheat crop and it was solely irrigated by tube well water. Though profit was not much even than irrigation water price was relatively higher. Results reported in Table 14.6 revealed that at Nalanda Corridor, irrigation water price of rice, wheat and moong was estimated as 12.96 Rs/m^3, 29.59 Rs./m^3, and 9.02 Rs./m^3, respectively. At Nalanda corridor site, ground water is used for irrigation and less amount of water when essentially required was applied, so water price in case of irrigation through ground water is high.

Mapping of the Extent of Flood-Affected Area in Bihar in 2020 and Estimation of Cropland Affected Due to Flood

In Bihar, the flood inundation maps (FIMs) at 2-3 days interval of monsoon months (June-October) along with the other layers such as rail, road network etc. are produced from satellite imageries and shared by Bihar Flood Management Information System (BFMIS) (http://www.fmis.bih.nic.in/). In this study, vector layer representing the flooded areas with respect to each FIM for the year 2020 was classified using the Maximum Likelihood classification method. It was observed after quantifying the flood extent on various dates that maximum spread of floodwater in 2020 in Bihar was observed on 27th July. District wise extent of flooding in Bihar on 27th July, 2020 is shown in Fig. 14.1 (a-b). Interpretation of these figures visualizes that the districts most affected by flooding in 2020 were Darbhanga, followed by Madhubani, Purbi Champaran, Muzaffarpur, etc. The land use and land cover (LULC) map of Bihar of 2015-16 in raster format was downloaded (https://bhuvan.nrsc.gov.in/bhuvan_links.php) and converted to its vector format. The LULC map of Bihar (Fig. 14.2a) and the area under each LULC is given in Table 14.7, which reveals that about 82% of the area of Bihar is under cropland. Overlaying the vector maps of flooded area on July 27, 2020 and LULC of Bihar produced a map that represents the LULCs affected by the flood on July 27, 2020 (Fig. 14.2b). After analyzing the

attributes of this map, it was observed that 0.54 m ha of cropland and 0.011 m ha of plantation area were affected by the flooding on 27th July, 2020.

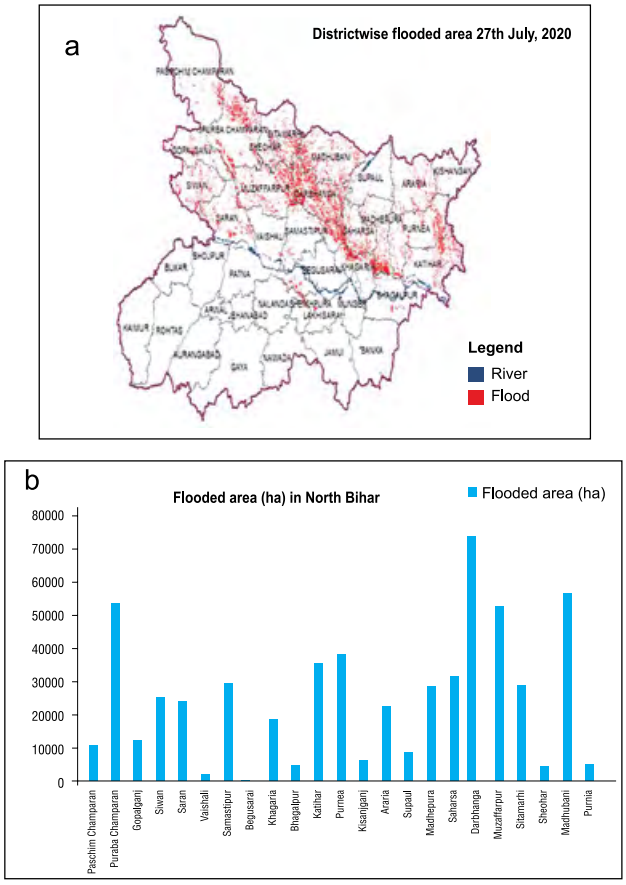


Fig 14.1. (a) District wise distribution of floodwater spread in Bihar and (b) area flooded in north Bihar on 27th July, 2020

Table 14.7. Land use and land cover of different classes in Bihar

LULC	Area (km^2)
Deciduous broadleaf forest	4620.2
Cropland	77410.6
Built-up land	705.6
Mixed forest	3.9
Shrubland	3797.2
Barren land	114.8
Fallow land	1750.7
Wasteland	148.7
Water bodies	3944.4
Plantations	373.9
Grassland	387.4
Permanent wetlands	1278.9

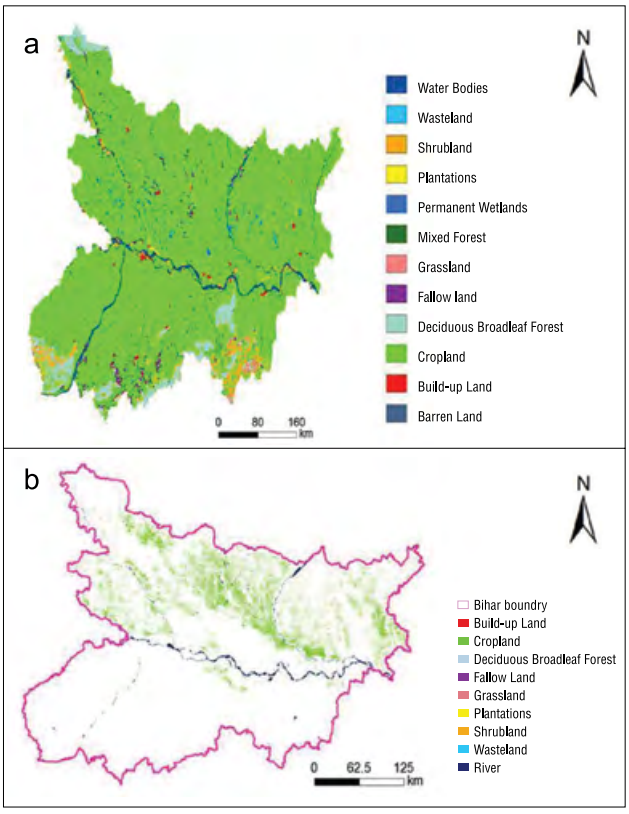


Fig. 14.2. (a) LULC map in 2015-16 of Bihar, (b) LULC affected due to flooding on 27th July, 2020

Variation of Soil Moisture in Guava Orchard and Effect of Fertigation Scheduling on Guava Yield

Soil moisture (%v/v) in guava orchard was recorded at interval of 5 days in 2020 at six locations and at six soil depths, i.e., 10, 20, 30, 40, 60, and 100 cm. Average soil moisture at field capacity (FC) and permanent wilting point (PWP) in the guava orchard was observed as 50.9% and 29.9%, respectively. It has been observed from the rainfall analysis that 86% of annual rainfall (1367 mm) occurred during the monsoon months (June to October) in 2020 and the last monsoonal rainfall event occurred on October 5, 2020. Due to the occurrence of normal and well-distributed rainfall during monsoon months, soil moisture at the subsurface was observed near FC, and soil moisture at the surface was well above the PWP. Now, the thumb rule for triggering irrigation in a crop field is when 50% of the available soil moisture is depleted. In this case, it is computed to be 40.4%. Thus, it is visible from the figure that the total available soil moisture in the surface as well as sub-surface is above 40.4% during the monsoon months. Hence, guava plants require no irrigation during the monsoon in 2020. However, for applying fertilizer as per the treatment schedule

through fertigation minimum irrigation was applied for fertigation during the monsoon. The fertigation in guava was applied through drip based fertigation unit which is operated by solar power. It has been observed that the 2-hp solar pump is well capable to deliver NPK fertilizer in liquid form through the fertigation unit. In this study, the treatments (T_1, T_2, and T_3) included the application of 75% recommended doses of N fertilizer during February to May than the control T_4 (recommended NPK fertilizer is applied during July-October). It showed that overall the median fruit yield in treatments T_1, T_2, and T_4 was approximately 1.7 t/ha whereas, for T_3, the median fruit yield is significantly less. It reveals from the 1st year of this study that advancing (starting from March) N fertilizer application (T_1 and T_2) does not increase overall fruit yield and more advancement of application of N fertilizer (application started from February) negatively affected the fruit yield.

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

Looking into the irregular water availability in Bharatpura sub-distributary, assured groundwater supply source (tube well) for irrigation in conjunction with canal water was created in 30.5 ha area in this sub-distributary by the installation of one 3.0 HP electric pump and two 5.0 HP electric submersible pumps, and one 2.0 HP solar submersible pump. In this command in Sihi village, farmers were encouraged to store canal water in ponds and replenish its water level with the created groundwater source when required for irrigating their fields as well as fish production. Average fish production for rohu and catla varieties from two ponds (dimension: 34 m x 35 m) of a farmer of this village was observed 2.0 t/ha.

Besides, para-lentil cultivation was demonstrated to farmers, and improved lentil variety (HUL 57) seed was distributed to 12 farmers. Lentil yield of the variety was recorded in the range of 0.75 - 0.9 t/ha with water productivity of 0.75 - 0.9 kg/m^3. A mini sprinkler irrigation system was introduced in a farmer's pea field and 36.6% and 91.2% higher green pod yield and water productivity were observed with the introduction of a mini sprinkler system than the conventional check basin irrigation.

In the command area, the cost incurred for irrigating five plots of paddy nursery of farmers with the solar pump was calculated and compared with the cost of irrigation required for diesel and electric pumps. It was found that the cost of irrigation through diesel and the electric pump were 73% and 21% higher than solar pump respectively (Fig. 14.3). Moreover, this solar pump was also fulfilling the domestic needs of the farmers and livestock.

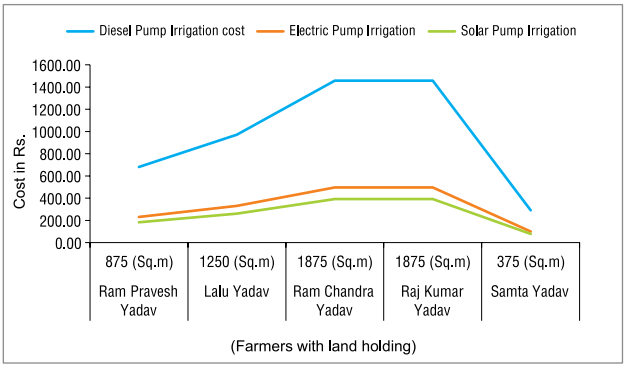


Fig. 14.3. Comparison of the cost incurred in irrigation through solar, diesel, and electric pumps

15. Conservation Agriculture

Effects of Long-Term Conservation Agriculture (CA) on Productivity of Rice-Based Cropping System

A long-term experiments has been undertaken under CSISA project on CA in rice-based cropping systems at the ICAR RCER Patna since 2009-10. After 7th year, ZTDSR in CA-based rice- mustard-maize system faced a severe problem of rice mealy bug (*Brevennia rehi*), and hence, divided into 4 plots (ZT DSR, CTDSR, puddle transplant and Unpuddle transplant). After two years of tillage, these plots were again converted to ZT-DSR. Results after 10th year revealed that maximum rice yield (6.17 t/ha) was recorded with ZTTPR in CA-based rice (ZTTPR)-wheat (ZT)-mungbean (ZT) production systems (Table 15.1).

Table 15.1. Rice yield as influenced by different tillage-cum-crop-establishment methods in long-term conservation agriculture production system

Crop scenario	Crop establishment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
CTR-CTW-Fallow (S1)	Broadcasted	5.96A	12.9B	18.9B	32.1BC
	Line transplanting	6.08A	13.9A	19.9AB	31.2BC
CTR-ZTW-ZTMU (S2)	CTMTR	6.17A	14.1A	20.3A	30.3C
ZTR-ZTW-ZTM (S3)	ZTTPR	6.21A	12.9B	19.1AB	33.2AB
ZTDSR-ZTM-ZTM (S4)	ZTTPR	5.17B	9.6C	14.8C	35.1A

CTR: Conventional-till rice, CTW: Conventional-till wheat, ZTMU: Zero-till mungbean, ZTDSR: Zero-till direct seeded rice, ZTM: Zero-till mustard

In the same project an experiment was initiated during 2015 to study the long-term effect of crop establishment methods in rice-wheat-mungbean production system. Results of 6th years of the experimentation revealed that ZTDSR tillage production system produced the maximum grain yield (5.59 t/ha), and was at par with SRI (5.54 t/ha) and RPTR (5.44 t/ha) (Table 15.2 and Fig. 15.1).

Table 15.2. Rice yields as influenced by different tillage-cum-crop establishment methods in long-term conservation agriculture production system

Tillage-cum-crop establishment methods	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
RPTR-CTW-CTM	5.44^{AB}	8.42^{A}	13.9^{A}	39.1^{BCD}
PLTR-CTW-CTM	5.33^{AB}	7.78^{B}	13.1^{A}	40.7^{AB}
CTMTR-ZTW-ZTM	4.92^{C}	8.48^{A}	13.4^{A}	36.7^{D}
ZTMTR-ZTW-ZTM	5.37^{AB}	7.26^{B}	12.6^{A}	42.3^{A}
SRI-SWI-ZTM	5.54^{A}	7.62^{B}	13.2^{A}	42.4^{A}
CTDSR-ZTW-ZTM	5.08^{BC}	8.63^{A}	13.7^{A}	37.1^{CD}
ZTDSR-ZTW-ZTM	5.59^{A}	8.42^{A}	14.0^{A}	39.7^{ABC}

RPTR: Random puddle transplanted rice, CTW: Conventional-till wheat, CTM: Conventional-till mungbean, PLTR: Puddle line transplanted rice, CTMTR: Conventional-till machine transplanted rice, ZTMTR: Zero-till machine transplanted rice, SRI: System of rice intensification, SWI: System of wheat intensification, CTDSR: Conventional-till direct seeded rice, ZTDSR: Zero-till direct seeded rice.

Fig. 15.1. Performance of rice in diverse tillage-cum-crop establishment methods

Conservation Agriculture for Rice-Fallow Management in Eastern Plateau and Hill region of India

An experiment was conducted at farmer's fields located in Jharkhand and Chhattisgarh to assess the effect of conservation agriculture on soil carbon

dynamics, crop yield and water productivity in rice-mustard-black gram cropping system. Three cultivation practices (Puddled transplanted rice (PTR), direct sown rice (DSR) and zero tillage-transplanted rice(ZT-TPR) were adopted for rice, while for *rabi* season crops the conservation agriculture (CA) practices were fallowed with mulch (M) and without mulch (NM). The results were compared with farmers practice (FP) of crop cultivation. The design of the experiment was randomized block design (RBD) with seven replications.

At Jharkhand site the highest yield of rice was recorded in farmer's practices 5.81, 4.89 and 5.28 t/ha for consecutively three years, however, the CA practices showed improved rice yield (2.89 t/ha) after third year. In case of winter crops, significantly higher grain yield of mustard was recorded for all the years in ZTT-M (3.1, 3.2 and 3.6 q/ha) over farmer's practice (FP). Grain yield of linseed was consistently highest (1.9, 1.8 and 2.3 q/ha) when cultivated after ZTT-M rice which was statistically at par with ZTDSR-NM. In summer crops, there was no significant difference in cowpea yields obtained under various treatments, however, in third year of experimentation, significantly higher yield of cowpea (93.0 q/ha) was recorded under ZTT-RM. The cowpea performed better under all the CA practices. Green gram yield during initial two years was significantly higher in the treatment ZTT-M. In third year, green gram recorded significantly higher yield (2.0 q/ha) in ZTDSR-M treatment which was statistically at par with ZTT-M (1.95 q/ha). The rice equivalent yield obtained under Rice-Mustard-Cowpea ranged between 5.7 to 9.2 t/ha while that for rice-linseed-green gram it ranged between 2.8 to 6.5 t/ha. Among different treatments the REY was significantly higher under farmer's practice of cultivation, while in the third year of experimentation it was significantly higher (7.6 t/ha) under ZTT-M and was statistically at par with ZTT-NM.

At Chhattisgarh site, for initial three year, the rice yield was higher under farmers practice, however, in fourth year, the highest yield of rice was recorded in ZTDSR treatment (5.48 t/ha) which was at par with ZTT-R (5.34 t/ha). In case of winter crops, significantly higher yields of lentil (2.3 q/ha) was recorded under ZTT-M in the third year of experimentation which was statistically at par with farmer's practices (1.60 q/ha). Under farmers practice, the lentil yield showed decreasing trend over three years mainly because of variations in planting dates. Although, during initial two years the mustard yield was less in CA than farmers practice, it increased significantly in the third year (6.23 q/ha) in ZTT-M which was statistically at par with DSR-M (6.14 q/ha). Significantly highest linseed yield (3.1-3.2 q/ha) was recorded for the second and third year of experimentation under the treatment ZTT-M. For summer crops, the green gram yield during the initial two years was higher under farmers' practices. In third year, the green gram yield (3.3 q/ha) was significantly higher under the treatment DSR-M which was statistically at par with ZTT-M (3.1 q/ha). The black gram yield was highest in ZTT-M (2.9 q/ha), however there was no significant difference among treatments. The cowpea pod yield was highest under ZTT-M (93.0 q/ha) treatment and was at par with DSR-M and FP. Rice equivalent yield of three cropping sequences viz. rice-lentil-black gram, rice-mustard-cowpea and rice-linseed-green gram were evaluated under different CA practices. It was observed that the REY of rice-mustard-cowpea was significantly better over other two cropping sequences. Among the treatments, higher REY of all these sequences were observed under the plots having ZTDSR-M treatment (10.95 t/ha) which was statistically at par with ZTT-M (10.82 t/ha).

Fig. 15.2. Field views of the crops under different treatments at farmer's fields

16. Solar Energy Application

Solar Energy Application in Groundwater Pumping

Solar pumps, installed at different locations in Bihar, were evaluated for quantifying mean monthly groundwater abstraction on daily basis for different months. The average incident solar radiation of this region was 3.6-6.4 kWh/m^2/day. Installed solar pumps were 2.0 HP DC centrifugal surface pumps energised by 1.8 kWp; 3.0 HP DC submersible pumps, energized by 3.0 kWp; 2.0 HP DC submersible pumps, energized by 1.8 kWp; and 1.0 HP DC submersible pump operated by 1.2 kWp solar array. Some of them were evaluated for groundwater depth regime ≤ 12m, (below ground level (bgl) for its suitability to small holders.

Performance of solar submersible pumps

The water yield of 1.0 HP DC - 1.2 kWp solar system on a bright sunshine day is reported in Table 16.1. The solar panel was manually tracked 3 times in a day. On a cloud free day the groundwater yield ranged from 30-50 m^3 with annual average of 43 m^3 per day. The change in water yield in different months was due to variation in solar radiation, day length and change in groundwater depth, bgl which was found enough to irrigate cropped area of 0.10 ha by conventional method. During low solar insolation months both groundwater yield and the crop water requirement were low; therefore, irrigated area were same. This pumping system is found suitable for landholding size 1.0 ha under major crops; however, the irrigation command area could vary with types of crops grown. Water saving devices, such as micro sprinklers and drips are not operable under direct coupling with this system.

Table 16.1. Water output from 1.0 HP DC submersible pump for different dry months

Water yield (m^3) per day on a cloud free day				Average water yield (m^3/day)
Sep-Nov	Dec-Jan	Feb	Mar-June	43
50-40	35-40	40-45	50-45	

Performance data of 2.0 HP DC - 1.8 kWp system is reported in Table 16.2. The groundwater yield, on a bright sunshine day for different months ranged from 40-70 m^3 and the yearly average water yield was found to be 59 m^3 per day. Irrigated cropped area with this water in a day was 0.14 ha. This system is found suitable for smallholders with cultivable area of 1.25 ha. Water saving devices, such as low pressure drippers can be operated under direct coupling.

Table 16.2. Water output from 2.0 HP-DC submersible in dry months

Water yield (m^3) per day on a cloud free day				Average water yield (m^3/day)
Sep-Nov	Dec-Jan	Feb	Mar-June	59
70-50	40-55	55-65	70-65	

3.0 HP DC - 3.0 kWp was also evaluated for its performance for groundwater yield on a bright sunshine day. The related data is reported in Table 16.3. The water yield on a cloud free day ranged from 70-130 m^3 with average yield 105 m^3/day This water was able to irrigate an area of 0.24 ha in a day of major crops under conventional methods. This system is suitable for landholding size of 1.5 ha; however, the command area may vary with types of crops. Water saving devices, such as micro sprinklers and drips can be operated successfully under direct coupling with available pressure head up to 0.80 kg/cm^2 during mid-day.The solar water pumping system with water storage is a better option, as it can be used for fish farming as well as for reserve during low solar insolation.

Table 16.3. Water output from 3.0 HP submersible pump in dry months

Water yield (m^3) per day on a cloud free day				Average water yield (m^3/day)
Sep-Nov	Dec-Jan	Feb	Mar-June	105
120- 100	70-90	100-110	130-120	

17. Farm Machinery

Field Evaluation of Motorized Crop Cutter for Harvesting of Wheat Crop Under CRP on Farm Mechanization and Precision Farming

A motorized crop cutter was evaluated for wheat harvesting under CRP on FM&PF project (Fig. 17.1). For harvesting one acre of wheat, on an average 16 hours were consumed, which included 4 hours of unproductive or rest time. The cost of productive and unproductive work during wheat harvesting in one acre using motorized crop cutter was Rs.1716 and Rs. 210, respectively. Time consumed in harvesting one acre of wheat using sickle was 176 man-hr which costs Rs. 7744. The study revealed that the motorized crop cutter, when compared to sickle, reduced the time consumption by eleven fold and labour charges by four folds.

Fig. 17.1. Evaluation of crop cutter in wheat harvesting

Design and development of woman friendly stirrup hoe

A stirrup hoe was designed and fabricated for intercultural operation. The stirrup hoe had three parts: blade, housing frame and handle (Fig. 17.2a-b). The blade was made up of spring steel (200×50×5 mm) with a cutting edge thickness of 0.8 mm. The frame structure was made up of mild steel flat and handle was fabricated from MS hollow pipe. The housing frame had a top width of 170 mm, bottom blade width of 200 mm and height between blade and top width was 120 mm. The blade was fitted with a housing frame with mechanical fasteners (M8 bolt)

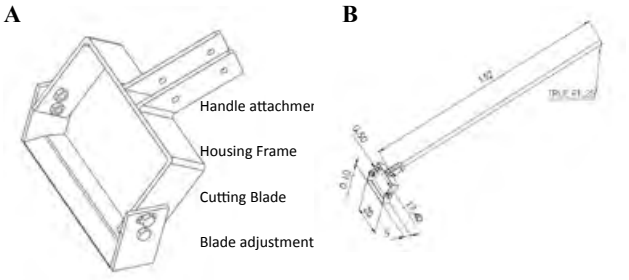


Fig. 17.2. (a) Housing frame and blade of stirrup hoe (b) Dimensions (cm) of the stirrup hoe

on both sides. For easy movement and operation, two sliding slots (18 × 9 mm) were made on both sides of the housing and just below a standard hole (8 mm). The slot helped in changing the tool working angle depending on the operator height. A clamp (angle: 60°) was welded on top of the frame where the handle was fixed with fasteners. The detailed specification is given in Table 17.1.

Table 17.1. Specifications of stirrup hoe

Components	Specifications
Length of blade	200 mm
Width of blade	50 mm
Blade thickness (centre) Side thickness	5 mm 1 mm
Weight of blade	465 gm
Blade material:	Spring steel
Length of handle	1520 mm
Diameter of handle	25 mm
Working height of handle	1100 mm
Weight of handle	1155 gm
Cutting edge angle	250
Weight of tool	2.35 kg

Field evaluation of women friendly Stirrup hoe for intercultural operation

A field experiment was conducted during *rabi* season at Krishi Vigyan Kendra farm, Ramgarh, Jharkhand to evaluate stirrup hoe with locally used khurpi for intercultural operation in garden pea (*Pisum sativum*) field (Fig. 17.3). The mean moisture content of the experimental plot was 9.37%. The monthly mean maximum and minimum temperature

Fig. 17.3. Field evaluation of stirrup hoe during intercultural operation

during the crop growing period ranged from 28°C and 12° C, respectively. The mean relative humidity during the month of November-December, 2020 was 70-80%. Weeding efficiency and effective field capacity for stirrup hoe were 80.65% and 0.0042 ha/hr whereas for khurpi the values were 75.86% and 0.0017 ha/hr, respectively. The cost of operation by khurpi was Rs.17908/ha and by stirrup hoe was Rs. 7440/ha.

Comparative Assessment of Energy Flow, Carbon Auditing and Eco-Efficiency of Diverse Tillage Systems for Cleaner and Sustainable Crop Production

Identification of the appropriate tillage production system having lower energy use and carbon- emission, and better crop productivity is becoming increasingly important to maintain the environmental sustainability. In the present study, a comprehensive system analysis was performed in three major agro ecosystems of eastern India: eastern Indo-Gangetic plain, coastal agro ecosystem, and hill & plateau region. Six rice-based production systems with different levels of farm mechanization *viz.*, a) fully mechanized tillage, b) partly mechanized tillage and c) traditional tillage were considered in the analysis. The main aim was to assess the energy flow and carbon-balance of the diverse tillage production systems. Among the different sources of total input energy, chemical fertilizer accounted for the highest energy used in partly mechanized tillage (44%) and mechanized tillage (38%) followed by diesel, irrigation water, plant protection chemicals, seed and electricity. Seed, human, animal energy and farmyard manure accounted for 21, 20, 16 and 16%, respectively, of the total energy input in traditional tillage. Maximum energy input (52161 MJ/ ha) was noted in mechanized tillage and minimum with traditional tillage (16879 MJ/ ha). Cropping systems followed in eastern Indo-Gangetic plain were more energy-intensive (50908 MJ/ ha) as compared to coastal-ecosystem (27459 MJ/ ha). On an average, total energy output in mechanized tillage (395245 MJ/ ha) were 32 and 241% higher over partly mechanized tillage and traditional tillage, respectively. Overall, the results indicated that partly mechanized tillage and coastal agro ecosystem were the most energy-efficient with an energy ratio of 8.88 and 9.81, respectively. Mechanized tillage was 24 and 166% more carbon-intensive in comparison to partly mechanized and traditional tillage. Mechanized tillage had higher carbon efficiency (3.75), carbon-sustainability index (2.75), carbon-footprint in spatial scales (4342 kg CO_2 eq./ ha), but had 34% less carbon-footprint in yield scales as compared to traditional tillage. Mechanized tillage showed 22 and 73% higher system productivity compared to partly mechanized and traditional tillage, respectively. Partly mechanized tillage had a 23% lower cultivation cost than mechanized tillage. Thus, the present study suggests that partly mechanize tillage was the most appropriate energy and carbon-efficient production system in eastern India.

Ergonomic Study of Farmers' Friendly Farm Implements in Eastern Region

Some of the available manually operated tools/ implements were ergonomically evaluated and modified based on the anthropometric data. The design parameters like handle length, handle diameter and handle width etc. were modified and tested in the field.

Refinement of grubber

It is a simple and light weight, manually operated equipment for weeding and inter-culture in upland row crops (Fig. 17.4a-b). It consists of long handle, ferrule, three tynes and sweep type blades. The specifications are given in Table 17.2. The operator uses pull force to break the soil crust and uproot the weeds. The weeding experiment was evaluated in bitter gourd field at Ramgarh, Jharkhand. The soil moisture of the field was 11.02%.

Table 17.2. Specifications of grubber

Particulars	Existing	Modified
Length of handle (mm)	1600	1350
Diameter of handle (mm)	35	26
Tool dimensions (mm)	240×160	240×160
Weight (kg)	1.8	1.57
Cost (Rs.)	400/-	450/-

Fig. 17.4. (a) Before modification: Wrist and back pain due to poorly designed grip and long handle (b) After modification: Eliminates pain and reduces drudgery

Benefits or advantages of modified grubber are: (i) easy and comfortable to operate, (ii) reduction in drudgery by 39.22%, (iii) 33.36% higher output of the improved grubber, (iv) 10.74% increase in efficiency

Refinement of twin wheel hoe

It consists of wheel frame, V-blade with tyne and handle (Fig. 17.5a-b). Weeds cutting and uprooting are done through push and pull action of the unit. The experiment was conducted in tomato field (8.55% soil moisture) to evaluate its performance. The specifications of the existing and modified wheel hoe are given in Table 17.3.

Table 17.3. Specifications of twin wheel hoe

Particulars	Existing	Modified
Length of handle (mm)	1790	1250
Diameter of handle (mm)	26	26
Handle width (mm)	600	520
Tool dimensions (mm)	660×520	660×520
Weight (kg)	9.5	5.24
Cost (Rs.)	800/-	800/-

Benefits or advantages of twin wheel hoe are: (i) reduces drudgery by 29.63%, (ii) increases efficiency to the tune of 13.73%, and (iii) increases output by 38.70%.

Ergonomic study of farm women for pedal operated paddy thresher

An ergonomic evaluation of pedal operated paddy thresher was carried out (Fig. 17.6a-b). Two methods of paddy threshing were used *viz.,* traditional method (manual beating on wooden log) and improved method (pedal operated paddy thresher). The output was recorded as 35 kg/h in pedal operated and 30 kg/h in manual beating. It was observed

Fig. 17.5 (a) Before modification: It does not suit to short heighted women worker and damages plants due to uncontrolled movement
(b) After modification: Modified the tool based on region specific anthropometric data

that there was 14.28% increase in output and 14.29% reduction in drudgery with pedal paddy thresher and 17.42% savings in energy expenditure as compared to traditional one.

It was observed that in pedal operated paddy thresher, continuous pedaling is required for uninterrupted work, which resulted in slight pain at lower leg and lower back whereas in manual beating of paddy crop, the body part discomfort was mainly in shoulder, in lower back, elbow and forearm due to hand movement and bending working posture.

Fig. 17.6. (a) Discomfort mostly in lower leg, lower back, forearm and wrist (traditional method) (b) Slight pain at lower leg and lower back (improved method)

18. Livestock and Fisheries

LIVESTOCK

Network Project on Buffalo Improvement

Under Network Project on Buffalo Improvement, superior germplasm of 86 Murrah buffaloes are being maintained including 56 breedable females and 2 teaser bulls. During the period 17 births with 9:8 male to female ratio were recorded. Artificial insemination was attempted in 42 breedable cyclic animals with 42.86 % conception rate. The production parameters during the period with respect to total lactation milk yield, standard lactation milk yield and the average peak yield were observed 2356.45±132.11 kg, 1977.05±109.36 kg and 11.51±0.43 kg, respectively. Similarly, lactation length, service period, dry period and inter-calving interval were found to be 345.68±18.76 days, 134.52±11.11 days, 94.85±12.66 days and 441.13±27.12 days, respectively. In an attempt to bring the anoestrus buffaloes to normal cyclic, mineral mixture supplementation, therapeutics and reproductive hormones were intervened.

Herd health was maintained by optimal feeding strategy with prophylaxis, which included vaccination against FMD, HS, BQ infection and regular rotational deworming and tick control. Low herd mortality of 5.17% was recorded during this period. The animals were fed with fodder, green berseem and oat during winter and maize during summer. Napier Hybrid was given as filler green fodder during the deficient periods.

Characterization of Lesser Known Breeds of Farm Animals in Eastern India

Seemanchali sheep

The detailed study on Seemanchali sheep (Fig. 18.1-18.2) indicated that, the reported population size of the breed is around 80,000, as estimated from Livestock Census, 2017. The population is comparatively higher in Supaul and Katihar districts of Bihar at the two extremes of the breeding tract. Further, it was reported that the population showed an alarming declining trend in the breeding tract.

Morphometric characteristics of Seemanchali lambs at the age of 3, 6, 9 and 12 months are given in Table 18.1. Chest girth was the highest body measurement at all ages followed by height at withers and body length while all the body measurements were increasing at decreasing rate. Between 3 and 12 months of age, the chest girth increased by 18.1% whereas the height increased by 26.7%. These variations in the morphometric characteristics may be due to genotype or environment interactions or both. Study on the morphometry indicated that the trend of having broad chest girth continued till adult stage. Though the growth almost stopped till 6-teeth stage, there was some insignificant increase in all morphometric traits up to full mouth stage.

Fig. 18.1. Dark brown Seemanchali ewe

Fig. 18.2. Black Seemanchali ewe

The body weights obtained (Table 18.2) for Seemanchali sheep/lamb showed that there was a huge variation in the traits at different ages. Body weight at three months of age was recorded 9.23±0.14 kg which increased to 15.60±0.22 kg in 6 months registering 69.0% of incremental gain. The per cent gain in body weights from 6 to 9 months, and 9 to 12 months

Table 18.1. Morphometric characteristics (cm) of Seemanchali lambs under field conditions

Traits	3 months		6 months		9 months		12 months	
	Male (35)	Female (42)	Male (18)	Female (55)	Male (15)	Female (50)	Male (14)	Female (105)
Height at withers	50.34± 0.25	50.15 ± 0.25	58.15± 0.42	57.74± 0.33	63.42± 0.47	60.25± 0.27	67.16± 0.45	63.16± 0.22
Body length	48.22± 0.31	47.53± 0.30	57.82± 0.53	54.72± 0.32	60.34± 0.44	58.53± 0.26	63.64± 0.46	60.44± 0.23
Chest girth	55.46± 0.28	54.87± 0.28	65.23± 0.54	61.57± 0.32	69.25± 0.48	67.12± 0.26	71.96± 0.46	64.19± 0.23
Face length	14.10± 0.43	14.14 ± 0.50	14.44± 0.38	14.48± 0.30	15.46± 0.38	15.18± 0.32	16.68± 0.35	15.77± 0.28
Ear length	14.06± 0.28	13.66± 0.27	14.54± 0.32	14.48± 0.29	15.19± 0.36	15.24± 0.30	16.53± 0.36	16.14± 0.28
Tail length	30.14± 0.26	30.45± 0.20	32.91± 0.58	32.06± 0.32	35.78± 0.56	35.33± 0.30	39.88± 0.36	38.63± 0.30

Table 18.2. Body weights (kg.) of Seemanchali sheep under field conditions

Age group	Male	Female
3 months	9.58± 0.28	8.95± 0.15
6 months	18.56± 0.32	14.63± 0.23
9 months	25.87± 0.30	19.53± 0.21
12 months	28.13± 0.28	24.86± 0.23

were 34.6% and 20.3%, respectively, showing that the body weight trait increased at decreasing rate after 6 months of age. Comparing the body weights of Seemanchali sheep at different ages with other sheep breeds of India shows that Seemanchali is a medium sized sheep of eastern region of Bihar.

Reproduction performance

The field study showed that the age at 1st mating and age at 1st lambing in Seemanchali sheep were 8.4 and 13.8 months, respectively. The lambing percentage in the flock was 72.5, whereas the lambing interval was found to be 11.2 months. Generally, an ewe was observed to give birth to a single lamb with an occasional twinning. The lambing rate was estimated to 0.9.

Socio-economic status of sheep farmers

On comparing the rearing of sheep and goats in the breeding tract, the major difference was the number of farmers rearing sheep or goat in a particular cluster. Though goats were the most preferred small ruminant among the farmers, sheep were reared by lesser farmers but as a larger herd. On the other hand, goats were maintained by small holder system with less or no input. As the flock size is comparatively larger in case of sheep, the farmers had to spend input in terms of labour management though other inputs were relatively lower.

Socio-economic study in the breeding tract revealed that the farmers possessing large flock fetched more income mostly through the sale of young lambs. The study further revealed that the sheep farmers were deriving major share of their household income from rearing Seemanchali sheep as they had undertaken rearing of sheep as full-term profession.

Scientific interventions in breeding, feeding and housing of Seemanchali sheep offer scope for improvement in the productivity vis-à-vis livelihood status of sheep farmers.

Kosi buffalo

The detailed study with respect to morphometric characteristics of Kosi buffaloes (Fig. 18.3) revealed that height of Kosi buffalo was almost equivalent to body length, whereas the chest girth was the highest for all age groups (Table 18.3). As the age progresses, ratio between height and chest girth was progressively increasing, which indicate that chest was broadening at faster rate during growth.

All the body measurements increased as the age advances from 1 year to 7 years. The height at withers and body length were more or less similar whereas the chest girth was almost 40% more than body length. On making comparison to Murrah buffaloes, Kosi buffaloes were marginally taller and longer but girth was relatively lesser. The height at withers, body length and chest girth of female Murrah buffaloes were 117.28±0.88 cm, 115.95±0.88 cm and 153.14±0.95 cm during 1-3 years and 133.60±0.69 cm, 138.36±0.74 cm and 200.79±0.95 cm for more than 7 years duration, respectively.

Fig. 18.3. Kosi female buffalo

Table 18.3. Morphometric characteristics (cm) of Kosi buffaloes in their breeding tract.

Morphometric traits	Kosi buffaloes belonging to different age groups					
	Male (1-3 years)	Female (1-3 years)	Male (3-7 years)	Female (3-7 years)	Male (> 7 years)	Female (> 7 years)
Height at withers	126.29±0.61 (7) [1.27]	119.81±0.65 (32) [3.09]	129.10±1.78 (10) [4.36]	133.72±0.36 (148) [3.26]	144.33±1.55 (3) [2.62]	138.34±0.61 (76) [3.87]
Body length	119.14±1.10 (7) [2.44]	116.56±0.52 (32) [2.52]	136.40±0.75 (10) [1.73]	137.81±0.36 (148) [3.21]	151.33±2.252 (3) [3.64]	141.25±0.63 (76) [3.89]
Chest girth	151.29±1.52 (7) [2.66]	154.63±0.55 (32) [2.00]	180.20±1.54 (10) [2.70]	188.14±0.38 (148) [2.47]	200.66±2.46 (3) [3.00]	195.14±0.59 (76) [2.65]
Face length	48.14±1.39 (7) [7.62]	48.19±0.38 (32) [4.49]	54.30±1.00 (10) [5.83]	55.14±0.26 (148) [5.79]	57.67±1.31 (3) [5.57]	57.87±0.35 (76) [5.27]
Face width	15.43±0.61 (7) [10.49]	15.28±0.40 (32) [14.98]	19.30±0.67 (10) [10.94]	19.08±0.22 (148) [13.73]	22.67±0.85 (3) [9.18]	22.04±0.37 (76) [14.49]
Ear length	22.57±0.90 (7) [10.50]	23.84±0.30 (32) [7.23]	25.10±0.46 (10) [5.77]	24.93±0.22 (148) [10.70]	31.00±1.08 (3) [8.53]	25.18±0.36 (76) [12.40]
Tail length	63.43±0.95 (7) [3.95]	65.97±0.66 (32) [5.63]	86.70±0.87 (10) [3.17]	79.78±0.37 (148) [5.66]	93.33±5.42 (3) [14.23]	84.63±0.61 (76) [6.28]
Horn length	16.71±0.84 (7) [13.25]	15.59±0.38 (32) [13.61]	20.50±0.62 (10) [9.55]	27.62±0.24 (148) [10.55]	29.67±0.62 (3) [5.15]	27.17±0.38 (76) [12.20]

Figures in round and square brackets are number of observations and coefficients of variations, respectively.

Estimated body weight of Kosi buffaloes under field conditions is given in Table 18.4. Kosi buffaloes can be represented as medium sized buffaloes with males heavier than females at all ages. Kosi buffaloes are marginally lesser in their body weights at all ages compared to Diara buffaloes.

Table 18.4. Body weights (kg) of Kosi buffaloes at different ages.

Age	Male	Female
1-3 years	255.18±20.49 (2) [38.46]	241.73±4.08 (43) [9.88]
3-7 years	401.15±13.14 (7) [9.33]	460.35±3.83 (187) [10.85]
> 7 years	586.85±12.46 (6) [5.73]	502.67±7.11 (106) [13.81]

Figures in round and square brackets are number of observations and coefficients of variations, respectively.

Production and reproduction traits

The study revealed that the peak yield of Kosi buffaloes ranged from 4 to 12 kg with an average being 5.26 kg. The estimated average lactation milk yield and lactation length of these buffaloes were found to be 975 kg and 192 days, respectively. The average age at sexual maturity, age at 1st calving and calving interval for Kosi buffaloes were found to be 42.6 months, 53.2 months and 20.2 months, respectively.

Development of Meat and Egg Strains of Duck Suitable for Backyard Farming

The project aims to improve the local duck germplasm by crossing them with White Pekin to generate a strain for meat production and crossing them with Khaki Campbell to produce/develop a strain for egg production. The work on synthesising meat production was initiated by selecting of local duck germplasms and White Pekin with high body weight gain. A total of 25 local female ducks and 6 White Pekin ducks were selected as parents (Fig. 18.4). By crossing these two germplasms, 43 eggs were collected and hatched (69.7%). Out of 30 chicks hatched out, 22 were alive. Further selection will be applied on these chicks before they are used as parents of next generation.

Fig. 18.4. Pekin ducks and (inset) Khaki Campbell

Assessment of Antimicrobial Drug Resistance in Bacteria of Animal Origin

A total of 55 *Escherichia coli* were isolated from faecal samples of cattles (25) and buffaloes (49). They were identified based on staining, cultural and biochemical characteristics. A total of 10 *Staphylococcus* spp. were also isolated from milk samples of cattles (15) and buffaloes (13) and were identified based on microbiological methods. All the bacterial isolates have been cryopreserved for studying their antibiotic sensitivity patterns, plasmid isolation, serotyping, and further characterization.

DNA extraction, primers and molecular confirmation by PCR: All the pure cultures of *E. coli* were subjected to genomic DNA isolation using boiling method. DNA quality was estimated by electrophoresis in ethidium bromide stained gels (Fig. 18.5). This method of DNA extraction was simple, economical and effective for use in regular downstream applications like PCR. The assessed DNA samples were stored at - 20 °C till further use in the molecular assay.

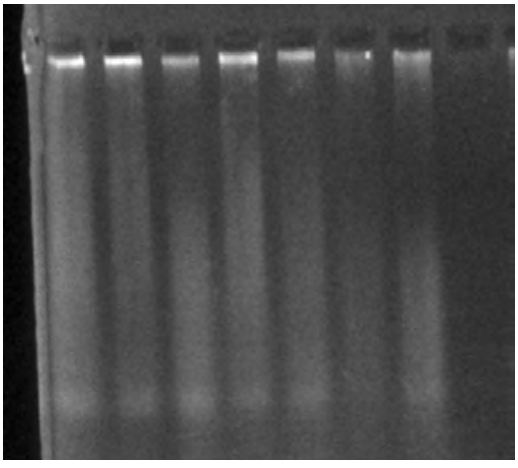


Fig. 18.5. Agarose gel electrophoresis showing genomic DNA of *E. coli* extracted using heat treatment.

16s rRNA gene PCR specific to *E. coli* were standardized and employed to confirm the bacterial isolates. The *E. coli* specific PCR targeting *16s rRNA* (forward 5′- GGAAGAAGCTTGCTTCTTTGCTGAC -3′ and reverse 5′- AGCCCGGGGATTTCACATCT-GACTTA -3′) gene produced amplicon of expected sizes of 544 bp as visualized through UV trans-illuminator (Fig. 18.6).

All India Coordinated Research Project on Goat Improvement

All India Coordinated Research Project on Goat Improvement programme was initiated in the institute in the year 2018-19. The centre, being at

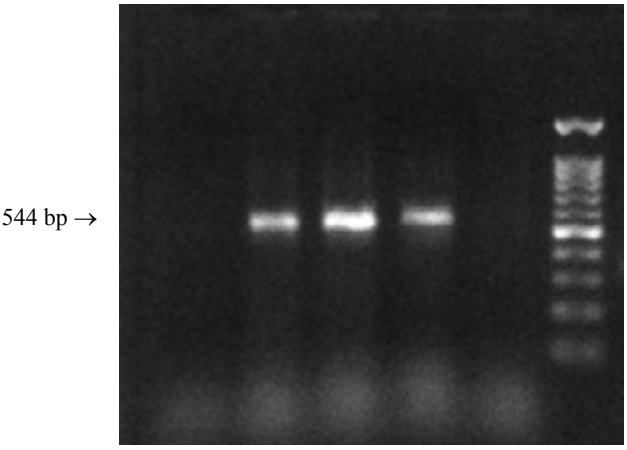


Fig. 18.6. *E. coli* specific PCR: A representative agarose gel electrophoresis showing 544 bp amplicons of 16S rRNA gene

initial stage, attention was paid on strengthening the 5 clusters, building rapport with the goat farmers in the clusters and consolidation of activities. The population growth of goat in the selected clusters were expanded to the tune of 141.56% with new addition of breed-able does and new births. The mortality percentage was controlled within 4% due to comprehensive efforts of vaccination, deworming and timely therapeutic interventions. The average body weight of goat increased from 4.11±0.15 kg to 4.19 ±0.25 kg at 3 months and 6.15±0.26 kg to 6.21±0.24 kg at 6 months of age when compared between 2018-19 (baseline) and 2020-21, respectively (Table 18.5). Average lactation milk yield was 21.02 ± 0.77 kg. With respect to reproduction parameters, there was no significant increase in reproductive parameters during the reported year, though there was a marginal increase in the parameters under evaluation (Table 18.6). In the selected clusters percentage of single kidding was highest (46.59%) followed by twining (30.57%). Quadruplet kidding was recorded at 1.31% in the tract. Overall kidding percentage was reported at 142.57% on the basis of numbers of does available. During the year 2019-20, 9 awareness programmes, 2 training programmes and 6 animal health camps were organized.

Assessment of Different Fodder Crop Rotation for Round the Year Fodder Production

Multicut sorghum-berseem crop rotation yielded 16.05% higher biomass than multicut sorghum-oat fodder rotation. The yield of different cultivars of *kharif* and *rabi* fodder crops has been presented in Table 18.7. Fodder yield of the multicut sorghum was recorded at 117 to 129 t/ha irrespective of cultivars.

Table 18.5. Body weight (kg) of Black Bengal goats at different ages

Factor	Weight at				
	Birth	3 months	6 months	9 months	12 months
Overall Mean	1.33 ± 0.01	4.19 ± 0.04	6.21 ± 0.04	7.99 ± 0.04	10.86 ± 0.06
Year of Birth					
2018-2019 (Base line)	1.12 ± 0.02	3.53 ± 0.15	5.56 ± 0.34	7.22 ± 0.45	9.42 ± 0.27
2019	1.37 ± 0.01	4.11 ± 0.25	6.15 ± 0.26	7.95 ± 0.24	10.27 ± 0.18
2020	1.33 ± 0.01	4.19 ± 0.14	6.21 ± 0.24	7.99 ± 0.13	10.86 ± 0.16
Sex of Kid (2020)					
Male	1.42 ± 0.02	4.44 ± 0.05	6.93 ± 0.06	8.80 ± 0.06	11.71 ± 0.06
Female	1.24 ± 0.01	3.95 ± 0.05	5.49 ± 0.06	7.18 ± 0.05	10.01 ± 0.01
Type of Birth (2020)					
Single	1.28 ± 0.02	4.06 ± 0.07	6.00 ± 0.09	8.02 ± 0.08	10.39 ± 0.18
Twin	1.20 ± 0.02	3.77 ± 0.13	5.83 ± 0.11	7.73 ± 0.09	10.12 ± 0.15
Triplet	1.14 ± 0.02	3.26 ± 0.07	5.78 ± 0.08	7.48 ± 0.10	10.04 ± 0.13

Table 18.6. Reproduction performance in Black Bengal goats

Particulars	2019	2020
No. of available does for breeding (X)	862	949
No. of does bred (Y)	768	812
Tupping % (Y*100/X)	89.10	89.09
Numbers of does died/sold/culled between kidding and breeding	67	24
No. of does available during kidding of those available for breeding	740	760
Numbers of tupped does available at kidding	740	788
Does kidded (nos)		
Single	312	355
Twin	225	233
Triplet	166	164
Quadruplet	15	10
No. of abortions	12	14
No. of still birth	10	12
Actual live birth (Nos)	1320	1353
Breeding efficiency/fertility (%) On the basis of does available On the basis of does tupped	 85.85 96.35	 83.03 97.04
Kidding (%) On the basis of does available On the basis of does tupped	 153.13 171.88	 142.57 171.70
Litter size (nos/kidding)	1.78	1.72

Similarly, yield of berseem was recorded at 64-70 t/ha in three cuttings. Annual rye yielded 64.33 t of fodder per ha area in three cuttings. Yield of Hybrid Napier was recorded at 201.09 t/ha (Fig. 18.7).

Table 18.7. Yield of different cultivars of *kharif* and *rabi* fodder crops

Season	Fodder crop	Cultivars	Yield (t/ha)
Kharif	Multicut sorghum	Red	128.88 ± 1.81
		White	117.76 ± 1.22
Rabi	Berseem	JHB 146	64.78 ± 0.67
		Wardan	66.27 ± 1.31
		Hybrid	70.26 ± 1.08
	Oat	JHO 822	61.54 ± 1.40
		Kent	58.45 ± 0.86
	Annual rye	Maximus	64.33 ± 1.01
Perennial	Hybrid Napier	CO4	201.09 ± 2.06

Fig. 18.7. Hybrid Napier on field bunds

Assessing Genetic Variability in Duck of Eastern States

The Genomic DNA was isolated from the blood samples of West Bengal duck (n=25) and amplification of 403 bp fragment of *prolactin gene* comprising partial intron 4, exon 5 and partial 3′ untranslated region (3′UTR) was performed (Fig. 18.8).

The Restriction fragment length polymorphism (RFLP) were used for identification of allelic variants of amplified *prolactin gene* fragment. XbaI restriction enzyme was used for RE digestion of PCR product. Two genotypes (Fig. 18.9) AB with three distinct bands (403 bp, 250 bp and 153 bp) and AA with two distinct bands (250 bp and 153 bp) were observed.

Genotyping of *prolactin gene* revealed two alleles A & B and two genotype AB & BB in West Bengal duck. The least square analysis revealed that West Bengal duck with AB genotype had superior egg quality being higher egg wt (60.19±3.55 vs 58.42±4.34 g) and Albumin wt (29.79±1.64 vs 27.9±2.45 g) but lower yolk wt (19.1±1.19 vs 21.02±2.66 g) than the

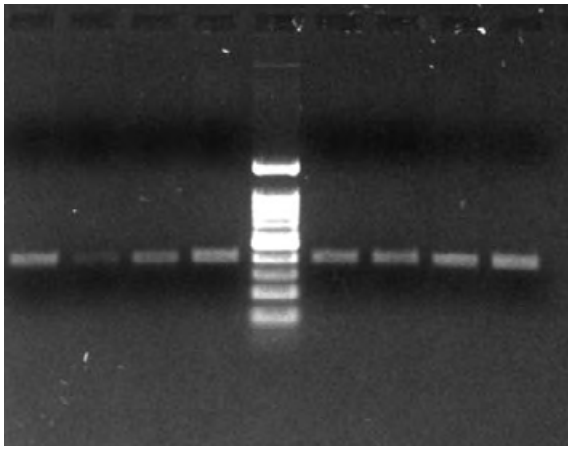


Fig. 18.8. PCR amplification of 403 bp fragment of Prolactin gene

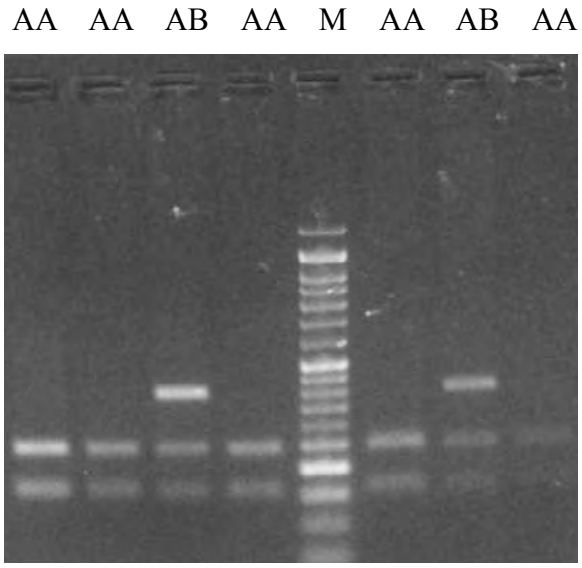


Fig. 18.9. RFLP pattern of Prolactin gene

duck having AA genotype. Therefore, *prolactin gene* can be used as marker for improving the egg weight and egg quality traits in West Bengal duck.

Characterization & Evaluation of Duck Germplasm in Eastern Region

Domestic duck production system in Eastern region of India

A study was conducted in the eastern plateau region of India (Jharkhand, Odisha and Chhattisgarh) to evaluate the smallholder duck production systems. A total of 251 duck farmers were selected for this study. The informations were collected by using an interview schedule. The majority of farmers reared the duck for more than 20 years. The average flock size was more in Chhattisgarh (11.76±0.60) compared to Jharkhand (9.51 ±0.67) and Odisha (9.47± 0.52). Ducks were mostly depended on scavenging for their nutritional needs. A very little percentage of ducks were used to hatch their eggs in Jharkhand (27.78%) and Odisha (24.44%) compared to Chhattisgarh (56.34%). Ducks were raised both for meat and eggs purposes. The average annual egg production per duck in Jharkhand, Odisha and Chhattisgarh was 50-70, 60-80 and 52-111 eggs, respectively.

Morphometry and morphology of Jharkhand duck

Information on phenotypic characteristics is a prerequisite in animal genetic resource conservation and improvement. Phenotypic characteristics of Jharkhand ducks from six districts (Palamu, Gadhwa, Latehar, Lohardaga, Khuti, and Simdega) were studied. Data on qualitative traits were analyzed with descriptive statistics (percentages), while one-way analysis of variance was used to analyze the observed quantitative traits. The results revealed that the predominant plumage colors of the head, neck, breast, wings and tails were black (56.25%) in drake and black & white mix (65.33%) in duck; white & black/brown mix (62.50%) in drake & white (79.33%) in duck; brown (41.25%) in drake & white & black/brown mix (52.67%) in duck; black/brown (43.75%) & white in drake (74.67%); black in drake (75%) & duck (90.00%), respectively. The dominant bill colour was greenish black (56.25%) followed by orange (25.00%) in drake & black (58.67%) followed by orange (22.00%) in duck, respectively, whereas dominant eye colour was brown in both the sexes (Fig. 18.10a and b). The predominant shank and web colour were orange (65.0%) in drake and duck (68.0%), respectively. The average egg production was found to be 66.92±2.00 eggs. The average adult body weights of drake and ducks were 1.64±23.19 and 1.51±30.09 kg, respectively. Variations were observed in qualitative traits. Egg production up to 52 weeks of age was 66.92±2.00. The observed phenotypic diversity in Jharkhand local ducks could be useful for designing the breeding programs and selection.

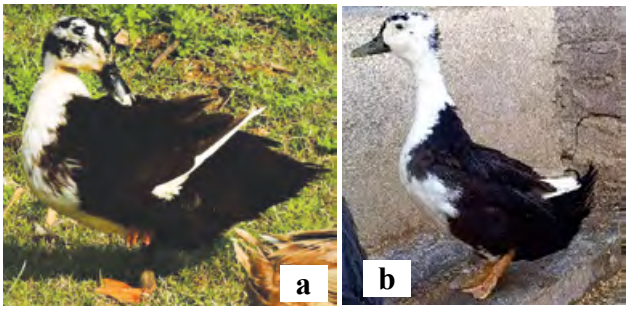


Fig. 18.10. (a) Duck (b) Drake of Jharkhand with black & white plumage pattern

Effect of Genetic & Non-Genetic Factors on Prolificacy of Bengal goat

Genetic factors on prolificacy of Bengal goat

The DNA was extracted from the collected blood samples of Bengal goats with history of high multiple birth for three consecutive parities. All the collected samples were screened for *FecB* gene polymorphism. For exploring the presence of *FecB* mutation in their genetic material, forced restriction fragment length polymorphism PCR technique and then gene sequencing were carried out. Sequencing of *FecB* gene in Bengal goats showed more than 95% uniformity with Bone Morphogenetic Promotor Gene (BMPR) already submitted in the gene bank.

When the sequences were cut with NEB cutter, 12% of the samples showed cutting site for Ava II enzyme. This showed there are 12% of animals whose higher fecundity was due to *FecB* mutation. Rest of the goats were found to be homozygous non-carriers indicating absence of *FecB* mutation. *FecB* mutation was found in both the sexes but correlation with phenotype could not be established. More number of animals which does not show any mutation to *FecB* had the phenotypic characteristics of high fecundity.

Non- genetic factors on prolificacy of Bengal goat

A study was conducted to analyze the effect of non-genetic factors influencing the reproductive performance of the high prolific Bengal goats. Body weight, age of does at breeding, parity and litter size of 181 pregnant Bengal goats were analysed using one-way Analysis of Variance. The litter sizes proportions for single, twin, triplet and quadruplet were 47.51%, 35.91%, 11.60%, 2.76 and 2.21%, respectively (Fig. 18.11). The birth of 1869 kids were recorded from 1008 kidding does, average 1.8 kids per doe and the prolificacy rate was 185.4%. Age of does at breeding (27.38 months), BW at breeding (18.49 kg) significantly influenced (P<0.01) the triplet, quadruplet or quintuplets litter sizes. Incidences of multiple birth were more (P<0.01) at higher parity (3.94) as compared to those of single kidding at lower parity (2.91). The increase in litter sizes with age, body weight and parity indicates improvement of reproductive traits as does reach maturity. Hence, these bodylinear traits could be used to discriminate the goats bearing multiple fetuses or bearing a single fetus and proper management could be taken for does carrying multiple kids.

Fig. 18.11. Bengal goat with triplets litter size

Molecular Epidemiology and Therapeutic Management of Bovine Theileriosis

During the period, 176 suspected bovines and 1 horse were screened for tick transmitted haemoparasitic infection. The collected blood samples were subjected to haematological and Giemsa stained blood smear examination. Serum was harvested for biochemical estimation and stored at -20°C till analysis. Whole genomic DNA was extracted using commercial kit and stored for further study. The analysis of sample indicated high percentage (60.23%) of infected bovine with tick transmitted haemo-parasites. Among these circulating in the population, highest percentage was infected with *Theileria* spp., followed by *Anaplasma marginale* and least with *Babesia* spp. Among the infected bovine samples, 35.85% samples had co-infection of both *Theileria* spp. and *A. marginale* parasite. The mortality rate in the screened bovine was 1.71 % even after administering specific therapy. The case fatality rate was 2.83 % restricted to Theileria spp. infection only. The animal infected with *Theileria* spp. responded favorably within 7 days of treatment with buvarvaquonone @ 2.5 mg/ kg body weight with or without supplementing vitamins and anti-oxidants (Table 18.8). However, those supplemented with vitamin and anti-oxidants responded favorable in restoring appetite and production parameters within 15 days of treatment. These parameters remained compromised in animal managed only using specific anti-parasitic drugs. Many animals (19.81 %) with respiratory distress were also administered loop diuretic and prednisolone at the recommended doses. Serological diagnosis was made using ELISA protocol developed and compared with conventional diagnosis. Lumpy skin disease like symptom were observed during sampling of blood samples in endemic area, co-infected with *A. marginale* infection (Fig. 18.12).

Table 18.8. Treatment modules for hemo-parasites and tick control

Hemo-parasites	Modules	Treatment
T	I	Buparvaquinone by deep intra-muscular route @ 2.5 mg/ kg body weight along with module IV
A	II	Imidocarb dipropionate @ 3.0 mg/ kg body weight by a subcutaneous route along with module IV
B	III	Diminazene accurate @ 5 mg/ kg body weight by the intramuscular route along with module IV
Ticks	IV	All buffaloes and cattle: Topical spraying amitraz (12.5% EC Solution) and the surrounding environment by applying deltamethrin (1.25% solution)

Where T= *Theileria* spp.; A= *A. marginale*; B= *Babesia* spp.

Fig. 18.12. Cattle found infected with *A. marginale* and showing clinical symptoms similar to lumpy skin disease (nodules and lumps spread over the whole body)

Studies on Development of Early Pregnancy Diagnosis Method in Buffalo

Investigation was carried out to determine expression profile of novel chemokine genes *CCL 8* (C-C motif chemokine 8) and *CXCL10* (C-X-C motif chemokine 10) during peri- implantation period in whole blood of artificially inseminated dairy buffaloes. Significant increase in transcriptional abundance of CCL8 gene was observed throughout the peri- implantation period in pregnant buffaloes with the value of 0.014 ± 0.001 on day 12 post artificial insemination (AI) to 0.062± 0.002 day 21, respectively (P <0.05) . Expression level of CCL8 gene remained unchanged (P >0.05) throughout the peri-implantation period in case of non-pregnant animals (Fig. 18.14 & 18.15)

Expression of CXCL10 in pregnant buffaloes showed significantly greater expression (P <0.05) on day 12 post AI to day 21 than control (non-pregnant) group. The expression showed significant increase (P

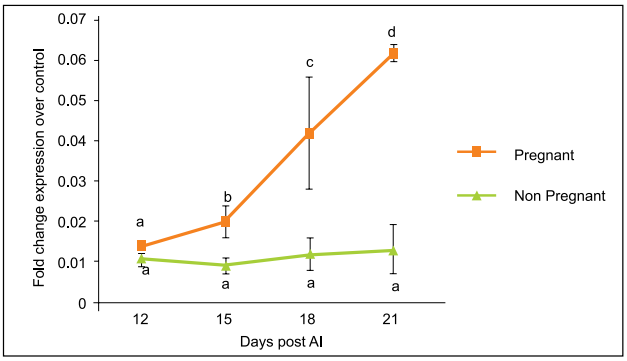


Fig. 18.14. Transcriptional abundance of CCL8 gene in pregnant and non-pregnant samples on different days post AI

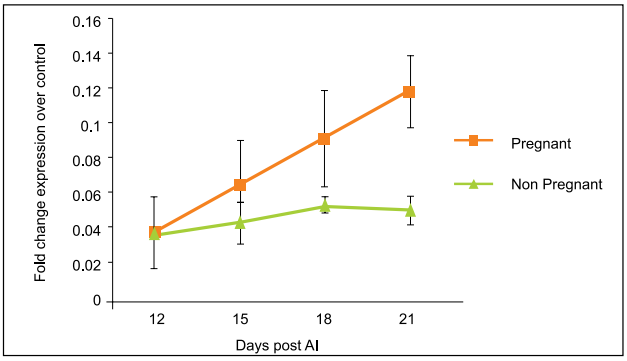


Fig. 18.15. Transcriptional abundance of CXCL10 gene in pregnant and non-pregnant samples on different days post AI

<0.05) at post day 12 to day 21 of AI with the values of 0.040 ± 0.001 and 0.12± 0.02, respectively. Difference in the expression level at day 15 and 18 was non-significant (P >0.05) with the values of 0.067 ±0.025 and 0.094 ± 0.027, respectively. The expression level of CXCL10 gene also remained unchanged (P>0.05) throughout the peri-implantation period in case of non-pregnant animals.

Our findings suggest that increased response of chemokines CCL8 and CXCL10 is a pregnancy dependent event and therefore, expression profiling of chemokines CCL8 and CXCL10 during peri- implantation period in buffaloes can act as signature for pregnancy establishment.

Outreach Programme on Zoonotic Diseases

Prevalence study of Brucellosis

An epidemiological study was conducted to know the current status of Brucellosis in Bihar. Therefore, random serum and milk samples were collected from 8 districts of four agro-climatic zones of Bihar to study the prevalence of Brucellosis in bovine and caprine species. The Rose Bengal Plate Antigen, procured from Indian Veterinary Research Institute, Izatnagar, Bareilly was used for prevalence

study. In Bihar, 4.51% of samples from a total of 310 bovine samples (Table 18.9) revealed sero-positivity by Rose Bengal Plate Test. The highest sero-positivity was found in agro-climatic zone I, where Brucella sero-positivity was 5.74%. All the 34 pooled milk samples collected from urban areas in Patna district were found negative by milk ring test. In goats, 3.16% (7/221) samples were positive for brucella antibodies by Rose Bengal Plate Test.

Table 18.9. Prevalence of brucellosis in different districts of Bihar.

Agro-climatic zone	Districts	Bovine		Caprine	
		No. of samples	No. of positive samples	No. of samples	No. of positive samples
Zone I	East Champaran	18	1(5.56%)	21	0
	Gopalganj	24	2(8.33%)	0	0
	Samastipur	45	2(4.45%)	26	1(3.84%)
Zone II	Araria	48	2(4.16%)	28	2(7.14%)
Zone IIIA	Jehanabad	18	0	18	1(5.56%)
	Kaimur	47	2(4.25%)	28	1 (3.57%)
	Patna	74	4(5.4%)	70	2 (2.85%)
Zone IIIB	Jamui	36	1 (2.77%)	30	0
	Total	310	14 (4.51%)	221	7 (3.16%)

Three animal health camp cum awareness programmes were organized to aware the farmers about risks of diseases transmitted between animals and human beings. About 140 farmers were participated in the awareness programmes. The farmers awared about the risks of brucellosis, tuberculosis, bird flu, rabies, leptospirosis, cysticercosis etc. The mode of spread and methods of prevention of these diseases was also discussed with the farmers. About 350 animals were dewormed and vaccinated against FMD, HS and BQ. The awareness camps were conducted in the Jamui and Araria districts of Bihar (Fig. 18.16).

Fig. 18.16. Awareness programme and animal vaccination program

Standardization of PCR Assay for Detection of Shiga- Like Toxin Producing *E. Coli* (STEC)

A pair of primers was selected for identification of vero cytotoxin-producing *Escherichia coli* organisms. Primer pair for *verototoxin gene* which identifies common verotoxins as described by Yamasaki et al. (1996) was selected for the identification of the STEC bacteria. About 140 faecal and milk samples were collected from cattle and buffaloes and used for isolation of *E.coli* bacteria on growth media. The PCR was done to confirm the *E.coli* organisms identified by culture characteristics and biochemical tests. Thirty isolates were identified from the faecal samples. Then the PCR method was standardised to identify the STEC from the isolated *E.coli* cultures. The PCR assay was standardized using primers. A 518 bp product was obtained after amplification (Fig. 18.17) in the samples positive for STEC organisms.

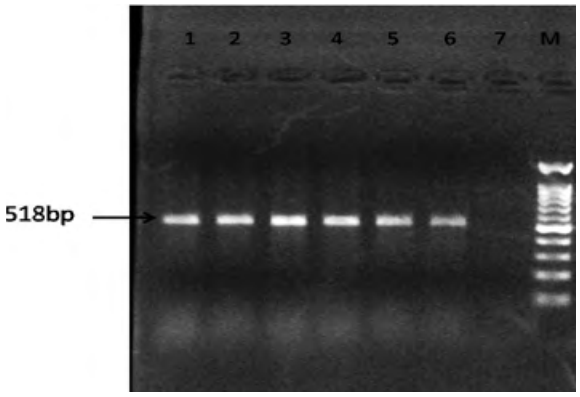


Fig 18.17. Gel Electrophoresis for PCR with primers VTcom-u and VTcom-d. Lanes 1-6 : Positive samples, Lane 7 : negative control, M 100 base pair marker Control, M: 100bp marker

Primer Sequence
VTcom-u: 5′- GAGCGAAATAATTTATATGTG -3′
VTcom-d: 5′- TGATGATGGCAATTCAGTAT -3′

PCR reaction set up :

2X PCR Master Mix (NEB)	12.5µl
VT com(10µM)	1.0 µl
B5(10µM)	1.0 µl
Template DNA	5.0 µl
Nuclease-free water	5.5µl

Thermal Profile

Initial Denaturation	94°C, 7 min.	
Denaturation	94°C, 30S	40 Cycles
Annealing	48°C, 1 Min.	
Extension	72°C, 1 Min.	
Final Extension	72°C, 10 min.	

Effect of Different Rearing Systems on Growth Performances of Divyan Red Poultry Birds During Winter Months

An experiment on rearing system was conducted during winter months (November 15, 2019 to February 15, 2020) under hill & plateau conditions. In total 100 Divyan Red chicks of both sexes with 50 in each treatment comprising 25 males and 25 females were reared with 5 replications (Fig. 18.18). All chicks under the experiment were provided uniform management practices viz. feeding, watering, vaccination, treatments etc as per the standard procedure. The effect of intensive (T_1) and semi-intensive (T_2) system of management was studied up to 90 days. The body weight of the birds were taken at 30 days then at fortnightly intervals from 60 to 150 days of age (Table 18.10). Significantly higher values of total body weight gain, average daily body weight gain and feed conversion efficiency (FCR) were recorded under intensive system over that of semi intensive system of rearing.

Table 18.10. Performance of Divyan Red poultry birds on different rearing systems

	Intensive system (T_1) (n=50)	Semi-intensive system (T_2) (n=50)
Body weight at 30 days	265.13±3.52	265.44±2.19
Body weight at 120 days	1149.56±26.59^a	1115.63±27.49^b
Total body weight gain (g)	884.43±11.22^a	850.19±16.23^b
Average daily weight gain (g/bird)	9.83±0.17^a	9.45±0.15^b
Total feed intake (kg/bird)	7.63±0.13^a	4.64±0.09^b
FCR	8.63	5.46

Fig. 18.18. Divyan Red poultry birds in semi-intensive system

Effect of Winter Management Systems on Growth Performance of Crossbred (T X D) Pigs

An experiment on winter management (four treatments) was conducted with crossbred (T x D) pigs comprising of 12 females and 12 males (90 days age with average body weight of 21.27 kg) (Table 18.11) (Fig. 18.19a & b). Equal amount of feed with different frequency per day was offered @ 1.50 kg/pig/day on dry matter basis to different groups. During 90 days (November 15, 2019 to February 15, 2020) trial it was observed that all the groups differed in total body weight gain and average daily gain and feed conversion efficiency. The minimum weight gain was observed in control group T_1 with cemented floor followed by T_2 with plastic sheet curtain at night and cemented floor, T_3 with gunny bag on floor and no plastic curtain during night, T_4 with gunny bag on floor and plastic curtain during night. Same trend was also followed in average daily weight gain. The maximum weight gain in T_4 group may be due to less winter stress associated with provision of both bedding materials with gunny bags and curtain during night.

Table 18.11. Effect of winter management on growth performance of crossbred (T x D) pigs at institute farm at Ranchi

Parameters	T_1 (Control) (Cemented floor only)	T_2 (Cemented floor and plastic curtain at night)	T_3 (Gunny bag on floor)	T_4 (Gunny bag on floor and curtain at night)
Initial body weight (kg) at 90 days	21.18± 0.98	21.13± 1.23	21.03± 41.29	21.10± 1.36
Body weight (kg) at 120 days	28.90± 0.21^a	31.47± 0.18^b	32.50± 0.18^c	34.67± 0.18^d
Body weight (kg) at 150 days	36.30± 0.17^a	39.10± 0.14^b	40.17± 0.18^c	42.75± 0.16^d
Body weight (kg) at 180 days	43.18± 0.21^a	48.22± 0.16^b	51.30± 0.18^c	55.38± 0.15^d
Total body weight gain (kg)	22.00± 0.19^a	27.08± 0.19^b	30.27± 0.16^c	34.28± 0.22^d
Average daily gain (g)	244.33± 2.04^a	301.17± 2.09^b	336.17 ± 1.82^c	381.17± 2.36^d
FCR	6.14	4.98	4.46	3.94

Fig.18.19. (a) Pigs in floor with gunny bags on floor, and (b) in the cemented floor

FISHERIES

Biofloc Technology: Exploring Production Optimization and Economic Viability for the Eastern Region

To explore the production performances of freshwater fish and shellfish in the biofloc with record of productivity and economic feasibility, biofloc unit of the capacity of 5,000 liters/ tank was established (Fig. 18.20). Freshwater prawn (*Macrobranchium rosenbergii*) and minor carp (*Labeo gonius*) species were stocked and cultured under different stocking combinations; T1: fish and prawn together; T2: prawn alone and T3: fish alone. The C:N ratio for the better floc activation was maintained between 10:1 to 15:1 by adding carbon source jaggery. The feeding in the bioflock tanks was managed by providing floating feed @ 2% of the total culture biomass. In the control tanks, floating feeds were given @6% of the total culture biomass. The growth assessment and evaluation of cultured organism for feeding quality adjust were carried out at monthly interval.

Fig. 18.20. (a) Biofloc experimental unit, (b) species used in biofloc culture and (c) floc concentration in imhoff-cone

Monthly weight gain of fish and prawn are depicted in Fig. 18.20, and average specific growth rate (SGR) and feed conversion rate (FCR) of the various treatments are given in Fig. 18.21. The study revealed that fish and prawn combination (T_1) performed better in terms of growth, SGR and FCR. This combination (T_1) also had maximum survivability for both fish (97.4%) and prawn (61.33%).

Regular water quality parameters from each tank were monitored and average range of water temperature (13.62-30.92°C), DO (5.40 -9.53 ppm), pH (6.93-8.47), hardness (126.78-244.22 ppm), alkalinity (120.44-291.33 ppm), ammonia (0.06-1.92 ppm) and water conductivity (379.42-801.42Ω) were found to be within the acceptable limit for fish culture. Monthly biofloc concentration was also recorded in each tanks which were in the range of 2.10-11.59 ml/l. Microscopic analysis revealed >20 dominant plankton species from the biofloc system (Fig. 18.22).

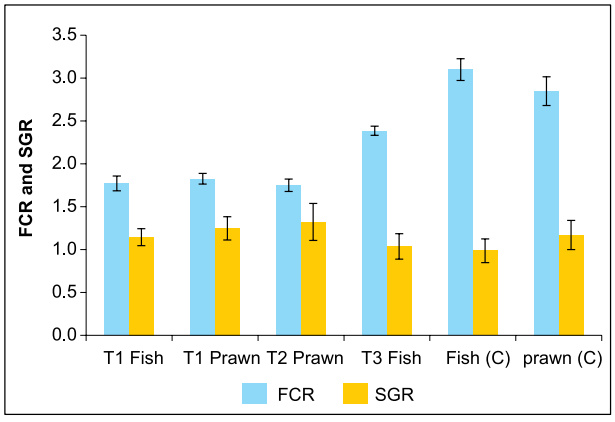


Fig. 18.21. SGR and FCR for various treatments in Biofloc technology

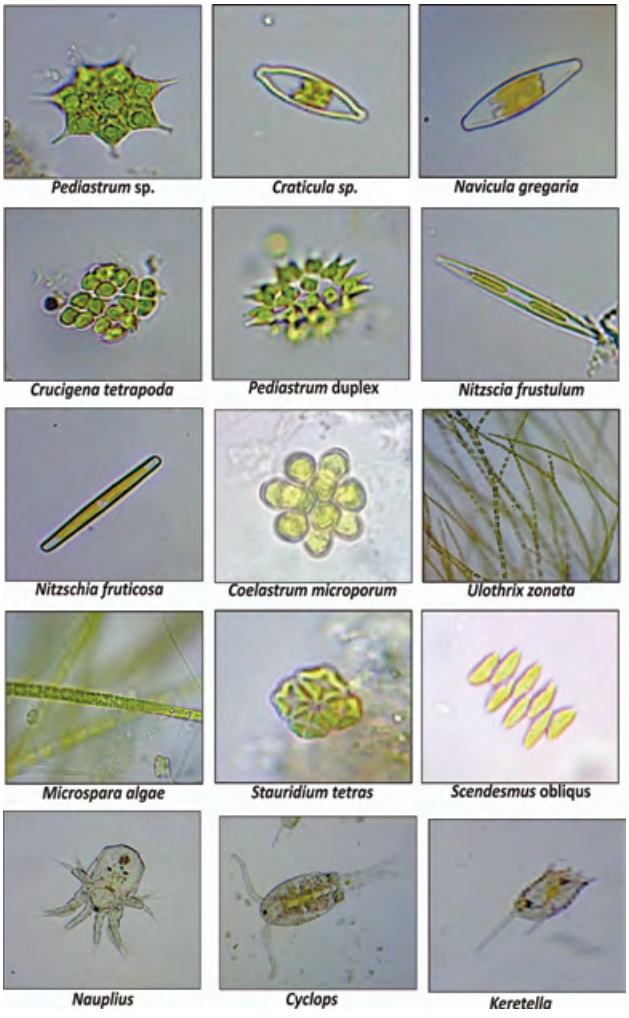


Fig. 18.22. Identified plankton species from the Biofloc system

Economic Feasibility of Integrated Prawn cum Fish Farming in Polyculture System

The experiment was conducted in an earthen pond of 1000 m^2 area. The pond was first drained and sundried, which was followed by refilling and application of lime @ 15 kg/0.1 ha area. The pond was initially manured using 10 kg of cow dung followed by mixture of rice bran (5 kg), agromine (100 g) and DAP (0.5 kg). The plankton was developed after 2-3 days of manure application. Hide out pipes/ shelters were provided to facilitate the growth and reduce the mortality of prawns. Stocking density of fish and prawn were 5000 and 20,000 numbers per hectare, respectively, and stocking was done in the month of July. Prawn (post larval; 0.005g) was stocked in polyculture system and was given starter feed (Starter 1) @ 100% body weight till they reached to 1 g of weight. Subsequently catla and rohu (250 numbers of each) were introduced and fed floating feed @ 4% of the body weight. Water quality parameters like DO (7.03 ±0.24 ppm), pH (7.65± 0.06), alkalinity (159.8± 3.73 mg/l), hardness (146.94±4.02 mg/l), ammonia (0.008±0.25 mg/l), nitrite (0.23± 0.02 mg/l) and phosphate (0.71± 0.02 mg/l) were within the acceptable limit. It was observed that growth rate of catla was faster than rohu (Fig. 18.23). The prawn (post larvae; 0.005g) attained the body weight of 80.53 g within the culture period of 461 days (Fig. 18.24).. At the end of culture, the productivity of catla, rohu and prawn was recorded at 1580, 1060 and 370 kg/ ha, respectively.

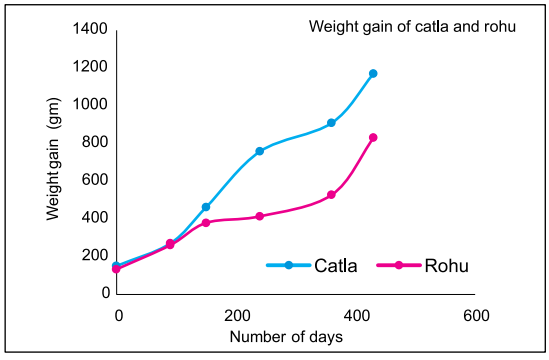


Fig. 18.23. Growth of catla and rohu in polyculture system

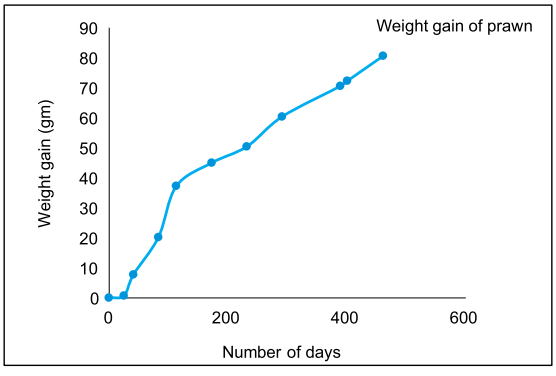


Fig. 18.24. Growth of prawn in polyculture system

Fingerling Rearing of Minor Carp, *Labeo Gonius* Based on Supplementary and Traditional Feeding

The incorporation of minor carp in polyculture system is gaining importance due to high demand and price, although the yield characteristics and concepts of competition among these species need to be more fully understood. Present study was undertaken to assess the growth performance of minor carp fingerlings (*Labeo gonius*) under supplementary feed (SF) and traditional feed (TF) conditions. Four types of feeding were used: SF with 5% & 10% body weight and TF with 5% & 10 % body weight. For the study, seeds were followed in cemented tank @ of 240 numbers in each tank. An aeration was provided in all the tanks from a centralized air blower. At the time of stocking, average length and body weight of fish was recorded at 9.9±0.07 g and 89.23±0.21 mm, respectively. In all the tanks 30% water exchange was done fortnightly in morning time. Regular sampling was done and growth achieved till 100 days is illustrated in the Fig. 18.25-18.26. It was found that SF with 32%

Fig. 18.25. Final harvest of *Labeo gonius*

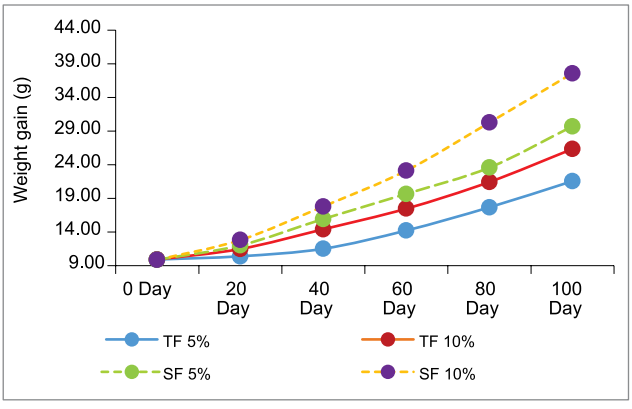


Fig. 18.26. Growth performance of *Labeo gonius* spawn reared under different feeding regimes

protein level and feeding at 10% body weight showed better growth rate and survival percentage compared to other feeding regime.

Impact of Combined Application of Organic Manure on Fish Production

To understand the impact of combined application of organic manure, a study was carried out in two identical fishponds (800 m^2) where in one integration combination of cattle and goat manure were applied and in other pond, cattle and duck manure were applied. Rohu (*Labeo rohita*) (88.5±5.36g) and catla (*Catla catla*) (109.7± 5.55g) were reared in those ponds at the rate of 6800 nos. per ha. No external feed was provided. In both the ponds livestock manure was applied on daily basis. During 7 month culture period, highest fish production was achieved in cattle + goat combination (2042.49 kg/ha) (Fig.18.27), similarly highest survivability was also recorded in cattle + goat-fish (95.79%) followed by cattle + duck-fish combinations (76.98%). The main reason of low productivity in the combined application of cattle + duck manure was due to poor recovery rate of fishes in the second combination (cattle + duck manure), attributed to escape of fishes during the heavy shower and subsequent inundation of the pond. Growth studies of rohu and catla were also recorded (Fig. 18.28) and found that rohu performed better in cattle + goat manure while catla performed better in cattle + duck manure combination (Fig. 18.29). Regular water quality parameters in different treatments were within the acceptable limit for survival and growth of fish. Based on the present findings, it can be concluded that combined application of livestock manure is also beneficial for fish culture and this integration did not show any deterioration in water quality parameters.

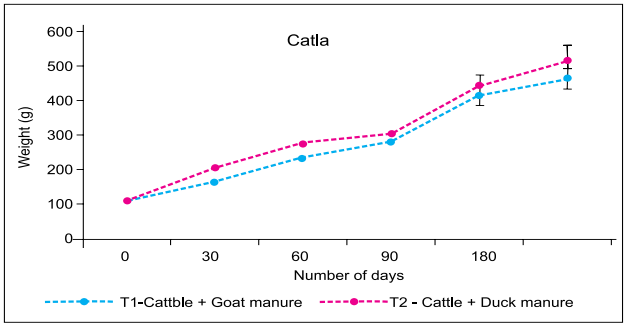


Fig. 18.27. Growth performance of catla under combined application of organic manure

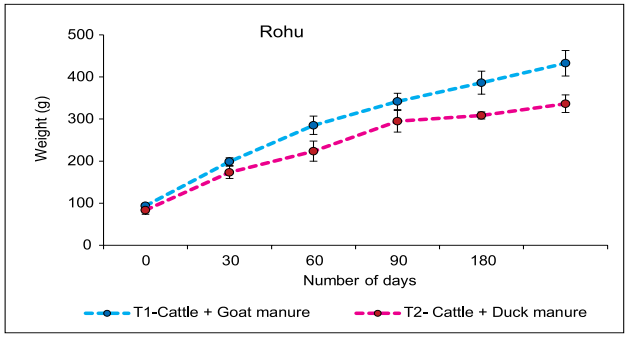


Fig. 18.28. Growth performance of rohu under combined application of organic manure

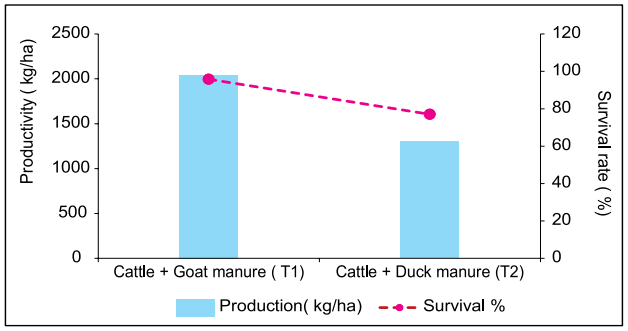


Fig. 18.29. Fish production under different integrated farming systems

Mass Seed Production of Climbing Perch (*Anabas testudineus*) in Earthen Pond

Climbing perch (A. testudineus) is an important air-breathing freshwater species distributed throughout India and other South-Asian countries.

During the onset of monsoon season, around 20 numbers of mature brooders (Fig. 18.30) were collected from brood-stock pond and kept separately in the cement cisterns. Brooders were fed daily with supplementary diet of 35% protein @ 5% of the total biomass. After 15 days of culture in the month of August 2020, induce breeding of *A. testudineus* was attempted. Brood fishes were selected based on their secondary sexual characters. Males (18.50±0.29g) are slander and milt oozes out upon gently pressing while females (19.5±0.45g) exhibit outgrowth at the vent in the form of genital papilla and having bulging abdomen. The selected brooders were injected with Ova-FH @ 0.1ml per fish and released again

Fig. 18.30. A healthy *A. testudineus*

into the earthen brood-stock pond. After 50 days. The fry of climbing perch was first collected by fined meshed net and subsequently by hand pick. More than 5000 numbers of anabas fry (36.23±0.41 mm and 0.83±0.04g) were collected from the breeding ground. Subsequently, rearing was done and weigh gain of *A. testudineus* was recorded to be 2.53 g.

Breeding and Rearing Techniques of Walking Catfish (*Clarias magur*)

To evaluate breeding performance and standardize the rearing techniques, an experiment was conducted using WOVA-FH hormone at the rate of 0.5, 1.0, 1.5 and 2.0 ml/kg body weight of female *C. magur*. The results indicated that the total weight of stripped eggs and spawning fecundity were highest when females were injected @1.0 ml of WOVA-FH hormone per kg body weight (BW). Rearing of larvae obtained from fishes injected with different doses of hormone did not result any significant difference in weight gain of magur seed and at 2.0 ml/kg body weight, no spawning response but plugging condition was observed (Table 18.12). Average larval weight gain at the end of 30, 60, 90 and 120 days was 0.003g, 0.085g, 4.47g, 11.77g and 23.77 g, respectively. Simultaneously natural breeding was also attempted where fishes were injected and released in a specially made earthen pond and fingerlings were harvested at the end of 90 days. At the end of 90 days, significantly lower weight gain ($p<0.05$) of *C. magur* fingerling was recorded from natural breeding compared to the artificial breeding and rearing at FRP tank condition.

Table 18.12. Effect of various doses of WOVA-FH® hormone on breeding performance and larval survivability of *C. magur*

Parameters	WOVA-FH® (dosage ml/kg)			
	0.5	1.0	1.5	2.0
Weight of females (g)	112.5 ± 18.9	118.5± 23.23	119.25± 14.04	121.5± 18.7
Spawning fecundity (nos.)	2697± 221[a]	5020 ± 258 [b]	3455± 18.93 [c]	-
Fertilization (%)	35.58 ± 8.69 [a]	70.23 ± 23.13 [b]	53.25 ± 1.37 [c]	-
Hatching (%)	36.25± 1.45 [a]	85± 2.04 [b]	46.25± 0.75 [a]	-
Duration of hatching (hrs)	27-34	28- 33	26 - 33	-
Weight at hatching (mg)	3.60 ±0.34	2.75±0.30	2.75±0.32	-
Survival rate(%)	26.25	40.75	35.5	

Data are expressed as mean±SE. Different superscript in a row indicates significant ($P>0.05$) difference.

Data are expressed as mean ± SE. Different small letter superscripts for weight gain in artificial breeding for 120 days of rearing and different capital letter superscripts of weight gain for artificial breeding and natural breeding at 90 days of rearing differ significantly ($p<0.05$)

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

Floodplain fish biodiversity of North Bihar

Floodplains are the habitats of diverse aquatic flora and fauna. Monitoring of fish diversity was begin during the monsoon season from different habitat of floodplain wetlands (*i.e. chaur* and *maun*) in North Bihar. Around 51 fish species were identified and 16 were archived in the museum at RCM, Darbhanga. The taxonomic study indicated various fish species in the order of *Cyprinidae* (41%), *Bagridae* (10%), *Osphronemidae* (3%), *Ambassidae* (3%), *Channidae* (2%), *Mastacembelidae* (2%), *Siluridae* (2%), *Notopteridae* (2%), *Cichlidae* (2%), *Schilbeidae* (1%), *Siluridae* (1%), *Belonidae* (1%), *Anabantidae* (1%), *Claridae* (1%), *Heteropneustidae* (1%), *Gobiidae* (1%), *Cobitidae* (1%), and *Nandidae* (1%).

Identification of compactible fish species with makhana

An experiment was conducted in "Makhana cum fish ponds" with three replicates. Each pond had an area of 800 m^2 and depth 1.3 m. The makhana seedlings (Swarna Vaidehi) were transplanted at 1m × 1m spacing in March and peripheral waste surface of 2 m kept free for dissolved oxygen in the pond. Six species of fish fingerlings namely *Catla catla* (catla), *Labeo rohita* (rohu), *Cirrhinus mrigala* (mrigal), *labeo bata* (bata), *Anabas testudineus* (climbing perch/kawai), and *Channa striatus* (snake head/garai) stocked at the ratio of 3:2:2:1:1:1, respectively. Organic and mineral fertilizers were used for fertilization of water and soil. According to the fish biomass, traditional supplementary feed was given in the range of 3-7%. The growth performance of fishes at harvesting has been depicted in Table 18.13. The average weight of catla (495.25±38.23 g) and rohu (503.21±60.23 g) were recorded higher than other fish species. Hence, both fishes could be compatible species with makhana cum fish culture. Other fishes like mrigal, bata, climbing perch and snake head required more culture duration for attaining their marketable size.

Table 18.13. Growth of fishes in experimental ponds

Species	Average body weight (g)
Catla catla	495.25±38.23
Labeo rohita	503.21±60.23
Cirrhinus mrigala	110.45±24.25
Labeo bata	52.31±8.48
Anabas testudineus	41.32±8.69
Channa striatus	60.79±3.72

Community Structure of Periphyton Assemblages

An artificial substrate were installed to monitor the accumulation and colonization of periphytons in the makhana-cum-fish pond. It would help to overcome some drawbacks like black water formation, lack of natural food availability and high mortality of fish fingerlings. The substrates were made from locally available tree branches and bamboo poles. The knitted fabric net made by high density polyethylene (HDPE) was also used in installation procedure.

All substrates were placed in submerged condition in the experiment ponds and kept away from the direct sunlight. Successional assemblages of periphytons were observed within a month in experimental unit, which appeared like a slime or bioflim structure on the surface of the substrates. Among the all-usable substrates, immersed bamboo pole showed more density on other hand tree branches showed more diversified periphyton assemblages. Dominant communities such as zooplankton, algae and invertebrates have been reported from the collected slime structure (Table 18.14).

Table 18.14. Composition of periphyton assemblages on substrates

Order	Species	Order	Species
Chlorophyceae	*Chlosterium*	Bacillariophyceae	*Gomphonema*
	Cosmarium		Gyrosigma,.
	Oedogonium		Navicula
	Spirogyra		*Nitzchia*
Rotifera	*Brachionus*		Hannaea
	Lecane	Cyanophyceae	*Chroococcales*
		Zygnematales	*Mougeotia*
		Cladocera	*Daphnia*
Testacida	*Difflugia*		*Moina*
Copepoda	*Cyclops*		*Bosmina*
Diptera	*Chironomous*		Ceriodaphnia

19. Transfer of Technology

The project "Scaling up climate smart agriculture through main streaming Climate Smart Villages (CSV) in Bihar" funded by National Adaptation Fund for Climate Change (NAFCC) was initiated in *rabi* 2018-19 with the aim to improve the adaptive capacity of farmers to cope up with the climate risks. Base line survey of farmers from selected villages was carried out. A total of 2500 farm families were included in the survey. Under this project, intervention of climate smart technologies *viz*., direct seeded rice, zero tillage wheat, lentil and moong in the selected blocks (Daniyawan and Fatuha) of Patna and (Chandi, Nagar Nausa and Noorsarai) of Nalanda districts of Bihar have been made. For demonstration of climate smart technologies, quality seed of rice (8300 kg), lentil (1000 kg), moong (1000 kg) and wheat (2500 kg) were provided to the farmers. Besides, all the required pre-emergence (Pendimethalin) and post-emergence (Bispyribac Sodium and 75% Sulfosulfuron + 5% WG Metsulfuron) herbicides were also provided to control the expected loss of the crop. The block wise details of crop grown, farmers and area covered during the year 2020-21 is given below in the Table 19.1. Among the different climate smart technologies intervened, the highest area was covered under ZT-moong (153.06 acre) followed by ZT-wheat (133.42 acre) (Fig. 19.1-19.2). The farmers of the selected blocks had realized the advantages of such climate smart technologies particularly under the present scenario. Moreover, farmers' feedback reflected towards subsidies and capacity building. Apart from these interventions, four field day-cum-training programmes on "Zero tillage in Rice-Wheat-Moongbean cropping system: a useful and profitable techniques" at selected villages were also organized during the period with the aim to sensitize different stakeholders engaged in implementation of this project.

Fig. 19.1. ZT-Wheat at Chakraja village, Patna

Fig. 19.2. ZT-Moong at Salarpur village, Patna

Transfer and Adoption of Improved Agricultural Technologies

Based on data collected from 73 officials of Bihar (mostly block level extension functionaries), it was found that maximum officials (72.60%) disseminated technology or information through personal contacts.

Table 19.1. Block-wise area covered under different climate smart technologies

Technologies	Patna				Nalanda					
	Daniyawan		Fatuha		Chandi		Nagar Nausa		Noorsarai	
	Area (Acre)	No. of farmers	Area (Acre)	No. of farmers	Area (Acre)	No. of farmers	Area (Acre)	No. of farmers	Area (Acre)	No. of farmers
ZT-Moong	40.79	63	6.60	10	41	49	22.46	25	42.21	64
DS Rice	20.58	24	16.87	32	14	14	7.78	9	25.77	30
ZT-Wheat	34.30	43	15.47	22	25	25	25.90	26	32.75	48
ZT-Lentil	8.12	16	10.03	16	10.3	15	7.21	8	15.00	23

Training, demonstrations, and *Kisan Melas* were also other sources of effective transfer of technologies by the majority of officials of Bihar (Fig. 19.3).

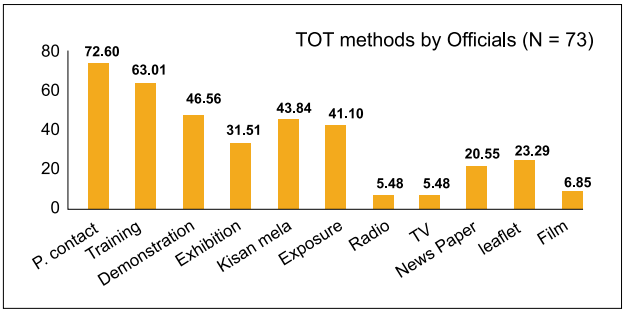


Fig. 19.3. Transfer of technology methods by the officials

Regular monitoring of government-funded schemes and activities is one of the important keys for the effective implementation of any program and its desired impact on society. A critical examination of the data revealed that most of the officials (55%) monitored the activities by field visits followed by individual contacts (29%).

Monitoring through social media or IT tools is now becoming an efficient tool for quick and frequent monitoring in Bihar. Eight percent of officials used social media or IT tools for monitoring different activities. Monitoring through monthly meetings (8%) with the officials or other stakeholders was also used by the officials.

Growth and Instability in Production of Principal Crops in Eastern India

The project was initiated to study the growth and instability in the production of principal food grains in eastern India. For this, more than thirty years of secondary data since 1981 on the area, production, and yield of principal crops from all the states of eastern India were collected and analyzed. During the year 2020, the data were collected and analyzed for Odisha. From the analysis of the last 36 years' data, it has been observed that rice is the main foodgrain crop, covering about 50 percent of gross cropped area (GCA) but the area under rice showed a declining trend after Triennium Ending (TE) 2001. However, the production of rice increased continuously over the entire period of study. It increased by about 4.7 and 2.7 percent annually during 2001-10 and 2010-16, respectively. It was possible only due to the increase in rice productivity during the period. Maize, wheat, and millets had covered 9.5 percent of GCA in the state but wheat did not have a presence at TE 2016 and maize declined to 73 thousand ha at TE 2016 from 1.55 lakh ha, accounting for less than one percent of GCA at TE 2016. Pulses were also important crops that covered about one-fifth of GCA at TE 1981. It's area increased to 36.70 lakh ha at TE 1991, covering one-third of GCA. But pulses crops observed a sharp decline during 1991-2016 and covered about 10 percent of GCA in Odisha. There was a similar decline in the area of oilseeds during the last two and half decades. The proportionate share of area under other crops observed a steady increase that was about 10 percent at TE 1981 to 34 percent at TE 2016. Horticultural crops including flowers, sunflower, and sugarcane gained in the area during the study period.

Despite the almost constant area under rice, production increased during the study period with very low instability of 1.29% to 4.70 %. It was made possible by a steady increase in productivity from only 887 kg/ ha to 1881 kg/ha during the period. Maize productivity increased much faster but there was instability in production due to a decline in the area during the period under study. Pulses productivity was also increased marginally but its production declined by 50 % due to massive decline in pulses area in Odisha during the last two and half decades. Despite frequent climatic disasters, agriculture in Odisha observed more stability and kept increasing trend in rice, horticultural, and millet crops, particularly in ragi production. Cropping intensity increased from 138 to 166 during the last 35 years. It may be considered the good performance of the farming system in Odisha.

Climate Resilient Agriculture Programme (CRAP)

The Climate Resilient Agriculture Programme was launched by Govt. of Bihar during the *Rabi* season in 2019 with the mandate to create awareness and capacity building of farmers towards climate resilient agriculture production in the state. The project is funded by the Government of Bihar under the umbrella program '*Jal Jeevan Hariyali*' scheme. It has been initially implemented in eight KVKs of Bihar by four implementing research organizations i.e Borlaug Institute of South Asia (BISA), Pusa; Bihar Agricultural University, Sabour; Dr. Rajendra Prasad Central Agricultural University, Pusa and ICAR Research Complex for Eastern Region, Patna. ICAR RCER, Patna is involved in implementing all research and extension activities related to climate-resilient agriculture in Gaya and Buxar district through respective Krishi Vigyan Kendras. In this programme, several climate resilient agricultural technologies were demonstrated in the study area.

Demonstration of zero tillage technology in wheat and lentil in Gaya

Under the project, long-term experiments on major climate resilient agriculture technologies and cropping systems were laid out at farmers' fields as well as KVK Farm. During the year, the physical target area under the *rabi* crops (Wheat-125 acre & Lentil-20 acre) was 144.5 acres. The quality seed of wheat (var. HD 2967) and Lentil (var. HUL 57) were provided to 138 farmers along with other inputs for demonstrating zero tillage technology in these two crops (Table 19.2).

Table 19.2. Demonstration of climate-resilient technology during *rabi* 2019-20

Crop	Variety	Villages/ KVK farm	Area (acre)	Technology demonstrated
Wheat	HD - 2967	Rasalpur, Nagar	80.0	Zero tillage wheat
Wheat	HD - 2967	Rasalpur, Manpur	27.0	Zero tillage wheat
Wheat	HD - 2967	Rupaspur, Manpur	18.0	Zero tillage wheat
Lentil	HUL -57	Rasalpur, Nagar	15.0	Zero tillage lentil
Lentil	HUL-57	Rupaspur, Manpur	2.0	Zero tillage lentil
Total area coverage in selected villages			142.0	
Wheat	HD - 2967	KVK, Manpur, Gaya	2.0	Zero tillage wheat
Lentil	HUL -57	KVK, Manpur, Gaya	0.4	Zero tillage lentil
Mustard	R. Sufalam	KVK, Manpur, Gaya	0.1	Zero tillage mustard
			2.5	

The data regarding the yield of demonstrated varieties and the local check was recorded after harvesting. It was observed that there was a significant increase in yield of both wheat and lentil under zero tillage as compared to traditional practices. Zero tillage wheat recorded a 4.15 t/ha grain yield which was 18% higher than the local check (Table 19.3). Zero tillage lentil also recorded higher yield as compared to local practice. Similar results were observed at the KVK farm also.

The economic analysis of selected technology was also carried out (Table 19.4). It was observed that in terms of net return, zero tillage wheat cultivation gave the highest net return of Rs. 51,476 per ha which was nearly 50% higher than the local check variety.

Table 19.3. Performance of zero tillage wheat and lentil at farmers' field in Gaya district, (*rabi* 2019-20)

Name of technology	Area (acre)	No. of farmers	Grain yield (t/ha)		Straw yield (t/ha)	
			Demo	Local check	Demo	Local check
Zero Tillage Wheat (HD–2967)	125	125	4.15	3.52	5.31	5.57
Zero Tillage Lentil (HUL 57)	17	20	0.87	0.75	1.19	1.05

Table 19.4. Economic analysis of zero tillage technology for wheat and lentil

Name of technology	Cost of cultivation (Rs./ha)		Gross return (Rs/ha)		Net return (Rs./ha)	
	Demo	Local check	Demo	Local check	Demo	Local check
Zero Tillage Wheat (HD–2967)	28,450	34,500	79,926	67,664	51,476	33,164
Zero Tillage Lentil (HUL 57)	20,225	17,540	41,760	36,096	21,535	18,556

In case of zero tillage lentil, the net return was 16% higher than the local check.

Experiments during summer season 2020

After *rabi* season, farmers of selected villages were convinced to grow moong bean using the zero tillage technique. Thus, moong crop (var. IPM-2-14) was demonstrated at farmer's field in the 45 acre area as per the target. Altogether, 49 farmers were provided quality seed with other inputs and technical guidance. The economics of zero tillage moong has been depicted in Table 19.5. The grain yield under the demonstration plot (0.85 t/ha) was found to be higher than the conventional technique (0.73 t/ha). In terms of net return, zero tillage moong gave a net return of Rs 33,200 per ha which was 36 % higher than the conventional technique.

Table 19.5. Economics of zero tillage moong bean at farmers field in Gaya

Particulars	Demonstration plots	Local check
Grain yield (t/ha)	0.85	0.73
Straw yield (t/ha)	2.25	1.95
Cost of cultivation (Rs./ha)	17800	19100
Gross return (Rs./ha)	51000	43500
Net return(Rs./ha)	33200	24400
B:C ratio	2.86	2.27

During *kharif* 2020, improved varieties of paddy, maize, pigeonpea and bajra were demonstrated in farmers'field for implementing climate-resilient technologies in the Gaya district. Total demonstrations in 170 ha area were laid out benefitting 220 farmers of selected villages. Yield at demonstration plots were found to be higher than local check. The details are given in the Table 19.6.

Extension of Climate Resilient Agriculture Programme in Buxar

In the year 2020, Bihar Govt. decided to extend this program to all districts of Bihar. Therefore, ICAR-RCER, Patna was entrusted to implement the program in the Buxar district through its KVK. Five villages namely Harikishunpur, Dalsagar, Churamanpur, Balapur, and Ramobariya were selected for implementing the activities of the CRA Programme. Quality seeds of four crops *viz.* wheat (var. HD 2967), chickpea (var. Pusa 3043/RVG 202), lentil (var. HUL 57), and mustard (RH 749) were distributed among 849 farmers covering an area of 618 acres for experimentation during *rabi* 2020.

Utilization of Digital Tools in Agriculture in Eastern India

The applications and utility of digital tools among extension functionaries were studied through an online survey in Bihar during 2019-20. A total of 320 extension functionaries were interviewed and schedules were sent online through Google Forms. Analysis of data revealed that the extension persons' age was between 23 to 57 years. Out of this, 54.37% were graduates, 44.68% were masters and only 1% were doctorate. These extension functionaries were directly or indirectly connected to the farmers. Nearly 38% extension functionaries were in contact with approximately 100 farmers, 44% were in contact with approximately 500 farmers, 10% were in contact with approximately 2000 farmers and 6% of them were in contact with more than 2000 farmers.

The scenario of digital tools used by extension personnel of Bihar during 2019-20 is presented in Table 19.7. The table revealed that the majority of respondents were observed to use the smartphone most frequently, i.e., on daily basis to the tune of 67.2%, probably because easy to handle with multiple useful features. About 2 to 26 percent of extension functionaries used digital devices at certain intervals of time, such as weekly, monthly, and half-yearly basis.

The opinion of extension functionaries on the importance of digital tools in Bihar was also studied, which is depicted in Table 19.8. Four elements of the importance of digital tools were outlined for the

Table 19.7. Scenario of digital tool use by extension functionaries in Bihar during 2019-20

Periodicity of digital tools	Digital tool					
	Computer	Laptop	Internet use	Mobile	Smartphone	Computer Tabs
Daily	0.3	0.6	6.3	15.6	67.2	8.4
Weekly	17.2	4.7	4.1	4.1	17.8	26.3
Monthly	15	10.3	4.1	2.2	13.4	7.5
Half yearly	10.3	5.3	2.2	2.5	10.3	5.3
Occasionally	13.1	4.7	4.1	4.7	8.1	2.8

Table 19.6. Performance of different interventions during *kharif* 2020 at farmers' field in Gaya district

Name of technology	Area (ha)	No. of farmers	Variety	Grain yield (t/ha)		Straw yield (t/ha)		Harvest Index	
				Demo	Local check	Demo	Local check	Demo	Local check
Transplanted rice (TPR)	65	65	Arize-6444 Gold	6.93	4.06	7.81	5.16	47.02	44.01
			S. Ardhjal	4.04	2.92	4.79	3.84	45.77	43.15
			S. Shreya	2.96	2.61	3.86	3.47	43.39	42.98
			Sahbhagi	3.63	3.15	4.23	3.75	46.13	45.63
			Rajendra Sweta	4.22	3.57	4.62	4.30	47.69	45.34
UPTR- Nutrient expert based nutrient management	15	20	Rajendra Sweta	4.58	3.52	4.79	4.29	48.88	45.13
CT-DSR	10	07	Rajendra Sweta	4.33	3.25	3.95	3.85	52.33	45.73
ZTD-DSR	25	25	Rajendra Sweta	4.08	3.26	4.41	4.06	48.05	44.54
Maize	20	39	P-3377	3.65	3.25	4.67	4.49	43.86	42.03
Bajra	05	06	Proagro-9450	2.75	2.56	3.84	3.67	41.74	41.07

Table 19.8. Opinion of extension functionaries on the importance of digital tools in Bihar during 2019-20

Importance of digital tools	Agree (%)	Strongly agree (%)	Dis-agree (%)	Neither agree nor disagree (%)	Oth-ers (%)
Basic needs	51.87	41.87	2.18	4.06	0.02
Provide informa-tion very quickly	42.18	55.62	0.10	2.08	0.02
Help in creating employment in agriculture	58.75	25.93	3.43	11.87	0.02
Improved social status	60.93	29.06	0.50	9.00	0.51

study, i.e., basic needs, provide information very quickly, help in creating employment in agriculture, and improved social status. Most of the respondents (60.93%) agreed with the view that these tools improve their social status, indicating their consciousness for social status. About 58.75% of respondent agreed that these tools helped in creating employment in agriculture; 51.87% of respondents agreed that these tools were for the basic needs of human being, and 42.18% of respondents agreed that these tools provided information very quickly. However, a sizeable percentage (55.62%) of respondents strongly felt that digital tool helped in providing information very quickly. Overall, it may be inferred that digital tools are highly useful for extension functionaries in the field of agriculture.

Production and Value Chain Analysis of Makhana

Makhana value chain at the national level was assessed by analyzing data collected from the major trading centers, i.e., Kharibowli at Delhi and Nayaganj mandi at Kanpur. The most important marketing channel was identified at the national level.

Structural analysis of value chain

Makhana value chain involves multiple stakeholders working at different levels for production, processing, marketing as well as consumption of makhana. They are interconnected with each other (Fig.19.4)

The value chain for makhana starts with the makhana growers who are responsible for the production and harvesting of the makhana seed locally called *guri*. These growers are supported by State Govt., R&D institutes, private input suppliers, banks, etc. The seed is sold to primary processors (*phodi*) who convert it to popped makhana lava by drying,

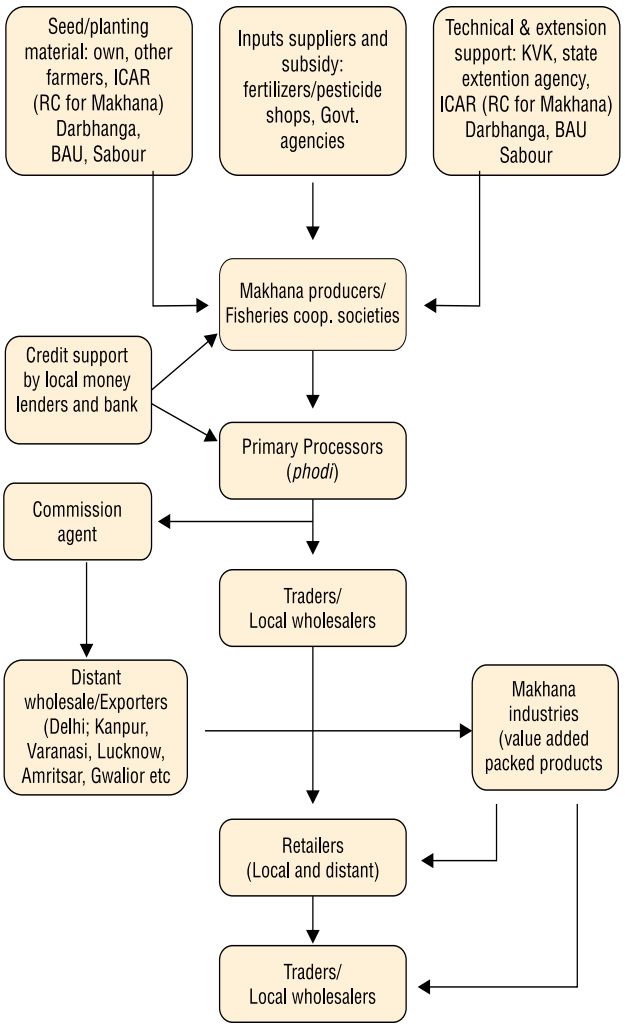


Fig. 19.4. A schematic diagram of stakeholders associated in makhana value chain value chain

roasting, and popping by traditional methods. Local money lenders play important role in the value chain since they provide credit support to both producers and processors. The popped makhana is purchased by local wholesalers either directly or through commission agents. A major quantity of popped makhana (70-75%) of the growing area is sold to distant wholesalers at various cities in India after grading at local wholesalers level. Some quantity is sold at the local and regional level by the local wholesalers. Few makhana industries prepare value-added products for high-end consumers and sale through retail outlets or online to consumers. A small number of large traders export makhana in USA, UK, Canada, and Gulf countries through waterways.

Functional analysis of value chain actors

Each actor plays important role in the value chain and they are interlinked with one another. Before the final product reaches to ultimate consumers, these

members of the value chain perform various functions related to the production, processing, marketing, and distribution of the product. A brief of functions performed by different value chain actors is given in the Table 19.9.

Table 19.9. Functional analysis of makhana value chain actors

Value chain actors	Activities	Output
Input suppliers	Supply of inputs *viz.* planting materials, fertilizers, pesticides, etc	Quality seed and inputs
Service providers (Bank, Govt. sector)	Credit, extension, and advisories	Training, subsidy, enhanced production
Farmers	Production of makhana seed	Makhana seed
Processors (primary and secondary)	Processing of seed into popped makhana, preparation of value-added products	Popped makhana and value-added flavored makhana products
Traders	Grading, packaging, transport, storage, and sale of makhana	Availability of makhana to consumers

Major marketing channel at national level

Nearly 70-75% of the total popped makhana is marketed through distant wholesalers located in major cities across the country. For this, the following marketing channel is used by traders.

Farmers → Processors → Local wholesalers → Distant wholesalers → Distant retailers consumers

In this channel, popped makhana is purchased by local wholesalers from processors directly or through commission agents at the rate of 2% commission. During the discussion with stakeholders, it was found that Shakti Sudha Industry, Patna is a big player and it directly purchases 2500 tonnes (20-25%) of popped makhana annually from the production area. These popped makhanas are mixed lava without any grading. The local wholesalers grade the makhana at their godown either manually or using a grader. The higher the size of pop, the higher will be the value in the market. Makhana is transported to long distances to large mandis at Delhi, Kanpur, Varanasi, Lucknow, Allahabad, Kolkata, Amritsar, etc by the local wholesalers. For this purpose, it is packed in gunny bags of dimension 28X44 inches with thick polythene lining to protect the pop from air and moisture. This packing costs around Rs 140-150 per 10 kg of mixed pop. The quantity may differ based on the quality of pop. High-quality makhana with a large pop size can weigh only 7-8 kg while the medium and low-quality product weigh around 9-10 and 12-15 kg, respectively. It is then transported to a large wholesale market through trucks/trains or other large vehicles. Being a bulky product, it requires a lot of space for smaller quantities as compared to grains. Makhana price in a distant market is generally 60-70% higher than local market and therefore, transportation adds a significant cost to the makhana. Grading, packing, and transport cost up to the distant market are borne by local wholesalers. Wholesalers at distant markets purchase it through commission agents who charge 5% of its sale value. From distant wholesalers, retailers purchase makhana from major mandis and sell it to consumers. The retail price of makhana in distant markets is in the range of Rs 650-800 per kg depending on quality. The majority of farmers are not involved in the processing and therefore could not get the benefit of the higher retail price in distant markets. In this channel, farmers generally get 27-30% of consumer price at distant markets.

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

Under this project, per capita food consumption of different income categories of farmers was assessed in two different seasons - summer and winter in two states. Data were collected from Lodhipur, Bodhibigha of Nalanda district; Karai, Rahgunathpur Bhelura from Patna in Bihar and Dewagain, Kerkata of Namkum district of Jharkhand. Data were collected based on personal observation measurements and 24 hours recall methods. It was found that on average a household had 5-7 members. With increasing income level from less than five thousand per month to more than eight thousand per month the households consumed 47.33 g more fruits, 76 g more vegetables and 10.4 g more pulses per capita per day. The lower-income household consumed 6.9 g more cereals, 9.4 g oil fats and 7.5 g more sugar per capita per day in comparison to higher-income household member. Except for sugar, consumption of all other food categories were significantly different ($p<0.01$) among different income group households.

The difference in the food intake in two different seasons, i.e., summer and winter was studied. It was observed that the lower-income group consumed 27.32 g more fruits; 12.7 g more cereals and 12.8 g more milk per capita per day in summer than winter, however, consumption of vegetables was 37.8 g higher in winter than summer. For the middle-income group (monthly income level Rs 5000-8000 per

month), it was found that during winter, consumption of vegetables per capita per day was 50.10 g more whereas, during summer, cereals, fruits and milk were consumed 31, 10.6 and 19 g per capita per day more than winter, respectively. For the higher-income group, during winter, the per capita daily consumption of vegetables was 80 g more than the summer season. It was also found that they consumed 11 g and 8.5 g more milk and cereals per capita during summer.

Average monthly expenditure in food for the higher, middle, and low-income groups was calculated as Rs. 6718.80, 3064.70 and 1797.00, respectively. Majority of the budget on food cost was incurred towards purchase of cereal food to the tune of 35.69, 44.51 and 57.60% for higher, middle and low income families, respectively. The majority of cereals were produced in their own land of the lower and middle-income groups. On average, it saved 43.00, 37.34 and 21.34 % of food costs for the poor, middle and higher-income groups, respectively.

The Fig. 19.5a & b indicates major calorie contribution in food during winter and summer for male and female in Bihar and Jharkhand. It was found that carbohydrate was the major source of calories in all the cases. For males, protein consumption was found more in winter whereas fat consumption was lower in winter. In the case of female members of the household, both protein and fat consumption were found more in winter than summer. The reason is the availability of more vegetable and fruits for the female households during winter than summer.

From the analysis represented in the Table 19.10, it was observed that significant difference ($p<0.05$) in protein and fat consumption between male and females. It indicates that the female members of households' intakes significantly less protein and fat-based food than the male members.

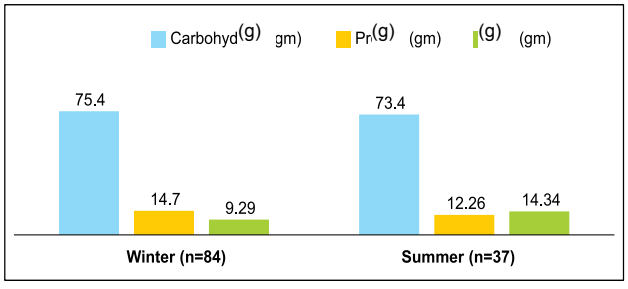


Fig. 19.5a. Major calorie contribution in food during winter and summer for male

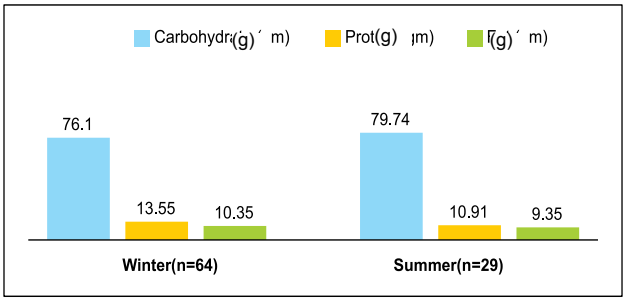


Fig. 19.5b. Major calorie contribution in food during winter and summer for female

Table 19.10. Comparison in BMI nutrient intake between male vs. female

	BMI	Energy (Kcal)	Carbohydrate (g)	Protein (g)	Fat (g)
Female (n=93)	20.57 ± 2.72	1954.55 ± 344.12	199.36 ± 28.61	32.36 ± 6.45	21.16 ± 9.95
Male (n=121)	20.83 ± 2.51	2206.52 ± 485.98	227.45 ± 46.22	39.87 ± 8.80	29.23 ±10.51
T test (p value)	0.661	0.582	0.964	0.040*	0.039*

Resource Inventorization in Flood Plain Wetlands in Eastern India

A preliminary survey was conducted in the recurrent flood-prone villages of Darbhanga and Madhubani districts (Fig. 19.6) during the post *kharif* season (November, 2020) through a semi-structured interview schedule. Information was collected on wetland location, available natural and anthropogenic resources, depth and duration of flood at the given locality, etc. Twenty five farmers were interviewed in four villages i.e., Hanumannagar in Darbhanga; Kathna Mohanpur, Raiyam & Lakshmipur in Madhubani district.

Observations showed that the Kamla Balan River is the major cause of flood every year during the last five years (2015-20). The flood comes during July and August every year and stays for 15-20 days. The depth of floodwater was found to be 1.25

Fig. 19.6. Survey of paddy field in Raiyam village, Jhanjharpur, Madhubani

to 1.5 meters. The livelihood in the rural area was dependent on agriculture, fisheries, livestock farming, and daily wages. Vermicomposting for fertilizer purposes was also a source of income. Paddy was the major *kharif* crop and PUSA 1176, CR 310, CR 311, CR 909 & Ramjanki were the major rice varieties. Twenty-eight rice varieties including some indigenous varieties were identified in the rice field of the villages in which 60-70% were aromatic rice varieties. Rice stem borer and rice gundhi bug were two major insect pests observed in the rice field. Nitrogen and zinc deficiency were also observed in the soil of rice field. HD 2967, HD 2824, HD 2733, and UP 262 were the major sown wheat varieties and Kufri Lalima & Kufri Sinduri were the major potato varieties grown in the *rabi* season. Masoor and moong bean were two pulses grown in the area. Berseem was grown as a fodder crop for cattle. Fisheries and makhana were two major aquatic resources. *Labeo rohita* (rohu), *Cirrhinus cirrhosus* (Mrigal), *Cirrhinus mrigala* (Naini), *Clarias batrachus* (Mangur), and *Anabas spp.* (Kawai) were the major fishes found in the wetland area while *Swarna Vaidehi* was the popular makhana variety in that area. Indigenous cattle, Sahiwal and buffalo were major dairy animals. Mango orchards dominated in the area. Besides, banana, jackfruit, jamun, and guava fruit trees were also available. Pumpkin, brinjal, potato, chili, and cucurbit vegetables were commonly raised. Local farmers sold paddy and wheat to both local mandi and Primary Agriculture Credit Societies (PACS). Makhana was sold locally as well as exported to the other states like Uttar Pradesh (Lucknow & Kanpur) and Delhi and fishes were sold to the local market.

Socio-economic Characterization of Farmers in Bihar and Jharkhand

Data were collected from 400 farmers from Madhubani, Supaul, Saharsa, Madhepura, Araria, Purnea, Katihar and Rohtas districts in the state of Bihar and Ranchi, Khunti, Gumla, Palamu, Chatra, Garwah and Giridih districts in the state of Jharkhand. Factor analysis was applied for identification of factors (indicators), variables (sub-indicators) and their weightage in the socio-economic status (SES) scale. A multi dimensional SES scale was developed which contained 11 factors and 30 variables for assessing SES of farmers.

Socio economic status scale for farmers of Bihar and Jharkhand was developed (Table 19.11).

Table 19.11. Socio economic status scale for farmers of Bihar and Jharkhand

S. No.	Factors (Items)	Variables (sub-items) along with weightage				
1	Land holding	Cultivable land- 0.945	Irrigated land- 0.895	Total land- 0.916	Land on lease- 0.547	
2	Health & hygiene	Healthy- 0.760	If not healthy, name of disease-0.871	Taking balance diet - 0.783	Cleaning house and nearby areas- 0.789	Use of gas cylinder in cooking-0.551
3	Family	No. of famly members employed-0.895	Family size 0.501	Invitation in the social function - 0.651		
4	Education	Years of schooling- 0.917	Class passed- 0.926			
5	Material possession	Smartphone- 0.882	Car- -0.858			
6	Housing	White washing of house- 0.684	No. of pucca house 0.715	Type of house 0.658		
7	Social participation	Member in the organization- 0.739	Post held in the organization- 0.779			
8	Personal behaviour	Relationship with neighbour- 0.657	Helping others-0.532			
9	Farming assets	No. of tractor- 0.706	Available sources of irrigation- .676	No. of ox- 0.512		
10	Livestock	Cattle shed- 0.677	No. of livestock- 0.480			
11	Income source	Name of business- 0.726	Duration of business- 0.599			

(This scale will be subjected to reliability and validity test. If required, suitable modification will be made in the scale before use for assessing SES of farmers).

DBT Biotech KISAN Hub Project for Seven Aspirational districts of Jharkhand and Bihar

Enhancing food, nutritional and livelihood security of marginal and small farmers in Jharkhand through need based agricultural technologies is the maintain of the project.

The project is being implemented in collaboration with KAUSHALYA Foundation in East Singhbhum, Khunti, Ramgarh and Bokaro districts of Jharkhand and Nawada, Sheikhoura and Jamui districts of Bihar with the objective to scale up the production of high value horticultural crops for ensuring livelihood security of small and marginal farmers. Baseline survey of farmers at the time of project initiation indicated higher overall productivity of vegetables as well as net profitability of vegetable cultivation in all the three districts in Bihar over the districts of Jharkhand. During the rainy and summer season, the highest net income from vegetable cultivation was reported by farmers from Sheikhpura district (Rs 1.33 lakh and Rs 1.25 lakh per ha, respectively) while during the *rabi*, it was highest in case of Jamui district (Rs 2.0 lakh per ha) (Fig. 19.7).

During the year 2020, technology demonstration was undertaken covering a total area of 42.47 ha and 648 numbers of animals. The details of performance of different technologies are mentioned in Table 19.12. The activities undertaken under the project had resulted in total additional net income of Rs 42.53 lakh to the farmers in the adopted villages.

During the first year of the project i.e. 2020-21, technology demonstration on cultivation of high value vegetables *viz.* sweet corn (variety NSC 901 B), broccoli (variety NSC 105 B), capsicum (variety NSC 619 B), pencil bean (Falguni), carrot (variety Klose), fruits crops like strawberry (variety Winter Dawn), papaya (variety Red Glory), off season cultivation of tomato, cauliflower and oyster mushroom was undertaken in 1373 number of farmers' fields covering a total area of 16.15 ha. Although, the adoption rate of the new crops was low during the first year of the project, the net income per ha from most of the vegetables were higher than that obtained by the farmers from the traditional vegetables. Among the different vegetables, the maximum net income was obtained in case of early cauliflower (Rs 4.70 lakh per ha) followed by broccoli (Rs 4.64 lakh per ha) (Table 19.13). The benefit : cost ratio of different crop ranged from 1.38 in mushroom to 10.22 in early cauliflower. However, estimation of net income per month of crop duration indicated highest value in case of broccoli (Rs 1.99 lakh per ha per month of crop duration). Among all the technological options, mushroom cultivation was found to be most profitable keeping in view the less land requirement. The activities undertaken during the first year of the project resulted in generation of additional profit of Rs 41.23 lakh among the farmers along with 2278 number of additional man-days in the adopted villages.

Table 19.12. Seasonwise productivity and net income from vegetable cultivation in farmers' fields at the beginning of the project

Districts	Rainy season vegetables		Rabi vegetables		Summer season vegetables	
	Productivity (t/ha)	Net income per ha (Rs in lakh)	Productivity (t/ha)	Net income per ha (Rs in lakh)	Productivity (t/ha)	Net income per ha (Rs in lakh)
East Singhbhum	6.31	0.21	6.31	0.56	17.63	1.24
Khunti	4.61	0.43	6.83	0.78	4.83	0.63
Ramgarh	5.32	0.60	3.43	0.62	3.01	0.46
Okaro	4.29	0.56	4.48	0.59	3.00	0.37
Nawada	4.39	1.08	12.37	1.29	6.31	0.92
Sheikhpura	5.78	1.33	13.90	1.60	13.64	1.25
Jamui	8.71	1.19	14.21	2.00	6.25	0.82

Bitter gourd variety Swarna Yamini

Tomato variety Swarna Sampada

Wheat variety HD 2967 in rice fallow

Fig. 19.7. Technology demonstrations in farmers' fields in adopted villages

Table 19.13. Productivity and income from different high value vegetables in adopted villages of seven aspirational districts of Jharkhand and Bihar

Crops	No. of farmers	Total area (ha)	Productivity (t/ha)	Quantity consumed by family (t)	Income from sale of produce (Rs in lakh)	Gross income (Rs/ha)	Net income (Rs in lakh/ ha)	Net income (Rs in lakh/ha) per month of crop duration	B:C ratio
Sweet corn	90	2.04	8.98	3.64	2.20	1.43	1.26	0.54	8.43
Broccoli	190	3.63	33.40	17.88	16.08	5.52	4.64	1.99	6.27
Rainy season tomato	55	0.92	5.11	0.44	1.85	2.15	1.54	0.38	3.52
Pencil bean	165	3.18	5.19	3.50	3.03	1.39	0.77	0.26	2.25
Carrot	413	1.55	27.99	0.08	6.24	4.51	4.06	1.62	10.02
Oyster mush-room	231	2.21 (tonnes of spawn)	78.8% (Biological efficiency)	2.04	3.89	27.68	16.61	11.07	1.38
Early cauli-flower	76	1.65	23.81	1.57	8.27	5.21	4.70	1.57	10.22

Establishment of Biotech-KISAN Hub at ICAR- Research Complex for Eastern Region, Patna

The project is being implemented in collaboration with Divyayan KVK, Ranchi and Holy Cross, Hazaribagh in Ranchi, Ramgarh and Hazaribagh districts of Jharkhand with the objective to demonstrate and scale-up the climate resilient and profitable technologies for small and marginal landholders of eastern plateau and hill region. The different activities being under taken under the project include 1. Development of climate resilient farming system models (Location: Ranchi and Ramgarh districts), 2. Demonstration of round the year mushroom cultivation (Location: Ranchi district), 3. Improvement of traditional pig farming through technological interventions (Location: Hazaribagh district), 4. Income generation through goat farming for resource poor farmers (Ranchi district).

Activity-1: Development of climate resilient farming system models

Based on survey in 99 numbers of farmers' fields from 3 villages near Ranchi, 12 numbers of predominant prevailing farming systems were identified. Among the different systems, Field crops + Horticulture + Goatry + Backyard Poultry was found to be the most prominent farming system of the villages (20.2% of farm family). The total agricultural income per ha of land holding was highest in the farming systems, Field crops + Horticulture + Dairy + Goatry + Backyard poultry (Rs 1.3 lakh per ha). During the first year, technological interventions were made for improving the productivity of existing farming systems. The different technological interventions included 1. Introduction of improved varieties of ragi, vegetable crops, pulses and oilseeds 2. Increasing the utilization of lac host plants, 3. Improved fruit production techniques, 4. Increasing the animal productivity through ecto-and endo- parasite control, supplementation of area specific mineral mixture, introduction of Black Bengal breed of buck and vaccination of goat against PPR, 5. Appropriate stocking density and feed management in pond, 6. Recycling of farm residue through mushroom cultivation and vermicomposting. After one year of technological intervention on participatory integrated farming system in 99 numbers of farmers fields in four project villages, the additional area of 78.32 ha was brought under cultivation out of which the additional area brought under pulses were 2.74 ha and under vegetables were 59.38 ha (Fig. 19.8). In fruits an additional area of 11.75 ha was brought under technology demonstration. Due to the technology demonstration, average agricultural income of the family increased from Rs 1.7 lakh to Rs 2.4 lakh whereas the average per ha income increased from Rs 0.80 lakh per ha to Rs 1.23 lakh per ha (Fig. 19.9). The maximum agricultural income of Rs 1.8 lakh was recorded in case of other group of farming systems followed by Rs 1.7 lakh in case of Field crops+ Horticulture+ Dairy+ Goat + Backyard poultry. The activity has also resulted in an additional agricultural income of Rs 77.7 lakh to the farmers. Apart from this the intervention resulted in generation of 4031 number of additional mandays in the project villages.

Cultivation of wheat in rice fallow area

Black gram variety PU 31

Cultivation of Niger variety Birsa Niger-2

Cultivation sponge gourd variety Swarna Prabha

High density orcharding in banana

Recycling of farm residue through vermicomposting

Fig. 19.8. Technology demonstrations in farmers' fields in Ranchi

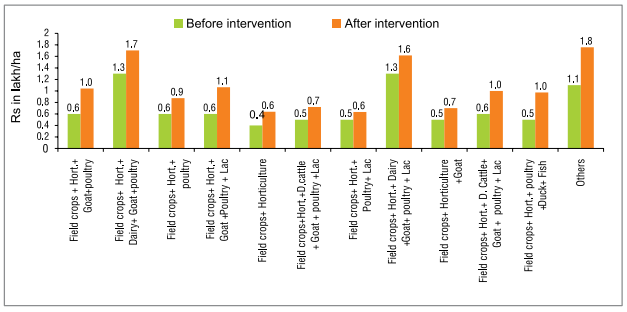


Fig. 19.9. Effect of technological intervention on total income of farming systems (Rs in lakh/ha) (N=99)

Activity 2: Demonstration of round the year mushroom cultivation

For technology demonstration on round the year cultivation of mushroom, three training programmes of one day duration were conducted in which a total of 100 farm women were provided training on mushroom cultivation and technology demonstration on oyster mushroom cultivation has been done in 57 farmers' fields during the 1st year of the project. During this period, the total quantity of mushroom production of 57 farmers was 3081 kg and the total income from mushroom cultivation was Rs. 396720/-. The activity has resulted in generation of 61.6 additional mandays in the project villages. Encouraged by the success of mushroom cultivation with the limited number of farmers during the first year, after September, 2020, more than 70 farmers have already sown mushroom spawn in bags. The number of farmers is increasing day by day. The mushroom growers of Sarwal village have constituted a farmers group named *Sarwal Ajeevika Mahila Mushroom Utpadak Sangh* for cluster based production of oyster mushroom (Fig. 19.10).

Smt Anshu Munda, Village-Sarwal

Branding of Oyster mushroom produced by Sarwal Ajeevika Mahila Mushroom Utpadak Sangh

Fig. 19.10. Mushroom cultivation in farmers' fields

Activity 3: Improvement of traditional pig farming through technological interventions

Technology demonstration of TXD (Birsa Jharsuk) breed of pigs was laid out in six farmers fields in Hazaribagh district. In a period of 4 months, the average body weight of the pigs (30 numbers) increased from 15.6 kg to 35.8 kg. In monetary terms, the total monetary profit by the six farmers in a period of four months was estimated to be Rs 60,000/-. This intervention and training raised their self-confidence and farmers started purchasing more pigs by their own resources. Every beneficiary started increasing the number of female pigs in their units and gradually adopted scientific methods of pig rearing.

Activity 4: Income generation through goat farming for resource poor farmers

Technology demonstration on improved goat farming including improved breed, feeding and housing management, health management, vaccination etc was done in 25 farmers fields in Ranchi. The farmers were trained for feeding and housing management of goats along with health management, vaccination etc. Field assistant who is appointed under this project has been given responsibility for maintaining the vaccination and de-worming schedule of goats. Each farmer was also provided 5 improved goats of Black Bengal breed. All beneficiaries started managing their farms scientifically, which decreased the morbidity and mortality percentage of goats. Every beneficiary started increasing no. of female goats in their units and gradually adopted scientific methods of goat rearing and increased the number of goats to 15 to 20 per unit. The average income of farmers from Goatery was Rs. 10,000/- to Rs. 12,000/- per month. This enterprise is proved to be more fruitful to the farmers during COVID – 19 pandemic in comparison to other agricultural enterprises which resulted in high employment generation to the migrant laborers also.

Improving livelihood of Small and Marginal Farmers through Collective Farming

With the introduction of the collective farming, there had been remarkable changes in the perceptions of small and marginal farmers about the dry season farming. The groups collectively operated and maintained their solar pump sets and shared them among group members in turns. These groups identified a key person for the purchase and marketing of agricultural inputs and produce which reduced the transportation cost to great extent. With the adoption of collective farming, farmers started cultivating contiguous plot of land rather than cultivating each plot individually.

NASF Project on "Development and validation of need based technology delivery model through Farmer Producer Organization for eastern region of India"

Development and Validation of Need-Based Technology Delivery Model through Farmers' Producer Organization for Eastern Region of India

The project, funded by ICAR-NASF, was awarded to ICAR-RCER as a lead center and three other centers ICAR- Research Complex for Eastern Region, Research Center, Ranchi, Jharkhand; ICAR-Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, and Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal as cooperating centers.

- Frontline Demonstration of Pusa Sugandha 5 (Basmati type) was conducted in 16.5 acres by 46 FPO farmers and 10 Acres by 5 Non FPO farmers (as contol group) in in East Champaran.
- Breeder seed production of Swarna Shreya was conducted through FLD Mode. In this programme 12 FPO farmers participated and produced foundation seed in 3 acres. As control group 5 Non FPO farmers were also participated and produced foundation seed in 1 acres in East Champaran.

ICAR Research Complex for Eastern Region, Farming System Research for Hill and Plateau Region, Plandu, Ranchi developed one Farmer Producer Organization (FPO) named "Greenery Agrotech Producer Company Limited, Ranchi (Corporate identity number is U01100JH2020PTC015360)". This FPO was registered on 19th October, 2020 and office is located at Malti village of Itki block in Ranchi district of Jharkhand.

Activities of FPOs

1. Increasing members of FPO in cluster approach: Three clusters of 15 acres each in Itki block have been identified and all farmers of these clusters became members of FPO. Farmers would take up production of high value crops in cluster.

2. Establishment of Oyster mushroom spawn production unit: Women farmers group of FPO would take up Oyster mushroom spawn as well as Oyster mushroom production in Malti village of Itki block.

3. Raising seedlings of mango and guava: Root-stocks of mango and guava are being raised in the FPO. It will be supplied to different nurseries.
4. Development of Business Plan: It is the blue print of business activities of FPO. It is being developed.
5. Training programmes and demonstrations of technologies were carried out in two selected FPOs and two control farmer groups under the project (Table 19.14).

Consultancy, Patents and Commercialization of Technology

National Agricultural Innovation Fund (NAIF)

Plant variety registration

- Plant variety registration certificate received for Swarna Safal (Faba bean) from PPV&FRA, New Delhi: REG/2018/597.
- Plant variety registration certificate received for Swarna Tripti (Snow pea) from PPV&FRA, New Delhi: REG/2016/942.
- Plant variety registration certificate received for Swarna Vasundhara (Vegetable soybean) from PPV&FRA, New Delhi: REG/2017/1389.
- Acknowledgement received for Swarna Raktim (Leaf Amaranthus) from PPV&FRA, New Delhi: REG/2020/365.
- Annual maintenance of 14 Plant varieties under PPV&FRA.

MoU

- MoU signed with M/s Rhizosphere, Ranchi on 10.11.2020 for large scale seed production of open pollinated varieties and lines of 21 vegetable crops.
- MoU signed with M/s Maitri Foundation, Ranchi on 17.121.2020 for the technique and expertise in grafting tomato with bacterial wilt resistant root stock of brinjal.

Material Transfer Agreement (MTA)

- One MTA signed with Ram Babu Sharma, Ph.D. Scholar, Department of Plant Pathology, SHUATS, Prayagraj, UP, for tomato germplasm on on 22.10.2020.

Agri-Business Incubators Project

During the first year of the project, seven number of webinars on different topics related to agri-entrepreneurship were conducted the details of which is given in Table 19.15.

Table 19.14. Transfer of technologies and observations in selected FPOs and farmers groups

Particulars	FPC (Greenery Agrotech Producer Company Limited)	FPC (Devgain-Kerketta)	Group I (Hahap village)	Group II (Kochbang)
Orientation training organized	76 farmers attended on 21/10/2020	39 farmers attended on 01/06/2020	38 farmers attended on 25/06/2020	22 farmers attended on 27/06/2020
Input distributed in demonstration of technologies	Grafted tomato-100 Pencil bean-130 kg Parwal-1200 vine	*Bemausami Sem*, Basmati Soyabean, Green Amaranth, LRG-41 & IPA-203- varieties of Arhar-37 kg; WBU-109 & PU-31 varieties of Urd-35 kg; VL-352 & BM-3 varieties of Ragi-16.5 kg; Rhizobium pkt-25; Grafted tomato-1000; Parwal-900 vine, Brood lac-10 kg	Bemausami Sem, Basmati Soyabean, Green Amaranth LRG-41 & IPA-203 varieties of Arhar-30 kg; WBU-109 & PU-31 varieties of Urd-54 kg; VL-352 & BM-3 varieties of Ragi-3 kg; Rhizobium pkt-20; Grafted tomato-300; Parwal-700 vine	Bemausami Sem, Basmati Soyabean, Green Amaranth LRG-41 & IPA-203 varieties of Arhar-4.5 kg; WBU-109 & PU-31 varieties of Urd-20 kg; VL-352 & BM-3 varieties of Ragi- 5 kg; Rhizobium pkt-8; Grafted tomato-100; Parwal-300 vine
Leadership observed	Shyamdhani Kumar	Shivcharan Kachchap	Lack of effective leadership	Karmu Munda
Farming methods adopted Market driven farming Improved farming			Traditional farming	Traditional farming

Table 19.15. Webinars conducted under the ABI project

Name of programme (training/workshop/seminar etc.) organized	Date of programme	Participants (No)
Webinar on "Essentials of entrepreneurship"	27th May, 2020	86
Webinar on "Entrepreneurship opportunity in horticultural nursery"	21st July, 2020	110
Webinar on "Market linkages for agri-entrepreneurs"	24th July, 2020	101
Webinar on "Entrepreneurship opportunity in mushroom production"	11th August, 2020	395
Webinar on "Entreprenuership opportunities in seed sector"	17th August, 2020	85
Webinar on "Achieving Agrarian Prosperity through Agri-Entrepreneurship"	21st August, 2020	65
Webinar on "Entrepreneurship in Agricultural Extension: Success Story of MASS"	3rd September, 2020	62

Apart from this, two numbers of entrepreneurs have been registered as Incubatees under the project the details of which are given in Table 19.16.

Table 19.16. Details of incubatees registered under the ABI project

Name of technology	Name of incubatee	Date of signing of MoA
Seed production of vegetable varieties released by ICAR RCER	Mr. Vijay Bharat, Hotwar, Ranchi	10/11/20
Nursery production in polyhouse	Dr. Alok Kumar Bihta, Patna	07/11/20

Linkages

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

International Collaborations

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

National Collaborations

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

20. Trainings and Capacity Building

Following employees of the Institute have undergone training during 2020

Table 20.1. List of employees undergone training

Category	Total no. of employees	No. of trainings planned for each category during 2020-21 as per ATP	Total No. of employees undergone training during January to December 2020	% Realization of trainings planned during 2020-21
Scientist	70	6	15	100.00
Technical	53	4	2	50.00
Administrative & Finance	21	6	2	33.33
SSS	43	1	0	0
Total	187	17	19	-

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

Table 20.2. HRD fund allocation and utilization (Rs. in Lakh)

S. No.	BE 2020-21 for HRD	Actual expenditure up to December, 2020	% Utilization
1	3.51	3.51	100.00

Sponsored Training Programmes

- Training programme on '**Hi-tech management practices in horticultural crops**', sponsored by SEWA, Ranchi, organized at ICAR-RCER, FSRCHPR, Ranchi during 2-4th January, 2020.
- Training programme on '**Recent advances in management practices in horticultural crops**', sponsored by ICAR-IINRG, Namkum, organized at ICAR-RCER, FSRCHPR, Ranchi during 2-4th January, 2020.
- Training programme on '**Recent advances in management practices in horticultural crops**', sponsored by ICAR-IINRG, Namkum, organized at ICAR-RCER, FSRCHPR, Ranchi during 6-10th January, 2020.
- Training programme on '**Recent advances in management practices in horticultural crops**', sponsored by ICAR-IINRG, Namkum, organized at ICAR-RCER, FSRCHPR, Ranchi during 13-17th January, 2020.
- Training programme on '**Recent advances in management practices in horticultural crops**', sponsored by ICAR-IINRG, Namkum, organized at ICAR-RCER, FSRCHPR, Ranchi during 20-24th January, 2020.
- Training programme on '**Recent advances in management practices in horticultural crops**', sponsored by ICAR-IINRG, Namkum, organized at ICAR-RCER, FSRCHPR, Ranchi during 27-31th January, 2020.
- Training programme on '**Techniques and management practices of scientific mushroom cultivation**', sponsored by ATMA, Lohardaga, organized at ICAR-RCER, FSRCHPR, Ranchi during 03-07th February, 2020.
- Training programme on '**Recent advances in management practices in horticultural crops**', sponsored by ATMA, Lohardaga, organized at ICAR-RCER, FSRCHPR, Ranchi during 10-14th February, 2020.
- Training programme on '**Recent advances in management practices in horticultural crops**', sponsored by ATMA, Lohardaga, organized at ICAR-RCER, FSRCHPR, Ranchi during 17-21th February, 2020.
- Training programme on '**Fruit based crop production system establishment and management**', sponsored by AICRP on fruit crops, organized at ICAR-RCER, FSRCHPR, Ranchi during 05-07th March, 2020.
- Training programme on '**Management practices of scientific vegetable cultivation**', sponsored by GBT, Madhubani (Bihar), organized at ICAR-RCER, FSRCHPR, Ranchi during 12-14th March, 2020.
- Training programme on '**Doubling the farmer's income through conservation agriculture techniques**', sponsored by CRP on CA, organized at ICAR-RCER, FSRCHPR, Ranchi during 16-18th March, 2020.

- Training programme on '**Integrated Farming Systems**', sponsored under ATMA, Purnea, organized at ICAR-RCER, Patna during 11-15th February, 2020.
- Training programme on '**Agronomic Management of Rabi crops with special reference to farming system approach**', sponsored by DCRFSMLI Project, organized at ICAR-RCER, Patna during 22-25th December, 2020.
- Training programme on '**Management of rabi crops through climate resilient farming practices',** sponsored by Climate resilient agricultural program (CRAP) project at ICAR-RCER, Patna during 22-23rd December, 2020.
- Training programme on '**Krishi utpadkata badhane hetu jalwayu anukil krishi kriyayen**', sponsored by CRAP project, organized at ICAR-RCER, Patna during 28-30th January, 2020.
- Training programme on '**Backyard poultry rearing**', sponsored by DCRFSMLI project, organized at Chandrahiya, Motihari, East Champaran on 7th December, 2020.
- Training programme on '**Integrated fish farming and management**', sponsored by DCRFSMLI project, organized at ICAR-MGIFRI, Piprakothi, East Champaran during 28-30th September 2020.
- Training programme on '**Scientific method of paddy cultivation**', sponsored by DCRFSMLI project, organized at ICAR-MGIFRI, Piprakothi, East Champaran during 17-20th June, 2020.

Trainings Attended by the Employees during 2020

- Abhishek Kumar Dubey, Scientist. Online training program on Basic Statistical Tool in Agriculture at ICAR RCER, Patna during 24-26th September, 2020.
- Arun Kumar Singh, Pr. Scientist. Virtual workshop-cum-training on Intellectual Property Rights in Agricultural Research & Education in India during 12-28th September, 2020.
- Bikash Das, Pr. Scientist. Virtual workshop-cum-training on Intellectual Property Rights in Agricultural Research & Education in India during 12-28th September, 2020.
- Govind Makarana, Scientist. Professional attachment training at ICAR-CSSRI, Karnal during 31st August – 28th November, 2020.
- Santosh Kumar, Senior Scientist. Online training programme on Basic Statistical Tools in Agriculture at ICAR RCER on 24-26th September, 2020.
- Kumari Shubha, Scientist. Online training program on Basic Statistical Tool in Agriculture held at ICAR RCER, on 24-26th September, 2020.
- Mahesh Kumar Dhakar, Scientist. Online training programme on Summer school GROW 2020 - Agrobiodiversity in a Changing Climate organized by Sapienza University, Rome in collaboration with Bioversity International, FAO and Mountain Partnership during 15- 25th September, 2020.
- Manisha Tamta, Scientist. Online training programme on Basic Statistical Tools in Agriculture at ICAR RCER, on 24-26th September, 2020.
- Manisha Tamta, Scientist. Training programme on Climate Change: Challenges and Response held at Centre for Disaster Management, LBSNAA, Mussoorie from 10-14th February, 2020.
- Mridusmita Debnath, Scientist. Online training programme on Basic Statistical Tools in Agriculture at ICAR RCER on 24-26th September, 2020.
- Mridusmita Debnath, Scientist. Online training programme on Climate Change: Challenges and Response(CCCR) organized by The Centre for Disaster Management, LBSNNA, Mussoori in collaboration with DST during 14-18th December, 2020.
- Nongmaithem Raju Singh, Scientist. Online training programme on Basic Statistical Tools in Agriculture at ICAR RCER, on 24-26th September, 2020.
- P. Bhavana, Sr. Scientist. Online International training on Recent Physio-molecular Digital Tools in Abiotic Stress Management for Crop Modelling held at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharastra during 29th June- 3rd July, 2020.
- P. Bhavana, Sr. Scientist. Online training programme on Basic Statistical Tools in Agriculture at ICAR RCER on 24-26th September, 2020.
- P. Bhavana, Sr. Scientist. Virtual workshop-cum-training on Intellectual Property Rights in Agricultural Research & Education in India during 12-28th September, 2020.
- Pradip Kumar Sarkar, Scientist. Online training programme on Basic Statistical Tools in Agriculture at ICAR RCER on 24-26 September, 2020.
- Reshma Shinde, Scientist. Online training programme on Basic Statistical Tools in Agriculture at ICAR RCER on 24-26th September, 2020.
- Saurabh Kumar, Scientist. Professional attachment training at ICAR-NBAIM during 7th September - 7th December, 2020.

- Shivani, Pr. Scientist. Online training programme on Climate Change: Challenges and Response(CCCR) organized by The Centre for Disaster Management, LBSNNA, Mussoori in collaboration with DST from 5-9th October, 2020.
- Singh N Raju, Scientist. Online training programme on Basic Statistical Tools in Agriculture at ICAR RCER on 24-26th September, 2020.
- Virendra Kumar Yadav, Pr. Scientist. MDP on Business Plan Development and Accelerating FPOs/FPCs held ICAR-NAARM, Hyderabad from 14-19 December, 2020.

Participation in Conferences/Seminars/ Workshops/Symposia/Meetings

Ahmed Akram and Manibhushan. 2020. Webinar on Drone Remote Sensing in Agriculture organized by Indian Society of Agrophysics, New Delhi on 9th September, 2020.

Ahmed Akram, Debnath M, Jeet Pawan. 2020. Webinar on Hydroinformatics for Smart Water Management in Agriculture jointly organized by CAE, RPCAU, Pusa, IIT Roorkee and ICAR-IARI, New Delhi on 20th October, 2020.

Barari S.K. 2020. Virtual international conference on New Generation Vaccines and Animal Disease Control Strategies – Roadmap for Enhancement of Animal and Human Heath' jointly organized by Department of Veterinary Microbiology, Veterinary College and Research Institute, Orathanadu, Thanjavur and Department of Veterinary Microbiology, College of Veterinary and Animal Sciences, Pookode, Kerala during 2-4th December, 2020.

Bhavana P, Chakrabarti A, Yadav VK, Shinde R, Singh AK. 2020. Webinar on Entrepreneurship in Agricultural Extension: Success Story of MASS organized by ICAR RCER FSRCHPR, Ranchi on 3rd September, 2020.

Bhavana P, Singh AK. 2020. Webinar on Entrepreneurship Opportunities in Seed Production organized by FSRCHPR, ICAR RCER, Ranchi on 17th August, 2020.

Bhavana P. 2020. International webinar on Pulses to Keep Soil Alive and Protect Biodiversity organized by Acharya N.G. Ranga Agricultural University, Lam, Guntur, A.P. on 4th December, 2020.

Bhavana P. 2020. National webinar on Recent Biotechnological Tools for Crop Improvement jointly organized by NAHEP (ICAR), and Acharya N.G. Ranga Agricultural University, Lam, Guntur on 24th June, 2020.

Bhavana P. 2020. National webinar on Seed Industry-Quality Production and Viable Agriculture jointly organized by NAHEP (ICAR) and Acharya N.G. Ranga Agricultural University, Lam, Guntur during 22-23rd September, 2020.

Bhavana P. 2020. Webinar on Achieving Agrarian Prosperity through Agri-Entrepreneurship organized by FSRCHPR, ICAR RCER, Ranchi on 21th August, 2020.

Bhavana P. 2020. Webinar on Formation and Effective Functioning of Farmers Producer Organization organized by ICAR-NASF Project, ICAR RCER, Patna on 18th August, 2020.

Bhavana P. 2020. Webinar on Future Perspectives in Agricultural Education organized by NAHEP (ICAR), New Delhi on 5th September, 2020.

Bhavana P. 2020. Webinar series on Solve a Puzzle in Agriculture Towards the Future through Innovation and Patents jointly organized by European Business and Technology Centre and Intellectual Property Facilitation Cell (IPFC), AIP- ICRISAT on 10th November, 2020.

Bhavana P. 2020. Webinar series: Knowledge Sessions on Plant Varieties Part I: Legal framework for Protection of Plant Varieties in India: Challenges and Opportunities jointly organized by European Business and Technology Centre and Intellectual Property Facilitation Cell (IPFC), AIP - ICRISAT on 26th August, 2020.

Bhavana P. 2020. Webinar series: Knowledge Sessions on Plant Varieties Part II: Protection of Plant varieties in India: Legal framework & Procedures" jointly organized by European Business and Technology Centre and Intellectual Property Facilitation Cell (IPFC), AIP – ICRISAT on 30th October, 2020.

Chakrabarti A, Mali SS, Shinde R. 2020. Online national workshop on Modern Interventions in Environmental Management organized by ICAR-IIAB, Ranchi on 28th November, 2020.

Chakrabarti A. 2020. International web conference on Climate Smart Agriculture for Sustainable Food and Nutritional Security jointly organized by Beni Singh College, Chenari, Rothas, Bihar and Society for Upliftment of Rural Economy, Varanasi, Uttar Pradesh from 10-11th July, 2020.

Chakrabarti A. 2020. Online international seminar on Challenges and Opportunities in Agriculture and Environment in the Scenario of COVID-19 Pandemic organized by the Udyaniki Krishi Anushandhan Samiti, Lucknow, Uttar Pradesh on 23rd November, 2020.

Chakrabarti A. 2020. Online national symposium on Veterinary Research Priorities in Transitional Animal Health, Production and Food Safety jointly organized by Tamil Nadu Veterinary & Animal Sciences University, Chennai & Indian Association for the Advancement of Veterinary Research during 21- 22th February, 2020.

Chaudhary AK 2020. International conference on Pulses as the Climate Smart Crops: Challenges and Opportunities, organized by the Indian Society of Pulses Research and Development at Bhopal during 10-12th February, 2020.

Chaudhary AK 2020. International web conference on Global Research Initiatives for Sustainable Agriculture and Allied Sciences (GRISAAS-2020), 28-30th December, 2020.

Chaudhary AK 2020. International webinar on Woman in Science and their Role in Sculpting Modern Agriculture on 26th August, 2020.

Chaudhary AK 2020. National seminar on Climate Smart Agriculture for Sustainable Food and Nutritional Security (CSASFNS-2020)", 10-11th July, 2020.

Chaudhary AK 2020. National webinar on Pulses for Human Health and Nutrition, organized by IIPR, Kanpur on 28th September, 2020.

Choudhary JS. 2020. National conference on Agricultural resource management for Atmanirbhar Bharat, organized by CAU, Imphal during 17-19th July, 2020.

Choudhary JS. 2020. National webinar on Transboundary Pests –Threats to Bio-Security and Bio-Safety issues, organized by Department of Entomology, S.V. Agricultural College, Tirupati, ANGRAU on 21st December 2020.

Choudhary JS. 2020. Technical webinar on Integrated Pest Management for Maize Crop with special reference to fall armyworm, organized by ICAR-Indian Institute of maize Research (IIMR), Ludhiana on 9th October, 2020.

Choudhary JS. 2020. Webinar on A session on accessing Taylor & Francis journals, organized by Taylor & Francis on 15th September, 2020.

Choudhary JS. 2020. Webinar on Integrated Insect Pests and Nematodes Management in Banana, organized by ICAR-NRCB, Tiruchirappalli on 4th August, 2020.

Das B, Yadav VK and Mali SS. 2020. Online orientation workshop and training programmes for ABI units, organized by ICAR-NAARM, Hyderabad from 17-19th August, 2020.

Debnath M. 2020. International workshop on Application of Remote Sensing and GIS for Water, Environment, Land and Society during 1-3 December, 2020.

Debnath M. 2020. Webinar on Jan Andolan for COVID-19 Appropriate Behaviour, organized by National Institute for Disaster Management on 01st December, 2020.

Debnath M. 2020. Webinar on Sustaining the Water Tower of Asia: Rivers, Communities, Livelihood and Challenges, organized by Asian Confluence on 22th August, 2020.

Debnath M. 2020. Webinar on Vulnerabilities of Wetlands and its Impact on Climate Change, organized by Centre for Environment, Energy and Climate Change, Asian Development Research Institute on 04th December 2020.

Dhakar MK and Das B. 2020. 7th Group Discussion of AICRP on Fruits held at PAU, Ludhiana (Punjab) during 16-19th January, 2020.

Dhakar, M.K. National e-conference on Empowering Tribal Women: Entrepreneurship & Skill Development, a way towards Atmanirbhar Bharat, organized by Jharkhand Rai University, Ranchi on 5th December, 2020.

Dubey AK. 2020. International conference on Phytopathology in Achieving UN Sustainable Goal, organized by Indian Phytopathological Society, New Delhi during 16-20th January, 2020.

Dubey AK. 2020. International e-conference on Multidisciplinary Approaches for Plant Disease Management for Achieving Sustainability in Agriculture, organized by Department of Plant Pathology, College of Horticulture, Bengaluru from 6-9th October, 2020.

Dubey, R. 2020. International web conference on Global Research Initiatives for Sustainable Agriculture and Allied Sciences (GRISAAS-2020) during 28-30th December, 2020.

Dubey, R. 2020. International webinar on Soil Spectroscopy: An Emerging Technique for Rapid Soil Health Assessment, jointly organized by ICAR-Indian Institute of Soil Science, Bhopal & World Agroforestry (ICRAF), Nairobi on 01st October 2020.

Dubey, R. 2020. Webinar on Genomics Strategies for Improvement of Abiotic Stress Tolerance in Crop Plants, organized by ICAR-National Institute of Abiotic Stress Management, Baramati on 27th November, 2020.

Dubey, R. 2020. Workshop on Creating Data Ecosystem, organised by International Agricultural Research Centers (CIMMYT, IRRI and IFPRI and National Agricultural Research System (NARS) at Patliputra, Patna.

Govind Hari. 2020. International conference on Pulses as the Climate Smart Crops : Challenges and Opportunities (ICPulse2020), jointly organized by Indian Society of Pulses Research and Development (ISPRD), ICAR-Indian Institute of Pulses Research (IIPR), Kanpur in collaboration with Indian Council of Agricultural Research (ICAR), New Delhi at Bhopal, Madhya Pradesh, India during 10-12th February, 2020.

Jeet P. 2020. 10th meeting of Core Group on Benchmarking of Irrigation Systems in India held at CWC, Sewa Bhawan, New Delhi on 30th January, 2020.

Jeet P. 2020. 19th Water talk on Conserving ecology & biodiversity and securing livelihood through rainwater harvesting, organized by National Water Mission, Ministry of Jal Shakti, DWR, RD & GR, GoI. on 20th November, 2020.

Jeet P. 2020. e-Learning training course on Urban Water Management, organized by Water Digest, Gurgaon, Haryana during 8-9th October, 2020.

Jeet P. 2020. International webinar on Impact of Water Stress on Crop Productivity: Its Mitigation and Adaptation Strategies, jointly organized by NAHEP & Centre of Excellence on Water Management, RPCAU, Pusa during 24-26th November, 2020.

Jeet P. 2020. International webinar on Omics in Agriculture, jointly organized by NAHEP & College of Basic Sciences & Humanities, RPCAU, Pusa during 7-9th October, 2020.

Jeet P. 2020. National webinar on Designing Fire Protection System Hydraulics using AFT Fathom, organized by Image Grandfix Software on 16th September, 2020.

Jeet P. 2020. National webinar on Explore Possibilities to Optimize Water Treatment with Reverse Osmosis, organized by Water Digest on 6th November, 2020.

Jeet P. 2020. National webinar on How Flow Analysis Helps to Focus on Reliability, Efficiency and Associated Cost for Piping Systems, organized by Image Grandfix Software on 4th September, 2020.

Jeet P. 2020. National webinar on How to utilized Automated Network Sizing (ANS) Module to optimize Pipe Sizes, organized by Image Grafix Software on 14th October, 2020.

Koley TK. 2020. International web conference on Biodiversity in Vegetable Crops for Healthier Life and Livelihood, organized by Bihar Agricultural University, Sabour, Bhagalpur held on 27-28th August, 2020.

Kumar Jyoti. 2020. E-workshop on Financing And Facilitating Credit Facility To MSME Sector, organized by Bihar Chapter of PHD Chamber of Commerce & Industry on 1st October, 2020.

Kumar Jyoti. 2020. National webinar on AMR Mitigation for Food Safety - One Health, organized by Ayurvet Research Foundation, Department of Animal Husbandry and Dairying, Government of India and SVPUAT, Meerut on 30th October, 2020.

Kumar Jyoti. 2020. National webinar on Climate Resilient Livestock Production: Opportunities and Threats, organized by ICAR-NIASM on 3rd November, 2020.

Kumar Jyoti. 2020. Webinar on Microbiome, Immunity and Vaccines, organized by Indian Association of Veterinary Microbiologists, Immunologists & Specialists in Infectious Diseases (IAVMI) on 30th August, 2020.

Kumar Jyoti. 2020. Webinar on Post Pandemic Challenges and Opportunities in Animal Health, organized by College of Veterinary & Animal Sciences, Meerut, Uttar Pradesh on 14th August, 2020.

Kumar Pankaj. 2020. International conference on Insights into Wildlife Conflicts, Rescue and Rehabilitation: Challenges and Opportunities for Conservation and 14th Annual Convention of Association of Indian Zoo and Wildlife Veterinarians, organized by Wildlife Research & Training Centre, Gorewada Rescue centre, Nagpur & Association of Indian Zoos & Wildlife Veterinarians, Nagpur held during 18-20th December, 2020.

Kumar Pankaj. 2020. Online national seminar on Big Data Analytics in Agriculture, organized by ICAR-NAARM, Hyderabad during 10-11th December, 2020.

Kumar Sanjeev. 2020. AICRP on IFS Biennial Workshop (virtual platform), organized by IIFSR, Modipuram, U.P. on 15-18th December, 2020.

Kumar Sanjeev. 2020. International web conference on Climate Smart Agriculture for Sustainable Food and Nutritional Security (CSASFNS -2020), organized by B S College, Chenari, Rohtas and SURE on 10-11th July, 2020.

Kumar Sanjeev. 2020. Stakeholders dialogue on Strategies for Safe and Sustainable Weed Management - A Way Forward, jointly organized by TAAS, ICAR, DWR, Jabalpur and ISWS on 9th December, 2020.

Kumar Santosh. 2020. 1st Indian Rice Congress-2020 (an international conference) held at ICAR National Rice Research Institute, Cuttack, Odisha during 8-9th December, 2020.

Kumar Santosh. 2020. International meeting on Rice Breeding: Global Coordination, organized by IRRI, Philippines during 15-16th September, 2020.

Kumar Santosh. 2020. International webinar on From Breeding to Genome Editing: Long-Term Strategies to Contain Plant Diseases, organized by Bioingene.com on 24th November, 2020.

Kumar Santosh. 2020. International webinar on Journey of Rice Research from Salinity to Fluoride Stress Response, organized by Bioingene.com on 31st December, 2020.

Kumar Santosh. 2020. International webinar on Molecular and Physiological Mechanisms of Drought Tolerance in Rice - A Tale of Backbencher Gene, organized by Bioingene.com on 19th October, 2020.

Kumar Santosh. 2020. International webinar on Women in Science and their Role in Sculpting Modern Agriculture, organized by Bihar Agricultural University, Sabour, Bhagalpur held on 26th August, 2020.

Kumar Santosh. 2020. Online national workshop on Intellectual Property Management in Agriculture, organized by ICAR-Indian Institute of Agricultural Biotechnology, Ranchi on 28th November 2020.

Kumar U. 2020. Extension Education Council Meeting of BAU, Sabour on 19th December 2020.

Kumar U. 2020. Webinar on Editor Talk Series-1, Agricultural System by Dr Val Snow, Organized by ICAR-CTCRI ABI along with MANAGE and CRISP, Hyderabad on 14th July, 2020.

Kumari Rajni. 2020. International e-Conference on "Immunology in 21 Century for Improvising One Health, organized by College of Biotechnology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, India and Department of Animal Husbandary and Dairying, Govt. of India, New Delhi during 7-8th August, 2020.

Kumari Rajni. 2020. International e-Conference on Expanding Horizons in Physio-Biochemical and Molecular Approaches for Improving Livestock Health and Production, Organized by the Department of Veterinary Physiology and Biochemistry, Veterinary College and Research Institute, Orathanadu, Thanjavur, Tamil Nadu, India from 19-20th October, 2020.

Kumari Rajni. 2020. Virtual symposium on Recent Developments in Buffalo Research, jointly organized by Indian Society for Buffalo Development and ICAR-CIRB on 8th October, 2020.

Mali SS, Shinde R. 2020. Online national workshop on Intellectual Property Management in Agriculture, organized by ICAR-IIAB, Ranchi on 28th November, 2020.

Manibhushan. 2020. National webinar on Geospatial approaches for agricultural water management, organized at Dr. Rajendra Prasad Central Agricultural University, Pusa (Bihar) during 7-9th October, 2020.

Mondal, S. 2020. International web conference on Soil Health Management for Sustainable Crop Productivity, organized by Mandan Bharti Agriculture College, Agwanpur, Saharsa, Bihar, India during 7-8th September, 2020.

Mondal, S. 2020. International webinar on Soil Spectroscopy: An Emerging Technique for Rapid Soil Health Assessment, jointly organized by ICAR-Indian Institute of Soil Science, Bhopal & World Agroforestry (ICRAF), Nairobi on 1st October 2020.

Mridusmita D. 2020. International e-conference on Vth Sustainable Energy and Environmental Challenges 2020, organized by ISEES during 19-21th December, 2020.

Pan RS, Sarkar PK, Singh AK, Bhavana P. 2020. Webinar on Entrepreneurship Opportunities in Seed Production, organized by Agri Business Incubator Project, ICAR RCER FSRCHPR, Ranchi on 17th August, 2020.

Pan RS. 2020. Online national seminar on Crop Breeding for Wider Adaptation, jointly organized by Birsa Agricultural University, Ranchi, Jharkhand and Indian Society of Genetics and Plant Breeding, New Delhi at Birsa Agricultural University, Ranchi on 12th December, 2020.

Rahman A. 2020. National webinar on Alternatives to Plastics for Sustainable Soil and Environmental Health, organized by ICAR-IISS, Bhopal on 30th December 2020.

Raman RK. 2020. Online national seminar on Big Data Analytics in Agriculture, organized by NAARM, Hyderabad during 10-11th December, 2020.

Raman RK. 2020. Workshop on Creating Data Ecosystem, organized by International Agricultural Research Centers (CIMMYT, IRRI and IFPRI and National Agricultural Research System (NARS) during 12-13th February 2020 at Patliputra, Patna.

Sarkar B, Jeet P, Sundaram PK. 2020. National webinar on Agri-Planning for Disaster Times: COVID-19 and Floods, jointly organized by DRP-CAU & Agrivision on 6th August, 2020.

Sarkar PK and Bhava P. 2020. International webinar on Omics in Agriculture, organized by Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur during 7-9th October, 2020,

Sarkar PK and Bhavana P, Shinde R. 2020. International webinar on Nanotechnology in Agriculture and Biotechnology, organized by Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur during 19-21st October, 2020.

Sarkar PK and Shinde R. 2020. Webinar on Innovative Water Soluble Fertilizer Formulation for Crop Nutrition Solution, organized by Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India, on 16th December, 2020.

Sarkar PK. 2020. International webinar on Health and Environmental Protection during Pandemic Outbreak of COVID-19, organized by SHIATS, Allahabad, Uttar Pradesh during 25-27th June, 2020.

Sarkar PK. 2020. International webinar on COVID-19 Impact and Implications on Environment, organized by Central University of Jharkhand, Ranchi, India on 11th August, 2020.

Sarkar PK. 2020. National webinar on Biodiversity Conservation and Management for Ecosystem Services and Climate Change Mitigation, organized by Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal on 15th October, 2020.

Sarkar PK. 2020. National webinar on Climate-Smart Integrated Farming System, organized by ICAR-NIASM, Baramati, Pune on 18th September, 2020.

Sarkar PK. 2020. National Webinar on Forest, Environment and Wildlife – Status and Developments in the 21st century, organized by College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Uttar Pradesh, India on 4th August, 2020.

Sarkar PK. 2020. National webinar on Organic farming a promising alternative for Indian agriculture, organized by Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India on 1st October, 2020.

Sarkar PK. 2020. Webinar on Enhancing Water Productivity of Canal Command through Technological Advancement in Water Management, organized by ICAR Research Complex for Eastern Region, Patna on 28th November, 2020.

Sarkar PK. 2020. Webinar on Entrepreneurial Opportunities in Food Processing Sector, organized by School of Agricultural Sciences & Technology (SAST), Narsee Monjee Institute of Management Studies (NMIMS) deemed to be University on 13th August, 2020.

Sarkar PK. 2020. Webinar on Exploring Horticultural Nursery as Profitable Enterprise in Eastern India, organized by Department of Agriculture, Jharkhand Rai University, Ranchi on 30th June, 2020.

Sarkar PK. 2020. Webinar on Innovative Water Soluble Fertilizer Formulation for Crop Nutrition Solution, organized by Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India on 16th December, 2020.

Sarkar PK. 2020. Webinar on Integrated Farming System for Small and Marginal Farmers, organized by CCS National Institute of Agricultural Marketing, Rajasthan on 06 August, 2020.

Sarkar PK. 2020. Webinar on Contemporary Environmental Issues: Concepts, Tools and Practices, organized by Department of Environmental Sciences, Central University of Jharkhand, Ranchi, held on 24th July, 2020.

Sarkar PK. Webinar on Shrinking of Wetland and Its Vulnerability to Climate Change: A Case Study for Kanwar Wetland, Begusarai, India, organized by ICAR Research Complex for Eastern Region, Patna on 16th November, 2020.

Shinde, R. 2020. Webinar cum online lecture Series on Innovative Approaches Towards Managing Soil health for climate Smart Agriculture, organized by Indian Society of Soil Science from 5th September to 5th December, 2020.

Shivani and Dubey R.2020. Online workshop on Gender Sensitization to Celebrate Seventh Anniversary of Notification of Act- The Sexual harassment of women at workplace (Prevention, prohibition and redressal) Act, 2013 on 15th December, 2020.

Shubha, K. 2020. Online international web conference on Biodiversity in Vegetable Crops for Healthier Life and Livelihood, organized by Bihar Agricultural University, Sabour, Bhagalpur held on 27–28th August, 2020.

Shubha, K. 2020. Online national webinar on Biotechnological Interventions for Improvement of Pulse Crops, organized by Bihar Agricultural University, Sabour, Bhagalpur on 7th August, 2020.

Shubha, K. 2020. Online national webinar on Recent Trends in Horticultural Entomology, organized by Department of Plant Protection, College of Horticulture, Sardarkrushinagar Dantiwada Agricultural University, Jagudan held on 27th August, 2020.

Singh AK, Bhavana P. 2020. Online QRT Review meeting of AICRP (VC) Centres of Eastern & North Eastern region, organized by ICAR AICRP(VC), IIVR, Varanasi on 5th August, 2020.

Singh AK. 2020. International web conference on Climate Smart Agriculture for Sustainable food and Nutritional Security (CSASFNS-2020) during 10-11th July, 2020 as Chief Organizing Secretary.

Singh AK. 2020. Webinar on Genomics Strategies for Improvement of Abiotic Stress Tolerance in Crop Plants, jointly organized by ICAR-National Institute of Abiotic Stress Management (NIASM), Baramati, India and the Alliance of Bioversity International and International Centre for Tropical Agriculture (CIAT), Asia-India, New Delhi on 27th November, 2020.

Singh DK. 2020. International webinar on Women in Science and Their Role in Sculpting Modern Agriculture, organized by BAU, Sabour on 26th August, 2020.

Singh Mandhata. 2020. International conference on Pulses as the Climate Smart Crops : Challenges and Opportunities (ICPulse 2020), organized by Indian Society of Pulses Research and Development (ISPRD) ICAR-Indian Institute of Pulses Research (IIPR), Kanpur, Uttar Pradesh, India, during 10-12th February, 2020 at Bhopal, Madhya Pradesh, India.

Singh, NR. 2020. International webinar on Achieving Land Degradation Neutrality, organized by Indian Association of Soil and Water Conservationists (IASWC), Dehradun in collaboration with ICAR-Indian Institute of Soil and Water Conservation (IISWC), Indian Council of Forestry Research and Education (ICFRE) during 22-24th July, 2020.

Singh, NR. 2020. International webinar on Women in Science and Their Role in Sculpting Modern Agriculture, organized by BAU, Sabour on 26th August, 2020.

Singh, NR. 2020. National webinar on Cultivation of Medicinal and Aromatic Plants (MAPs): An Innovative Effort towards Sustainable Development, organized by BAU, Sabour on 1st September, 2020.

Sundaram PK and Sarkar B. 2020. Webinar on Conversion of Agricultural Crop Residue to Sustainable Biofuel Production, organized by Uttar Banga Krishi Viswavidyalaya Pundibari, Cooch Behar, West Bengal on 5th November, 2020.

Sundaram PK. 2020. Webinar on Trash to Treasure: Managing crop residues into winning investment, organized by BAU, Sabour on 5 November, 2020.

Tamta M. 2020. International webinar on Building Climate Resilience in Agriculture through Agrometeorology and other Technological Interventions, organized by Dr. Rajendra Prasad Central Agricultural University, Pusa during 15-17th December, 2020.

Tamta M. 2020. International webinar on Harnessing the Potential of Tropical Tuber Crops under Changing Climate (HPTTC-2020), organized by ICAR - Central Tuner Crops Research Institute, Kerala on 27th October, 2020.

Tamta M. 2020. National workshop on Modern Interventions in Environmental Management, organized by ICAR - Indian Institute of Agricultural Biotechnology, Ranchi on 30th December, 2020.

Upadhyaya A, Kumar Ajay, Ahmed Akram, D Mridusmita and Rahman A. 2020. Webinar on Achieving Land Degradation Neutrality, organized by IASWC and ICFRE Dehradun during 22-24th July, 2020.

Upadhyaya A. 2020. 54th Annual convention of ISAE and International symposium on Artificial Intelligence based Future Technologies in Agriculture, held at Pune, Maharashtra during 7-9th January, 2020.

Upadhyaya A. 2020. International web conference on Climate Smart Agriculture for Sustainable Food and Nutritional Security, during 10-11th July, 2020.

Upadhyaya A. 2020. World Food Day, organized at Bihar State Productivity Council, Patna on 16th October, 2020.

Upadhyaya A. National web conference on Technological Approaches for Resource Conservation and Management for Environmental Sustainability, organized by the Academy of Natural Resources Conservation and Management (ANRCM), Lucknow during 16-17th August, 2020.

Yadav VK. 2020. Technical webinar on Integrated Pest Management for Maize Crop with special reference to Fall Armyworm, organized by ICAR-Indian Institute of maize Research, Ludhiana on 9th October, 2020.

Yadav VK. 2020. Webinar on Future Perspectives in Agricultural Education, organized by NAHEP (ICAR)- CAAST, on 5th September 2020.

21. Events Organized

*Inauguration of Custom Hiring Centre at Krishi Vigyan Kendra, Ramgarh

A Custom Hiring Centre was inaugurated at Krishi Vigyan Kendra, Ramgarh (Jharkhand) on 8th January 2020 by Dr. R.K. Samantha, Chairman, QRT, KVKs of Jharkhand and Bihar. Dr Samanta said that farmers in Ramgarh would be benefitted by this agriculture equipment hiring centre and they would not have to look for anywhere else for hiring of these tractors drawn as well as hand operated equipments. He also added that apart from accessibility of farmers to these modern implements, agriculture practices in the district would be modernised and could contribute to greater farm yield.

On this occasion, Dr. Anjani Kumar, Director, ATARI, Patna applauded this move and articulated the importance and use of advanced equipments in agricultural production and said that CHCs were found to have rented out machinery particularly Happy seeder, which is in huge demand during wheat sowing season at exorbitant rents as the sowing period lasts for just 2-3 weeks. The members of the QRT team and scientists from different centres/ institutes, Dr. R. B. Sharma, Dr.F.H.Rahman and Dr Amrendra Kumar gave fruitful and valuable suggestions to develop this recently started Krishi Vigyan Kendra.

Stakeholders' Meeting organized at ICAR-Agricultural Technology Application Research Institute, Kolkata (Zone-V)

A Stakeholder's meeting was organized on 28th January 2020 at ICAR ATARI, Kolkata under the

Chairmanship of Dr. A.N. Mukhopadhyay, Chairman, QRT of the institute (2012-17) and Ex-Vice Chancellor, AAU, Jorhat to understand the issues, problems and priorities of agriculture and its allied sectors in eastern states specifically for West Bengal and Assam and to develop a common platform & linkages for research & extension programme involving SAUs, ICAR Institutes, line departments, public sector, and private sector organisations. Other QRT members Dr. V. Sadamate and Dr. P. K. Mahapatra graced the occasion. Several dignitaries like, Vice-Chancellors of BCKV, UBKV, Directors of ICAR institutes i.e. ATARI of Kolkata & Guwahati, CRIJAF, Barrackpore, NINFET, Kolkata and ICAR- RCER Patna were present. Head of regional stations of ICAR institutes like NBSS&LUP, Kolkata, NDRI Eastern Regional Station, Kalyani, IVRI Eastern Regional Station, Kolkata, NRC Pig, Guwahati and CIFE Regional Station, Kolkata; Deputy Director of Research, AAU, Khanapara, Assam; representatives from Department of Agriculture and Animal Resource Development, Govt. of West Bengal; representatives from Maulana Abul Kalam Azad University- Kolkata; representatives from various other ICAR institutes & SAUs were present.

Farmer's Training Programme on Climate Resilient Agriculture Practices Organized

A Three-days Farmer's Training Programme on "Climate Resilient Agricultural Practices for Enhancing Farm productivity" was organised during 28-30 January, 2020 at ICAR Research Complex for Eastern Region, Patna. The training was organized under the ongoing project on "Climate Resilient Agriculture

Programme" funded by Government of Bihar for creating awareness about climate resilient practices and technologies to farmers of Gaya district of Bihar. The training was inaugurated by Dr Ujjwal Kumar, Head, DSEE and Principal Investigator of CRAP project. In his address to farmers, he talked about various approaches to be used for increasing farmers' income. This training covered a range of topics related to climate smart agriculture viz. Climate smart technologies for increasing farm productivity, conservation agriculture practices, diversification of cropping system, integrated farming system, management of soil residues and machineries used in conservation agriculture.

Field visits to farms of ICAR-RCER campus and Sabjpura were also conducted for trainees so that they can see the implementation of climate resilient practices in farm and learn about it. A Total of 14 farmers participated in this training course.

International Women's Day Celebrated

International women's day was celebrated at ICAR RCER Patna on 8th March 2020. Mrs. Suman Singh, Secretary, Sakhi was the Chief Guest of the function. She was felicitated by the In charge Director, Dr. Ujjwal Kumar. Mrs Singh delivered an inspiring lecture on women empowerment and emphasized on role of women power in holistic development of society. Earlier, Dr. Ujjwal Kumar, I/C Director of the Institute elucidated the role of women in various activities. He also discussed about the women centric schemes, like PM Ujjwala Yojana, Beti Bachao Beti Padhao, Sukanya Samridhi Yojana, Mahila E-haat, Working Women Hostels, etc. In this event, 25 women farm workers were felicitated. All the women participants were very delighted and expressed their joy by singing folk songs. This celebration was attended by 55 persons including scientific, technical, administrative staff of the institute.

National webinar on "Formation and Effective Functioning of Farmers Producer Organization"

Farmers Producer Companies have tremendous potential in enhancing farmers income, farmers empowerment and making India self reliant through Agriculture. On the call of Honourable Prime Minister in 74th Independence Day, ICAR-RCER, Patna organized a webinar on "Formation and effective functioning of FPO" on 18th August, 2020 under ICAR-NASF project "Development and validation of need based technology delivery model through Farmers Producer Organization for eastern Region of India".

Dr Ujjwal Kumar, Head, Division of Socio-economics and Extension discussed about Importance of FPOs in achieving *Atma Nirbhar Krishi and* linking market. Mr. Avinash Kumar of Kaushalya Foundation talked about the steps and legal formalities in formation and registration of FPO in India. Dr. Anirban Mukherjee, Principal Investigator of the Project presented strategies for effective functioning of Farmers Producer Company in India. Mr. Parmanand Pandey, BOD member, Lavkush Producer Company Limited, East Champaran, Bihar also provided his experiences in FPO and how farmers are benefitted through the FPO.

In this webinar 320 stakeholders, i.e., farmers, scientists, SMS, assistant professor, students etc. participated across the India.

Organization of Field Day at Phusbangla (Kawakol) village, Nawada

A field day was organized by ICAR RCER, Patna in collaboration with KVK, Nawada at Phusbangla (Kawakol) village in Nawada district, Bihar on 16th October, 2020 with objective to see the performance of newly released aerobic rice variety Swarna Shreya at farmer's field grown under frontline demonstration (FLDs) programme. More than 100 farmers (both men and women), scientific staff of Krishi Vigyan Kendra, Nawada and scientists of ICAR RCER were participated in the field days progarmme. All participants visited the demonstration plots of Swarna Shreya and shared their experiences.

Field Day on Rice

A Rice field day was organized on 17th October 2020 in which large no. of farmers participated widely and shared their experience about these varieties. They preferred Swarna Shreya for better climate resilience.

Field Day cum Training Program on the Use of Zero Tillage in Rice-Wheat-Summer Mung based Cropping System under NAFCC Project

Under the NAFCC funded Project "*Scaling up Climate Smart Agriculture Through Climate-Smart Village in Bihar*" a one day training cum field day on benefits of Rice-wheat-summer mung based cropping system through zero-tillage was organized on 21st October 2020 at Chakrajja Village of Daniyawan, Patna and Lodhipur village of Nagarnausa, Nalanda. In the field day program, feedback training was also organized by the project team. On this field day program, the importance of climate-smart agriculture, smart nutrient management, and adoption of zero tillage was advised.

Vigilance Awareness Week 2020

In consonance with the directions of the Central Vigilance Commission, the ICAR Research Complex for Eastern Region, Patna observed the Vigilance Awareness Week "SATARK BHARAT, SAMRIDDH BHARAT (Vigilant India, Prosperous India)" from 27 October-2 November, 2020 with great enthusiasm and active participation.

Keeping in view COVID-19 guidelines, the week began with the administering of the Integrity Pledge to all officers and staff of institute HQ, Patna by Dr. Ujjwal Kumar, Director (Acting).

World Soil Day Organized

The World Soil Day was organized on 5th of December 2020 at ICAR Research Complex for Eastern Region, Patna. Fifty farmers from Gangapur, Kharphur, Gowrichak, Sampatchak from Fatuah block of Patna district attended the programme. In

this programme, Dr Ujjwal Kumar, I/C Director, ICAR RCER emphasized on balanced application of fertilizers based on soil test to maintain the soil health and crop productivity. He also suggested keeping our soils healthy and creating awareness about soil testing among farmers. Dr A.K. Choudhary, Head, Division of Crop research addressed the farmers and stressed the need for the judicious application of fertilizer, inclusion of pulses and leguminous oilseed crops in rotation and importance of maintaining soil fertility. Dr A. Upadhyaya, Head, Division of Land and water management emphasized the ill effects of soil and water pollution due to overuse of nitrogenous fertilizer and importance of soil microorganisms. After completion of the formal Inaugural programme, a farmer-scientist interaction was organized. After the interaction programme, a filed visit was organized and farmers visited various experimental plots and got acquainted with the latest production technologies.

Farmer's Training Programme on Climate Resilient Agriculture

On the occasion of Kisan Diwas, a two days **Farmer's Training cum Field visit** on **"Management of Rabi Crops through Climate Resilient Agricultural Practices"** was organised during **22-23th December, 2020 at ICAR Research Complex for Eastern Region, Patna**. The programme was organized under the ongoing project on "Climate Resilient Agriculture Programme" funded by Government of Bihar for enhancing knowledge and skills of farmers about climate resilient practices and technologies specially for rabi crops like wheat, lentil, chickpea etc. Interacting with all the trainees, Director, ICAR-RCER, Patna; Dr Ujjwal Kumar advised farmers to set up custom hiring centre in order to fulfil large machineries required for lanting and harvesting purposes. Dr Abhay Kumar, Principal Investigator of CRA Programme, in his address to farmers, talked about various climate resilient agriculture practices being implemented in selected villages of Gaya district under the project. He also took feedback on present varieties given to them and their field performance. This training covered a range of topics related to cropping system for climate smart agriculture, improved practices for scientific cultivation of wheat, lentil, chickpea, potato etc. and use of machineries used in conservation agriculture. A Total of 19 farmers participated in this training course. The programme concluded after distribution of certificates to all the trainees for successful completion of programme.

Foundation Stone Laying Ceremony of Administrative-cum-Lab Building of KVK, Ramgarh, Jharkhand

Hon'ble MP, Hazaribagh, Shri Jayant Sinha and Dr. Trilochan Mohapatra , Secretary, DARE & Director General, ICAR virtually laid the Foundation Stone of the Administrative-cum-Lab Building of Krishi Vigyan Kendra, Ramgarh on 31st December, 2020.

Shri Jayant Sinha, Hon'ble MP, Hazaribagh said that agriculture and farmers represent the heritage of the country. Speaking as Chief Guest, he told that the new Administrative-cum-Lab Building will give additional strength to KVK, Ramgarh. He also

highlighted the role of science in improving the agricultural scenario of the region. Hon'ble MP also highlighted the role of central government for adopting several developmental programmes, schemes, reforms and policies that focus on improving incomes for the farmers..

Regarding the KVK as a livelihood institution of the farmers', Dr. Trilochan Mohapatra accentuated that the eastern region's climatic condition favours animal husbandry, fishery and horticulture. He urged the farmers to diversify the cultivation in these new income generation sectors. In his address, Dr. Mohapatra explained the effectiveness of integrated farming system models in increasing the income of farmers 2-3 times and ensuring the food and nutritional security of farmers at the same time.

Dr. Ashok Kumar Singh, Deputy Director General (Agricultural Extension), ICAR emphasized on entrepreneurship and incubation programmes of the KVKs. He said that the KVK became the brand name among farmers and helped the farmers in their day-to-day farming. This new KVK will be strengthened as the technology-focused institution to solve the agricultural problems of this region.

Dr. S.K. Chaudhary, Deputy Director General (NRM) highlighted the work of KVK, Ramgarh and stressed upon increasing the farmers' income by including secondary agriculture interventions, and capacity building of farmers, and capacity building among farmers.

Earlier, Dr Ujjwal Kumar, Director (A), ICAR-Research Complex for Eastern Region, Patna, welcomed the dignitaries and outlined the efforts being made in making of KVK, Ramgarh so far. He informed that the proposed building of the KVK, Ramgarh will be built at an estimated cost of Rs1.38 crore, and is expected to be completed by end of the year, 2021. Dr Anjani Kumar, Director, ATARI, Patna highlighted the role of the KVKs in agricultural development. A Kishan Goshthi was also organized on this occasion. More than 100 farmers from Ramgarh district participated in the event. The Officials of ICAR and State Agricultural Universities, directors of different ICAR institute, staff members from ICAR sister institutes, KVKs and farmers virtually participated in the event.

Online Training on Basic Statistical tools in Agriculture

ICAR Research Complex for Eastern Region organised a training programme on "Basic Statistical Tools in Agriculture" at Patna from 24-26 September 2020. Around 104 participants from ICAR/CAUs/SAUs/KVKs and other organisations from Kashmir, Gujarat, Punjab, Haryana, New Delhi, Odisha, Bihar,

Jharkhand and UP attended through online mode in this programme. The programme was started with the welcome address and introduction by Dr. Ujjwal Kumar, HoD, DSEE, coordinator of the programme. Dr. B.P. Bhatt, Director of the institute highlighted the importance of statistical design, survey, data collection, missing plot techniques and data analysis in the field of agricultural research. In this programme several lectures on concept of data and dollection method, treatment comparisons, concept of hypothesis testing and statistical tools and data analysis using excel and analytical hierarchy process were delivered in the training programme. Training performances was also evaluated through feed back of the trainees.

22. Krishi Vigyan Kendra

KRISHI VIGYAN KENDRA, BUXAR

Cluster Frontline Demonstration Conducted

KVK Buxar demonstrated cluster front line demonstration on Pulses funded by National Food Security Mission and oilseed funded by National Mission on Oilseed and Oil Palm (Fig. 22.1 & 22.2). The details are given below:

Crop	Technology	Area (ha)	No of beneficiaries			Village covered
			Male	Female	Total	
Pigeon-pea	IPA 203+seed treatment with FIR+foliar spray of micronutrient (MO and B) @1ml/l water before flowering and management of legume pod borer (*Maruca vitrata*) using Emamectin benzoate 0.66 g/l water	10	30	3	33	Pandeypatti, Chousa, Kamarpur, Pavni, Chunni,
Chick-pea	GNG 1581+seed treatment with FIR+foliar spray of micronutrient (MO and B)@1ml/l water before flowering and management of Gram pod borer (*Helicoverpa armigera*) by using bioinsecticide.	10	44	4	48	Indoore, Ekderva, Mahdah Varuna, Bhakhwa, Bijhora
Lentil	PL 8 + seed treatment with FIR + management of aphid (*Aphis craccivora*) by using bioinsecticide	10	49	6	55	Jagdishpur, Sonvarsha, Hukha, Mahdah, Lalganj
Mustard	RH 406 + soil application of sulphur 20 kg/ha and management of aphid (*Lipaphis erysimi*) by using bioinsecticide	150	278	15	293	Pawani, Chunni, Suroudha, Ramobariya, Niyajipur, Badka Rajpur, Rajdiha, Kasiya, Mahdah, Hukha, Lalganj, Sondhila
Green gram	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 0.33 g/ l water or Acetamiprid 1 g/l water.	10	38	2	40	Sondhila, Navanagar, Barri, Rajapur, Kukurah

Fig. 22.1. CFLD plot at farmer's field in Buxar

Fig. 22.2. A view of field day and field visit

Training Programme organized

KVK Buxar conducted different training programmes for up-gradation of knowledge and to enhance adoption of different agro-techniques in farming for harnessing higher yield with minimum cost. Details of trainings are given below:

Off campus training programme for practicing farmers

Topic	Date	No of beneficiaries		
		Male	Female	Total
Best management practices for chickpea & lentil production.	3-4, Jan. 2020	21	4	25
Scientific Cultivation of *Potato*	6-7, Jan. 2020	21	4	25
Integrated weed management and liquid foliar spray of micro nutrients (Mo&B) in chickpea & lentil	08-09, Jan. 2020	22	3	25
RCT in rice-wheat cropping system	13-14, Jan. 2020	25	0	25
Seed production of late variety of chick pea	13-14, Jan. 2020	21	6	27
Water & integrated nutrient management techniques in wheat	15-16, Jan. 2020	25	0	25
Linseed production for better health	17-18, Jan. 2020	23	2	25
Seed production of vegetable pea	17-18, Jan. 2020	23	2	25
Advance sowing of wheat by ZT	20-21, Jan. 2020	25	0	25
Crop residue management in wheat crop by Happy Seeder	1-3, Feb. 2020	23	2	25
Scientific method of soil and water sampling	03-04, Feb. 2020	10	15	25
Techniques for micro nutrient applications in pulses and oilseed crops.	4-5, Feb. 2020	20	5	25
Diseases of crops caused by abiotic factors and their management	5-6, Feb. 2020	25	0	25
Application technologies of bio-fertilizer (Rhizobium, PSB, BGA, Azatobactor) in crops, rice, chickpea, lentil and wheat and its role.	05-06, Feb. 2020	16	10	26
Nutrient and weed management in mangrela *(Nigella sativa)*	06-07, Feb. 2020	24	1	25
Formulation of bio ingredients for control of insect in Paddy	07-08, Feb. 2020	19	6	25
Integrated nutrient management technologies in potato.	07-08, Feb. 2020	15	10	25
Application of sulphur in pulses and oilseed.	10-12, Feb. 2020	25	0	25
Integrated nutrient management in cauliflower	13-14, Feb. 2020	26	0	26
Seed production of potato	18-19, Feb. 2020	25	0	25
Quality seed production of lentil	22-23, Feb. 2020	26	0	26
Integrated nutrient management in wheat.	24-25, Feb. 2020	20	6	26
Production of organic products (vermin-compost, vermiwash , punchgavya and amritpani)	02-03, Mar. 2020	5	20	25
Seed production of carrot & radish	04-05, Mar. 2020	25	0	25
Foliar application of liquid NPK and micro-nutrients in pulses & fruits plants.	04-05, Mar. 2020	29	0	29
Seed production of cole crop	11-12, Mar. 2020	22	3	25
Method of fertigation through micro-irrigation system in horticulture crops	12-13, Mar. 2020	25	0	25
Quality seed production of chickpea	13-14, Mar. 2020	17	8	25
Water management during critical period in rabi crops	14-15, Mar. 2020	16	10	26
Integrated nutrient management in onion.	16-17, Mar. 2020	25	0	25
Nature of damage, symptom and management of rice moth and khapra beetle in wheat	02-03, Sep. 2020	26	0	26
Nature of damage, symptom and management of insect pests of pulses in gram, lentil, pigeon pea and pea.	09-10, Sep. 2020	28	0	28
Crop establishment methods and weed management in pigeon pea	05-06, Oct. 2020	23	2	25
Best Management Practices for high productivity in stress tolerant rice	07-08, Oct. 2020	23	1	25
Soil borne diseases, their symptoms and management through summer ploughing & soil solarization	11-12, Oct. 2020	25	0	25
Weed and nutrient management in pearl millet for higher productivity in diara areas	19-20, Oct. 2020	23	2	25
Integrated weed and nutrient management for maize production	25-26, Oct. 2020	23	2	25
Insects and disease of summer vegetables and their management	02-03, Nov. 2020	25	0	25
Post flood scientific cultivation of potato	03-04, Nov. 2020	24	1	25
Quality seed production of paddy	03-04, Nov. 2020	14	13	27

Application method and precaution during uses of chemical pesticides	04-05, Nov. 2020	18	8	26
Rain water harvesting methods for multifarious use of water.	06-07, Nov. 2020	28	0	28
Seed production of millet crops	9-11, Nov. 2020	32	0	32
In-situ crop residue management for sustainable soil health	09-10, Nov. 2020	25	0	25
Scientific cultivation of rapeseed and mustard	11-12, Nov. 2020	23	2	25
Method of *in-situ* moisture conservation measures.	12-13, Nov. 2020	11	20	31
Best management practices for chickpea and lentil production	16-17, Nov. 2020	23	2	25
Method of soil and water conservation	17-18, Nov. 2020	24	0	24
Scientific method of soil and water sample collection	20-21, Nov. 2020	28	0	28
Insects and diseases of rice nursery and control measures	23-24, Nov. 2020	27	0	27
Integrated disease management in rice	27-28, Nov. 2020	25	0	25
Zero tillage techniques: operation and importance	28-29, Nov. 2020	22	3	25
Seed production of pigeon pea	29-30, Dec. 2020	22	5	27
Application technologies of bio-fertilizer (Rhizobium, PSB, BGA, Azatobactor) in crops, rice, chickpea, lentil and wheat and its role	29-30, Dec. 2020	29	4	33

Training programme for Extension Functionaries

Topic	Date	No of beneficiaries		
		Male	Female	Total
Quality seed production of rabi pulses (chickpea and lentil)		25	0	25
Importance of Jan Jaiv Vividhata	9-10, Oct. 2020	113	0	113
Seed production and certification of rabi season crops	03, Dec. 2020	90	10	100

Training programme for Rural Youth

Topic	Date	No of beneficiaries		
		Male	Female	Total
Mushroom production: a source of income generation	16 to 20, Jan. 2020	25	0	25
Quality seed production of vegetable pea	28 Feb. to 03 Mar. 2020	25	0	25
Integrated farming system	27 to 1, Jan. 2020	50	0	50

Training programme for Rural Youth under Garib Kalyan Rojgar Abhiyan (GKRA)

Topic	Date	No of beneficiaries		
		Male	Female	Total
Income generation through mushroom production	05-07, Aug. 2020	34	1	35
Income generation through mushroom production	08-10, Aug. 2020	28	7	35
Income generation through integrated farming system	11-13, Aug. 2020	35	0	35
Income generation through vermin- compost production	17-19, Aug. 2020	35	0	35
Income generation through vegetable production	18-20, Aug. 2020	34	1	35
Income generation through vermin-compost production	20-22, Aug. 2020	35	0	35
Income generation through integrated farming system	24-26, Aug. 2020	35	0	35
Income generation through vegetable production	24-26, Aug. 2020	35	0	35
Income generation through vermi- compost production	08-10, Sep. 2020	35	0	35
Income generation through vegetable production	14-16, Sep. 2020	35	0	35
Income generation through integrated farming system	14-16, Sep. 2020	35	0	35
Income generation through mushroom production	18-20, Sep. 2020	29	6	35
Income generation through integrated farming system	21-23, Sep. 2020	35	0	35
Income generation through mushroom production	24-26, Sep. 2020	31	4	35
Income generation through vegetable production	26-28, Sep. 2020	35	0	35
Income generation through vermin-compost production	28-30, Sep. 2020	33	2	35

Skill development training programme under Agriculture Skill Council of India (ASCI)

Topic	Date	No of beneficiaries		
		Male	Female	Total
Organic grower	17-20, Feb. 2020	20	0	20
Bee keeper	20, Feb. 2020	20	0	20
Operation and maintenance of farm implements	23-25, Feb. 2020	30	0	20

Certificate course training programme for fertilizer input dealers

Topic	Date	No of beneficiaries		
		Male	Female	Total
Integrated nutrient management (INM)	18 Feb. to 06 Mar., 2020	40	0	40

On Farm Testing conducted

Topic	Village covered	No of beneficiaries		
		Male	Female	Total
Effect of microbial inoculation (Azospirillum and PSB) and zinc fertification on growth, yield and economics of pearl millet	Ahirouli, Dullahpur, Ramobariya	9	1	10
Assessment of seed dressing with Azotobacter and PSB and micronutrient Zn and B application on yield and economics of mustard	Harikishunpur, Pawani, Ramobariya	8	2	10
Evaluation of chickpea late sown variety in Buxar district	Badki Basouli, Dafa Dehri, Pawani, Chunni	9	1	10
Assessment of varietal & Nutrient management of pigeon pea in Buxar district	Pandeypatti, Pawani, Kamarpur	10	0	10
Assessment of new molecule for the management of rice stem borer (*Scirpophaga incertulas*)	Jagdishpur, Mahdah, Vishrampur	10	0	10
Assessment of new combination of insecticide against Hellicoverpa in chickpea crop	Pawani, Sondhila Jagdishpur, Mahdah, Vishrampur	8	2	10
Management of Fall army worm *Spodoptera frugiperda* in maize	Ekderva, Mahdah, Pawani, Pandeypatti	10	0	10
Effect of zinc and bio fertilizer application on yield and yield attributes of moongbean	Bijhoura, Kukurah, Mahdah	9	1	10
Assessment of different crop establishment method on yield of lentil in rice-lentil cropping system	Harikishunpur, Dalsagar, Kukurah, Ramobariya	10	0	10

Seed Hub programme

KVK, Buxar produced the quality seed of chickpea crop under seed hub programme. Details of participatory seed production given below:

Crop/variety	Area (ha)	Production (q)	No of beneficiaries		
			Male	Female	Total
Chickpea (RVG 202)	6.1	70	7	0	7
Chickpea (Pusa 3043)	1.0	8	1	0	1
Kabuli Chana (Subhra)	0.12	0.85	1	0	1

Demonstration under Schedule Caste Sub Plan (SCSP)

KVK Buxar conducted demonstrations under SCSP programme. Details are given below:

Crop	Area (ha)	Village coverage	No. of beneficiaries		
			Male	Female	Total
Wheat	35.8	Gurudas Mathiya, Hukha, Pawani, Ramobariya, Vishrampur, Mahdah, Mathiya, Nadaon, Lalganj	53	73	126
Lentil	7.74	Bhatouli, Chakrahasi	23	1	26

Field Day on oilseed, pulses and rice

To popularize the demonstrated technology amongst the gathering of farmers, KVK Buxar organize seven field days on different pulse crops (Pigeonpea, Chickpea and Lentil) & oilseed crop (Mustard), rice and farm machinery. In every field day scientific staff, technical staff, social workers, members of FPO, progressive farmers and farm women's had participated and apprised about the demonstrated technology in the different crops. Details of field days are give below:

Field day organized	Date and place of activity	No. of farmer participated
Field day on pigeonpea	17/3/2020 Pawani	100
Field day on chickpea	18/03/2020 Mahdah	100
Field day on lentil	19/03/2020 Jagdishpur	100
Field day on mustard	20/03/2020 Pawani	100
Field day on rice (var. Swarna Shreya)	20/10/2020 Pandeypatti	75
Field day on rice (var. CO 51)	Harikishunpur	50
Field day on zero tillage sowing of wheat	09/12/2020 Harikishunpur	60

Front line demonstrations conducted

Crop	Technology	Area (ha)	No of beneficiaries			Village covered
			Male	Female	Total	
Rice	Medium duration scented rice variety Rajendra Kasturi	10	42	3	45	Kisath, Chougai, Indoor,Murarpur, Magrav, Mahdah, Paliya, Kukurah Bijhoura, Kadipur
Rice	Medium duration fine rice variety Rajendra Shweta	10	27	0	27	Mahila, devkali, Churamanpur, Murar, Dhakaich, Turkpurva, Sapahi
Rice	Drought tolerance rice variety Swarna Shreya	10	16	1	17	Baradhi, Kasiya, Chotki Basouli, Karahasi
Rice	Short Duration Rice Variety CO 51	12.5	18	3	21	Jagdishpur, Indoor, Murar, Dullahpur, Pawani, Chilbila, Hitan Padri
Wheat	ZT sowing of wheat variety HD 2967	8	19	2	21	Rajapur, Dhansoi, Mahdah, Chougai, Geruabandh, Dumrao, Chotka Rajpur
Wheat	Zinc Bio fortified variety BHU 31 & BHU 25	5	10	3	13	Mahdah, Barri, Pawani, Patalpur, Lalganj, Ramobariya, Dalsagar, Harikishunpur, Churamanpur, Balapur
Pearl millets	Hybrid 45	5	10	4	14	Simri, Chotka Rajpur, Ramobariya, Ahirouli
Waste Decomposer	Decomposition of rice crop residue	90	170	25	195	Mahdah, Ramobariya, Sangrav,Chunni, Pavni, Sondhila, Geruabandh, Lohandi, Kukurah

Activity under NICRA Project

Natural Resource Management interventions

Interventions	Technology demonstrated	Critical inputs provided seed etc	No. of farmers	Area under practice (ha)		Crop yields* (q/ha) (average)		% Yield increased/ BCR
				Before intervention	After intervention	Demo	Local practice	
Crop residue incorporation instead of burning	Application of waste decomposer for wheat crop residue management.	Waste decomposer	24	42	2.5	49.25	42.5	3.12
Conservation tillage where appropriate like zero tillage/ minimum tillage etc.	Deep summer ploughing	MB Plough	17	21	3.0	46.2	42.4	8.9/ 2.5
In-situ moisture conservation measures (BBF/ Ridge & furrow /contour trenching /mulching/conservation furrow/ bunding etc.)	Raising bund height around rice field	Training and awareness	66	73	12	49.4	42.5	16.2/ 3.0
	Production of pigeon pea var. IPA 203 on farm bund	Variety seed	30	6.5	-	15.4	-	-/ 3.5
Application of micro-nutrients	Application of nano zinc in paddy crop.	Fertilizer	6	2.5	-	52.5	42.5	23.5

Crop Production interventions *kharif*

Interventions	Technology demonstrated	Critical input	No. of farmers	Area (ha.)	Crop yield (kg/ha)		% increase in yield over local
					Demo	Local	
Demonstration of Lathyrus in rainfed area.	Lathyrus var. Ratna	Seed	07	1.50	15.20	13.40	13.42
Demonstration of Toria in Rice fallow field.	Toria var. T9	Seed	06	2.5	10.4	-	-
Demonstration of HYV of Mustard	Mustard var. RH 406	Seed	19	8.0	24.5	21.0	16.66

Demonstration of low water requirment wheat	Wheat var. Sabour Nirjal	Seed	03	1.5	38.50	34.70	8.0
Demonstration of timely sowing wheat	Wheat var. HD2967	Seed	08	02	41.50	34.70	19.5
Demonstration of drought tolerant variety	Drought tolerant paddy var. Swarna Shreya	Seed	14	05	46.80	42.75	9.5
Demonstration of flood tolerant paddy variety	Demonstration of flood tolerant paddy var. Swarna Sub1	Seed	08	3	48.50	43.60	11.2
Demonstration of short duration paddy variety for upland area	Demonstration of short duration paddy var. CO51	Seed	12	06	46.40	42.75	8.5
Demonstration of long duration paddy variety for low land area	Demonstration of paddy var. MTU7029 for low land area.	Seed	12	9.0	53	46.4	14.2
Demonstration of mid duration paddy	Demonstration of paddy Var. Rajendra Sweta for medium up land area.	Seed	04	2.0	47.30	43.50	8.0
Demonstration of herbicide	Application of Bispyribac sodium for weed control in paddy	Chemical	5	5	48.40	41.2	17.47
Demonstration of bio fertilizer	Application of BGA in Paddy	Seedling & BGA	6	6.2	51.9	46.4	11.85

Livestock & fisheries

Interventions	Technology demonstrated	Critical input	No. of farmers	Unit/ No. / Area (ha)	Measurable indicators of output* (Average)		% increase over local
					Demo	Local	
Vaccination against cattle diseases.	Anthrax, BQ, FMD, Mastitis	Medicine	325	-	-	-	-
Quality fodder production	Hybrid napier CO3	Rootslips	6	22	378	329	14.8
	Hybrid napier CO4	Rootslips	5	17			
Deworming of small ruminant	Medicine (Almendazole)	Rootslips	109	280	-	-	

Institutional interventions

Seed bank

Name of crops /varieties Commodity groups/ Implements	Quantity produced (Kilogram)/ Number/ Rent/ Charges	Critical input (Breed / Variety / Medicine (doses)	No. of farmers involved	Unit / No. / Area (ha)
Drought tolerant paddy	980	Swarna Shreya Sahbhagi Dhan	4	0.40
Flood tolerant rice	310	Swarna Sub 1	3	0.30
Wheat	5600	HD 2967	9	0.75
Chick pea	900	GNG 1581	4	0.40
Wheat	1550	Sabour Nirjal	3	1.0

Custom hiring centre

Available implements	Name of implements	Revenue (Rs.)	Critical input	No of farmers/ Area ha
MB Plough, Rotavator, Happy seeder, Zero trill drill. Power weeder Power sprayer Leveler	MB Plough	2735	Implements	58/ 52
	Power weeder	1390		
	Zero tillage machine	10300		
	Happy seeder	2740		
	Total:	17165		

Community nursery of paddy

CROP	MTU7029	BPT5204	CO51	Rajendra Sweta	Swarn Shreya
No of unit	03	03	03	02	04
Area (ha)	0.35	0.30	0.4	0.45	1.0
Area (ha)	05	03	04	05	10
Beneficiaries	09	09	12	16	19

Seed production

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

Crop	Variety	Quantity of seed (q)	Number of farmers to whom seed provided
Paddy	MTU 7029	39	151
	BPT 5204	18	68
	Rajendra Sweta	22	118
	CO 51	4	36
	Rajendra Kasturi	18	50
Wheat	HD 2967	10	25
	DBW 187	11	15
Pigeon pea	IPA 203	1.51	41
Chickpea	RVG 202	30	75
	Pusa 3043	7.5	9
Kabuli chickpea	Subhra	0.85	4
Total		161.86	592

Training Programme on Operation and Maintenance of Farm Implements

Three days training programme on "Operation and Maintenance of Farm Implements" under CRP on FM & PF was organized during 23rd to 25th January 2020 at KVK, Buxar. Total 30 nos. of farmers participated (Fig. 22.3).

Fig. 22.3. Training programme and demonstration of field operation of implements

Training Programme on Integrated Farming System

Five days training programme on "Integrated farming fystem" was organized during 27-31th January, 2020. Training programme was sponsored by Satluj Jal Vidyut Nigam Ltd. (SJVN), Chousa. Total 50 nos. of farmers participated in the training (Fig. 22.4)

Fig. 22.4. Training programme and distribution of certificates

Technology Demonstration fair

Technology demonstration fair was organized by KVK, Buxar under the project CRP on FM& PF on 14th February, 2020. Total 75 nos. of farmers participated in the programme. Major focus of the technology demonstration fair was showcasing the modern hi-tech agricultural machinery *viz.* Happy seeder, Zero tillage, Multicrop Thresher, Tractor Mounted Power Sprayer, Seed Drill, Raised Bed Planter, MB Plough, Disc Plough, Rotavator etc. and trained to the farmers for their operation and maintenance (Fig. 22.5)

Fig. 22.5. A view of Technology Demonstration Fair

Skill development training programme under Agriculture Skill Council of India

Organic grower

One skill development training programme on organic grower covering 200 hrs was organized at KVK, Buxar from 17th February to 20th March 2020. Total 20 nos. of participants enrolled under the training programme. Programme was inaugurated by "Kishan Shree" Sri Vinod Kumar Singh.Training programme covered 80 hrs under theory classes and 120 hrs under practical classes (Fig. 22.6).

Fig. 22.6. Inaugural session of Organic Grower training programme

Bee keeper

One skill development training programme on "Bee Keeper" covering 200 hrs was organized at KVK, Buxar from 25th February 2020 to 20 March, 2020. Total 20 participants enrolled under the training programme. Dr Ujjwal Kumar Head, DSEE and Nodal Officer, KVKs and Dr J S Mishra Head, DCR, ICAR RCER, Patna inaugurated the training programme. Training programme covered the 80 hrs under theory classes and 120 hrs under practical classes (Fig. 22.7).

Fig. 22.7. Inaugural session of Bee Keeper training programme

Training programme on Integrated Nutrient Management

A training programme (15 days certificate course) for fertilizer input dealers were organized by KVK, Buxar during 18th February to 6th March 2020. Total 40 nos. of input dealers enrolled the training programme. Training programme was inaugurated Sri Vinay Kumar Singh Chief Field Manager, IFFCO, Patna. Expert of KVK, Buxar, KVK, Bhojpur, VKS College of Agriculture, Dumraon, ICAR RCER, Patna delivered the different lecture on plant nutrient management, crop production, sustainable soil management, fertilizer acts etc. (Fig. 22.8).

Fig. 22.8. Inaugural session of INM training programme

Monitoring of Seed Hub and CFLD project

Dr Sumit Mishra, Joint Director, Directorate of Rice Development monitored the ongoing field activity of Seed Hub project and CFLD project on 10th and 11th January 2020. He also interacted with the farmers and visited the demonstration plots of farmers field.

Dr Arvind Kumar, Assistant Director, Directorate of Rice Development monitored the ongoing field activity of Seed Hub project and CFLD project on 6th and 7th October 2020. He also interacted with the farmers and visited the demonstration plots of farmers field (Fig. 22.9).

Fig. 22.9. Visit of seed processing unit and pigeon pea crop field

Celebration of International Women Day

KVK Buxar celebrated the International Women Day on 8th March, 2020. Programme was jointly inaugurated by CDPO, Rajpur and Head I/c, KVK Buxar. Total 50 nos. of Aganwadi workers participated in the programme (Fig. 22.10). Experts of the KVK delivered the lectures on health and nutrition, development of nutritional garden at Aganwadi Centre. Aganwadi workers also visited the demonstration units of KVK, Buxar.

Fig. 22.10. Inaugural session of International Women Day

Training programme on Seed Production and Certification

One day training programme on seed production and certification was organized in collaboration with Bihar State Seed and Organic Certification Agency (BSSOCA) on 24th February, 2020. Deputy Director, BSSOCA, PD, ATMA, Buxar and Head I/c, KVK Buxar jointly inaugurated the programme. Total 60 nos. of farmers participated in the training programme (Fig. 22.11).

Another one day training programme on seed production and certification was jointly organized by KVK Buxar and Bihar State Seed and Organic Certification Agency, Patna at KVK Buxar on 3rd December, 2020. Programme was jointly inaugurated by Head I/c, KVK Buxar and Seed Certification Inspector, Buxar. Total 52 nos. of farmers participated in the programme.

Fig. 22.11. Inaugural session of Seed Production and Certification training programme

Skill Development Training Programme under Garib Kalian Rojgar Abhiyan

KVK Buxar organized 16 numbers of training programmes in the month of July to September, 2020 for migrant workers/labours. Four training (three days each) of each topic especially Integrated Farming System, Vermi compost production, Mushroom production and Vegetable production was imparted to migrant workers. In each batch 35 participants enrolled. Total 560 nos. of migrant workers were trained for self-employment (Fig. 22.12).

Fig. 22.12. Skill Development Trainiing Programme conducted under GKRA

Celebration of Poshan Mah

KVK Buxar celebrated the Poshan Mah in the month of September, 2020. In the poshan mah 3 training programme on Nutri Thali and Nutri Garden was organized at KVK Buxar on 17th, 21st and 25th September, 2020 for Aganwadi workers and farm women. KVK experts delivered the lectures on Nutri Thali and Nutri Garden and distributed the Nutri Garden Kit to Aganwadi workers and farm women. Total 100 nos. of Aganwadi workers and 80 farm women participated in the programme and received the Nutri Garden kits (Fig. 22.13).

Fig. 22.13. Training on Nutri Garden and Nutri Thali and distribution of Nutri Garden Kits

Kisan gosthi on 150nd Birth Anniversary of Mahatma Gandhi

On the occasion of 150th Birth anniversary programme of Mahatma Gandhi, KVK Buxar organized the Kisan Gosthi on 2nd October, 2020 at KVK Buxar. In the programme 45 faremrs/farm women participated and took the oath of Cleanliness. KVK experts delivered the lectures on cleanliness (Fig. 22.14).

Fig. 22.14. Oath Taking ceremony and Kisan Gosthi

Jan Jaiv Vividhata training programme

KVK Buxar organised the Jan Jaiv Vividhata training programme during 9-10th October, 2020 for Kisan Salahkar of the Buxar district. State Government, Bihar started the programme to collect the Jaiv vividhata related information from each panchayat level. The experts of KVK had given training to Kisan Salahkar for collection of information and filling the information in the developed booklet for further compilation (Fig. 22.15).

Fig. 22.15. Training programme on Jan Jaiv Vividhata

Mahila Kisan Diwas

KVK Buxar organized the Mahila Kisan Diwas on 15th October 2020 at KVK Buxar. Total number of 46 women farmers participated in the programme. KVK experts delivered the lecture on women empowerment, formation of group and self-employment (Fig. 22.16).

Fig. 22.16. A view of Mahila Kisan Diwas

One day training and demonstration programme under CRP on FM & PF

One day training and demonstration programme for small farmers on topic "Harvesting, Threshing, Winnowing of paddy and management in Storage pest" was organized at KVK Buxar during 5-7th November, 2020 under CRP on FM and PF. Total 135 farmers participated in the programme and learn the operation and management of paddy harvesting, threshing, winnowing and post-harvest management (Fig. 22.17).

Fig. 22.17. One day training programme under CRP on FM&PF

World Soil Day

KVK Buxar celebrated World Soil Day on 5th Dec, 2020 at its premises. Hon'ble MLA, Buxar Sadar Sri Sanjay Kumar Tiwari was Chief Guest and inaugurated the programme. He encouraged the farmers to come forward for organic farming, adopt the proper management techniques for crop residue management (Fig. 22.18). Total 55 farmers participated in the programme. Scientist of the KVKs advised to the farmers to avoid the crop residue burning and use waste decomposer for decomposition of crop residue.

Fig. 22.18. Hon'ble MLA interacted with farmers on occasion of World Soil Day

Live Telecast of launching of Climate Resilient Agriculture programme

Climate Resilient Agriculture Programme was started by Govt of Bihar and was launched by Hon'ble Chief Minister, Bihar Sri Nitish Kumar on 14th December, 2020. Live Telecast of launching programme was aired in all the districts of Bihar. KVK Buxar also organized the Kisan Gosthi and field operation of zero tillage technology in wheat. Total 100 farmers participated in the programme (Fig. 22.19).

Fig. 22.19. Live Telecast of programme and Kisan gosthi

Field Day on rice variety Swarna Shreya

KVK Buxar organized the field day on drought tolerant rice variety Swarna Shreya on 20th October 2020 at farmer's field to popularize the new high yielding drought tolerant rice variety amongst the farmers (Fig. 22.20). In field day scientific staff, technical staff, social workers, members of FPO and progressive farmers and farm women participated.

Scientific Advisory Committee (SAC) meeting

The 11th Scientific Advisory Committee (SAC) meeting of KVK Buxar was held on 22nd December, 2020 at Training Hall of KVK, Buxar under the Chairmanship of the Director, ICAR-RCER Patna Dr Ujjwal Kumar. The meeting was also attended by Dr Abhay Kumar, Head DSEE, ICAR RCER, Patna.,

Fig. 22.20. Field Day of Swarna Shreya

Sri Krishna Nand Chakravarti, District Agriculture Officer (Buxar), Assistant Director Horticulture Sri Giriraj, *PC and* SMS/staffs of KVK Buxar, progressive famrers/member of this meeting and officials from State Agriculture Department/other departments (Fig. 22.21).

Fig. 22.21. Inauguration of 11th SAC meeting

Live Telecast of PM Programme on the occasion of transfer of Kisan Samman Nidhi

KVK Buxar arranged the live telecast of Prime Minister Programme on occasion of transfer of Kisan Samman Nidhi on 25th December, 2020. Total 220 farmers participated in the programme.

Station trial

Topic	Area (ha)	No of replications	Place
Evaluation aerobic and drought tolerant rice genotypes	0.2	3	KVK, Buxar, Chotki Basouli
Evaluation of conservation agricultural practices under rice-fallow system of eastern region	0.25	3	KVK, Buxar, Kukurah

On Farm Trial under KVK-CSISA project

Topic	No of beneficiaries	Place
Comparative performance of rice establishment methods in different ecologies of Bihar and EUP	10	Indapur, Rajapur, Mahdah, Chotki Basouli, Gerua bandh
Impact of age of rice nursery on the growth and yield of transplanted rice	5	Konawali, Mango dehri, Geruabandha
Performance of conventional till DSR with and without pre-sowing irrigation	5	Bocsa, Mahdah, Geruabandha, Diwan ka Badkagaon
Weed management in direct seeded rice dominated *Cyperus rotundus* based mixed weed flora	7	Rajapur, Konawali, Basahi, Bocsa, Chotki Basouli, Mahdah, Mango dehri, Chougai, 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
Quantifying the gains in wheat productivity through zero-tillage mediated advance sowing of wheat.	5	Rajapur, Gerua Bandh,Mahdah, Chotki Basouli
Residue management in rice – wheat system.	3	Jogiya, Geruabandha, Kukurah

Performance of Custom Hiring Centre under CRP on FM & PF project

Particulars	No of beneficiaries	Area covered (ha)	Amount generated (INR)
Tractor, multi-crop thresher, rotavator, seed drill, disc plough, power harrow, post hole digger, knapsack sprayer, planker, case wheel	63	73.6	90320

Extension activity

Nature of extension activity	No. of activities	Total		
		Male	Female	Total
Field day	7	561	55	616
Kisan ghosthi	4	325	81	406
Exhibition	7	3709	90	3799
Film show	73	3624	84	3708
Group meetings	2	104	2	106
Lectures delivered as resource persons	107	2526	175	2701
Advisory services	798	2000	46	2046
Scientific visit to farmers field	192	1100	40	1140
Farmers visit to KVK	646	600	46	646
Diagnostic visits	65	300	60	360
Soil test campaigns	2	77	9	86
Self help group conveners meetings	1	50	3	53
Swatchta hi Sewa	13	500	22	522

KRISHI VIGYAN KENDRA, RAMGARH

Cluster Demonstration on Oilseeds & Pulses

Performance of the demonstration under CFLD on Pulse and Oilseed Crops

Conducted Cluster Front Line Demonstration on horsegram on 10 ha, Groundnut in 20.0 ha, Niger in 20.0 ha, Sesame in 30.0 ha, Black gram in 10.0 ha on fellow land area in *kharif* season. Conducted CFLD on Mustard in 30.0 ha area, Field Pea in 10 ha area and Lentil on 10.0 ha area under rice fellow area in Rabi season under National Food Security Mission (NFSM) and National Mission of Oil seed and Oil Palm (NMOOP) by Ministry of Agriculture & Farmers Welfare, Department of Agriculture & Cooperation, Govt. of India. All demonstrations were laid in cluster approach emphasizing on rice fallow and new released varieties. Farmers were advised to adopt the good agronomic practices, balanced fertilization and IPM Practice to reduce the cost of cultivation to get better economic returns. KVK also demonstrated the cafeteria of each crop at their farm to popularize the varieties and production technology of pulse and oilseeds among the farmers.

Crop & variety/ technology demonstrated	No. of demo	Area (ha)
Horsegram: Variety BirsaKulthi 1 + Rhizobium culture seed treatment +line sowing, Foliar spray of NPK 19:19:19 and use of neem oil	25	10
Groundnut: Variety Dharni, Seed treatment with carbendazim 2.5 g/kg Foliar spray of NPK 19:19:19 and use of neem oil	50	20
Niger: Variety BN-1, Seed treatment with Trichodermaviridi+ Line sowing+ IPM Foliar spray of NPK 19:19:19 and use of neem oil	50	20
Sesame: Variety RT-351 Seed treatment with Trichodermaviridi+ Line sowing+ IPM	75	30
Black gram:Variety IPU-02-043, Rhizobium culture seed treatment +line sowing, Foliar spray of NPK 19:19:19 and use of neem oil	25	10
Field Pea :Variety IPF-4-9, Rhizobium culture seed treatment +line sowing, Foliar spray of NPK 19:19:19 and use of neem oil	25	10
Mustard: Variety-Pusa Mustard -30 @5kg/ha, Line sowing, (30X10cm) application of sulphur and foliar spray of NPK 19:19:19: @ 2.5kg/ha Spray of neem oil at the time of flowering @ 5ml/liter water +Sulphur @2 gm/lt water	75	30
Lentil: Variety- PL-8 @25kg/ha,Rhizobium culture seed treatment +line sowing, Foliar spray of NPK 19:19:19 and use of neem oil	25	10

Front Line Demonstrations (FLDs)

Crop & variety/ technology demonstrated	No. of farmers	Area (ha)
Paddy variety –Swarna Shakti Dhan Drought resistance	10	2
Pigeon pea variety- NDA-2 and seed treant with Trichoderma viridi & Rhizobium culture + Line sowing+ Need based Chemical spray	45	10
Button mushroom cultivation for high return	20	-
Brinjal (Swarna Shyamali) - Wilt resistant varietal popularization	10	1
Onion (Arka Niketan) - Popularization of var. for good shelf life	10	1

Training for Practicing Farmers and Farm Women/Rural Youth/ Extension Functionaries

Topic of practicing farmer s and farm woman training	Date	No. of. course	No. of trainees
Location : Off Campus			
Scientific cultivation techniques of tomato & tomato and IPM	09, Jan., 2020	1	25

On-farm Trails (OFTs)

Thematic area	Technology intervention	No. of farmers	Technology Options	Area (ha)
IPM	Management of Fall Armyworm, *Spodoptera frugiperda* in maize	8	Farmers practice (Application of Carbofuran) T.O. I- i. Application of sand (After whorl formation and at 5% damage symptoms appearance) ii. Spraying of Emamectin benzoate 5SG @ 0.4g/l of water at 5 days of application of sand iii. Spraying of Thaimethoxam 12.6% + Lambda-cyhalothrin 9.5% @ 0.5 ml/ltr at 15 days of after 1st spray T.O.II - i. Application of soil (After whorl formation and at 5% damage symptoms appearance) ii. Spraying of Fipronil 5SC @ 1ml/ltr of water at 5 days of application of soil iii. Spraying of Spinosad @ 0.2 ml/l at 15 days of after 1st spray	1.0
INM	Yield optimization through INM in sweet potato (Var. Shree Bhadra) under rainfed farming condition	06	TO 1: Farmer's practice (NPK 20:30:0) TO 2: Shree Bhadra + RDF (N:P:K 60:60:60) + B (01 kg in soil TO 3: Shree Bhadra + STCR (N:P:K:B)	1.0
INM	Assessment of INM along with micronutrients application on yield and quality of mango cv. Amrapali	06	TO1: Farmers practices- FYM @ 10 kg / tree + Urea 0.5 kg/ tree (05 years old tree) during fruit development stage. TO2: RDF + 0.2% ZnSO4 + 0.1% boric acid - 2 foliar spray 1) before flowering and 2) at marble stage. TO3: RDF + 0.2% ZnSO4 + 0.1% CuSO4 + 0.1 % boric acid- 2 foliar spray 1) before flowering and 2) at marble stage. (RDF 0.5:0.5:0.3 NPK Kg/ tree (05 years old tree) + 100 g zinc sulphate + 50 g copper sulphate + 50g boric acid (soil application) in basin after harvest).	72 Plants

Scientific cultivation techniques of onion	09, Jan., 2020	1	22
Use of agriculture tools in horticulture	16, Jan., 2020	1	35
Training of kitchen garden, mulching, horticulture, plant protection	27, Jan., 2020	1	47
Scientific cultivation techniques of bottle gourd	10, Feb., 2020	1	24
Scientific cultivation techniques of watermelon and IPM	10, Feb., 2020	1	21
Techniques of pruning in guava	11, Feb., 2020	1	18
Hands on training on pruning techniques in guava	25, Feb., 2020	1	35
Vegetable production and pest management in *rabi* season crops	08, Mar., 2020	1	22
Training programme in kitchen garden	13, Mar., 2020	1	25
Nursery management in vegetable crop	16, Mar., 2020	1	20
Planning, layout and establishment of fruit orchard	11, June, 2020	1	23
Precautions and prevention from the attacks of hoppers in paddy	11, June, 2020	1	27
Crop production management of horsegram	02, Jul., 2020	1	25
Management of fall army warm in maize	17, Jul., 2020	1	27
Prevention and precautions from COVID-19 and Scientific cultivation techniques of capsicum	17, Jul., 2020	1	25
IPM and cultivation techniques of cabbage	04, Aug, 2020	1	22
IP and cultivation techniques of cauliflower	11, Aug, 2020	1	21
Crop diversification	17, Aug, 2020	1	32
Scientific method of papaya cultivation and IPM	22, Aug, 2020	1	26
Crop production management of Niger	07, Sep., 2020	1	25
Promotion of Nutri Garden, NutriThaali, and Nutri Villages	18, Sep., 2020	1	50
Promotion of Bio-fortified crop varieties for Nutritional Security among farm women and Children	19, Sep., 2020	1	50
Promoting Nutri Sensitive innovative practices and Value chain development	22, Sep., 2020	1	50
Awareness on Nutri Sensitive Agriculture among farming community through capacity development and different level of interfaces	26, Sep., 2020	1	50
Awareness programme on Poshan Abhiyan for Anganbadi workers and farm women	28, Sep., 2020	1	30
Awareness programme on Poshan Abhiyan for Nutritional Security	29, Sep., 2020	1	30
Promoting Nutri Sensitive innovative practices and Value chain development	30, Sep., 2020	1	36
INM in fruit crops	30, Sep., 2020	1	36
Training cum practical sowing of mustard variety PM-30 by zero till machine	20, Oct., 2020	1	25
Insect –pest management in paddy crop	29, Oct., 2020	1	20
Scientific method of potato cultivation	10, Nov., 2020	1	21
Scientific method of potato cultivation	19, Nov., 2020	1	22
Management of FAW in maize crop	12, Nov., 2020	1	31
Button mushroom cultivation and management	17, Nov., 2020	1	22
INM in fruit crops	05, Nov., 2020	1	36
Sowing and weeding equipments for small land holders	16-17, Dec., 20	1	30
Nutritional garden	21, Dec., 2020	1	15

Training for Rural Youth

Topics of Training	Date	Duration	Location	No. of trainees
Oyster mushroom production and management	18-22, Nov. 20	5 days	On campus	50

Professional training programme integrated nutrient management for fertilizer dealers, PACS members and unemployed youth

Training programme	Venue	Date
Integrated nutrient management training	KVK, Ramgarh	21 Sept – 05 Oct, 2020
		05-20 Nov, 2020
		23 Nov-07 Dec, 2020

HRD/Webinar training

Topics of training	Date	Name of institute
Best practices in agri logistic	29 Jul., 2020	Ch. Charan Singh National Institute of Agricultural Marketing, Jaipur
National Webinar on Plant Biological Interventions for Climate Smart Agriculture"	30 Jul., 2020	Bihar Agricultural University, Sabour, Bhagalpur
Entrepreneurship opportunities in mushroom production	11 Aug. 2020	Agri-business Incubator Projects, FSRCHPR, Ranchi

Online training on Ergonomics methodologies for designing and assessing women friendly agriculture tools and technologies	17–21, Aug. 2020	Department of Resource Management and Consumer Sciences, College of Community and Applied Sciences, MPUAT, Udaipur, Rajasthan, under NAHEP
Entrepreneurship development through mushroom production and processing technology	18, Aug. 2020	Department of Agriculture and Environment science, NIFTEM
Webinar on Formation and effective functioning of farmers producer organization	18, Aug.2020	ICAR-Research Complex for Eastern Region, Patna, Bihar -800014
National web conference on augmenting vegetable productivity through recent techniques"	9-10, Nov. 2020	Bihar Agricultural University, Sabour, Bhagalpur
Mitigation and adaptation strategies for alleviating impact of climate change on food security	25, Aug.2020	B.S.N.V.P.G. College deptt. Of Botany (KKV), Lucknow, U P
International web conference on biodiversity in vegetable crops for healthier life and livelihood	27–28, Aug. 2020	Bihar Agricultural University, Sabour, Bhagalpur, Bihar
Best practices in agri logistic- a Journey of apna godam	31, Aug., 2020	Ch. Charan Singh National Institute of Agricultural Marketing, Jaipur, Rajsthan
Entrepreneurship in agricultural extension; success story of MASS	03, Sep., 2020	Agri-business Incubator Projects, FSRCHPR, Ranchi, Jharkhand
Prevention and Resolution of Conflict at Work Place	07, Oct., 2020	Ch. Charan Singh National Institute of Agricultural Marketing Jaipur Rajsthan
Hydro informatics for smart water management in agriculture	20, Oct., 2020	CAE, RPCAU, Pusa; NIH, Roorkee; Deptt. of WRDM, IIT Roorkee & Div. of Agril. Engg., IARI, New Delhi
Communication and management skills for extension personal	01-21, Oct., 2020	NAARM, Hyderabad
National webinar on management of root- rot disease of horticultural crops"	24 Nov., 2020	Deptt of Pathology, under NAHEP,RPCAU, Pusa Samastipur, Bihar
Market research and value chain management of agricultural commodities	17-21 Nov., 2020	NAARM, Hyderabad
Entrepreneurial opportunities in fabricating pre & post-harvest machineries related to horticulture	26 Nov. 2020	BESST-HORT A TBI of ICAR-IIHR
National webinar on "Maximization of input use efficiencies for doubling farmer's income"	28, Nov., 2020	Department of Agronomy, Ch. Chhotu Ram (P.G.) College, Muzaffar-nagar (UP), India

Sponsored/vocational training programme

Date	No of Course	Duration (Days)	No of Participants			Sponsoring Agency
			M	F	Total	
16-18, Jan 2020 13 Oct., 2020 16-17 Dec., 2020	3	2	43	82	125	CRP, ICAR -RCER Patna
28/01/2020	1	1	34	6	40	CCL, Kujju
01/02/2020	1	1			32	CCL, Kujju
03, Feb. 2020	1	1			35	CCL, Kujju
11, Feb.2020	1	1			32	CCL, Kujju
07, Feb. 2020	1	1			18	NAMI, Ranchi

Skill India Training programme

Topic	Duration of training	No. of participants	Trainer	Sponsor
Mushroom cultivation	200 hrs	20	Dr. D.K. Raghav	Agriculture Skill Council of India (ASCI)
Group farming practitioner	200 hrs	20	Dr. Indra Jeet	

Training program for Anganwadi workers on Nutri-Garden, Nutri-Thali & Bio-fortified varieties

A special program was organized on POSHAN maah for Anganwadi and JSLPS workers for creating the awareness on Nutri-Garden, Nutri-Thali & Bio-fortified varieties organized at Krishi Vigyan Kendra, Ramgarh held on 17th September, 2020. Scientists of KVK explained about Nutri-Garden, Nutri-Thali & Bio-fortified varieties and their role in human growth and development. During the program 100 packets of seasonal vegetable seed kit sponsored by IFFCO were distributed and 1000 nos. of vegetable seedlings, 450 medicinal plants were also distributed for creating awareness, establishment of Nutri-garden around their household and at Anganwadi Centres. A farm visit were also arranged to show the display of

Nutri Garden, and other technologies demonstration in KVK farm. More than 147Anganwadi Workers and farm women participated from different villages of the district (Fig. 22.22).

Fig. 22.22. Women farmers and Aganwadi workers in the training programme

Other important activities

Date	Activity	No. of Participant	Place
10, Jul. 2020	Animal health camp	30	KVK Ramgarh
16-22, Aug. 2020	Gajar has Unmulan Saptah		

World Soil Day

The World Soil Day was organized on 5th of December 2020 at Krishi Vigyan Kendra, Ramgarh. Hon'ble MLA, Mandu Shri Jai Prakash Bhai Patel was the Chief Guest of the programme. Sixty farmers from different villages of Ramgarh district attended the programme. Hon'ble MLA suggested to maintain the soil health and bio-diversity. Dr D. K. Raghav, I/c Head, KVK, Ramgarh told on balanced use of fertilizers based on soil test for crop productivity and maintain the soil health. Twenty five nos. of Soil Health Cards were distributed in the occasion (Fig. 22.23).

Fig. 22.23. Celebration of World Soil day

Training programme on Integrated Nutrient Management

Three nos. of Integrated Nutrient Management (INM) trainings was conducted at Krishi Vigyan Kendra for 15 days duration. 1st batch of training was completed on 5th Oct, 2020 with distribution of certificates by Director, ATARI, Patna and renewal of licensee of fertilizer dealers by liaisoning of line department. 2nd batch was started from 5 Nov, 2020. Hon'ble MP, Hazaribagh, Shri Jayant Sinha was the Chief Guest in inaugural program for the 3rd batch of the training w.e.f. 23-07, Dec, 2020 (Fig. 22.24).

Fig. 22.24. Integrated Nutrient Management (INM) training at KVK Ramgarh

Training Programme under CRP on FM&PF

Two numbers of one day duration training-cum-demonstration programme was conducted on 'Popularization of sowing and weeding equipments for small land holders' at KVK, Ramgarh under the project, Consortia Research Platform on Farm Mechanization and Precision Farming (CRP on FM & PF) during 16-17 December, 2020 (Fig. 22.25). During the training programme, Dr. P K Sundaram (ICAR RCER, Patna) appraised farmers about different sowing and

Fig. 22.25. Training-cum-demonstration programme on 'Popularization of sowing and weeding equipments for small land holders

weeding equipment suitable for their region. He also informed about different horticultural tools useful for hilly terrain. Dr. D K Raghav (Head, KVK Ramgarh) informed the farmers about the Custom Haring Centre (CHC) at KVK Ramgarh, demonstrated different machines under CHC and the mechanism to hire the equipments .

Skill Development training

Two nos. of training program on Skill development, mushroom cultivation and group farming was conducted at KVK Ramgarh from 21 Jan, 2020. Training was 200 hrs for a batch and 20 participants in each batch. The training was sponsored by Skill Development Council of India, Govt. of India. Dr. D.K. Raghav was master trainer for Mushroom cultivation and Dr. Indra Jeet was master trainer for Group farming practitioner (Fig. 22.26).

Fig. 22.26. Skill development training

Swachhta Pakhawada

Swachhta Pakhawada awareness programme was organized at KVK, Ramgarh from 16-31 Dec, 2020. Programme was started with display of banners at prominent places, taking Swachhata Pledge & briefing of the activities and plantation of trees. During the programme date wise various activities were undertaken under Swachhta Pakhawada .

Field Day on Importance of manually operated tools and implements for increasing farm productivity

A field day on "Importance of manually operated tools and implements for increasing farm productivity" was organized under 'Consortia Research Platform on Farm Mechanization and Precision Farming' project at Aara Basti village, P.O. Sarubeda of Mandu block, Ramgarh on 13th October 2020. The field day was organized for increasing awareness about region specific small tools and implements. Hands-on-training on existing and ergonomically modified grubber and twin wheel hoe was also given to the participating farmers. The field day was aimed at enhancing the competency of women farmers in the tribal dominant region for adopting and using these tools. Dr. Bikash Sarkar, Pr. Scientist (ICAR RCER, Patna) stressed the need to adopt ergonomically improved tools and implements for the farmers of the region. The participants were appraised about the recently started Custom Hiring Centre (CHC) at KVK Ramgarh by Dr DK Raghav. Dr P K Sundaram informed the farmers about locally available small hand tools for different agricultural operations *viz.,* land preparation, weeding and harvesting for small holders (Fig. 22.27).

Fig. 22.27. Field day on "Importance of manually operated tools and implements for increasing farm productivity"

Other extension activities organized

Activities	No.	No. of Parti.
Field Day		
Kisan Gosthi	5	144
Kisan Mela (No.)	0	0
Exposure Visit	5	137
Film Show	2	320
Advisory Service	1125	6680
News Paper Coverage (No.)	34	–
Radio Talk (No.)	6	–
T.V. Telecast (No.)	5	–
Extn. Litera-ture	2	–
Technology Week	1	35

Soil Health Cards distributed

Name of KVK	No. of samples	No. of village	No. of soil health cards distributed among farmers
Ramgarh	25	2	25

23. Awards and Recognitions

Awards and Recognitions

AK Choudhary, **'Distinguished Scientist Award',** by Society of Scientific Development for Agriculture and Technology, Meerut.

AK Dubey, **'Prof. M.J. Narasimhan Academic Merit Award (Commendation)'**, by Indian Phytopathological Society, New Delhi.

AK Dubey, **'Research Excellence Award 2020',** by Institute of Scholars (InSc) Bengaluru, Karnataka.

Anirban Mukherjee, **'Jwaharlal Neheru Award for P.G. Outstanding Doctoral Thesis Research in Agriculture and Allied Sciences 2019 for Social Science'**, by Indian Council of Agricultural Research, New Delhi.

Anirban Mukherjee, **'Outstanding Research Scholar Award for Ph.D.'**, by Society for Community Mobilization for Sustainable Development, New Delhi.

Asit Chakrabarti, **'Outstanding Achievement in Livestock Award'**, by Udyaniki Krishi Anushandhan Samiti, Lucknow.

Bikash Das, '**Fellow of Indian Academy of Horticultural Sciences, Fruit Science 2020'**, by Indian Academy of Horticultural Sciences, New Delhi.

Jaipal S. Choudhary, **'ESI Young Entomologist Award 2020'**, by Entomological Society of India, New Delhi.

Jaipal S. Choudhary, **'Fellow of Entomological Society of India'**, by Entomological Society of India, New Delhi.

Jaipal S. Choudhary, **'Outstanding Scientist Award'**, by VDGOOD Professional Association, Tamil Nadu.

Jaipal S. Choudhary, **'Research Excellence Award',** by Institute of Scholars (InSc) Bengaluru, Karnataka.

Jaipal S. Choudhary, **'Young Scientist Award 2020',** by Dr B. Vasantharaj David Foundation, Chennai.

Jaspreet Singh, **'Young Scientist Award',** by VD-GOOD Professional Association, Tamil Nadu.

Manoj Kumar, **'Fellow of Society for Biotic and Environmental Research',** by Society for Biotic and Environmental Research, Tripura.

Manoj Kumar, **'Research Excellence Award 2020',** by Society for Biotic and Environmental Research, Tripura.

Manoj Kumar, **'Young Scientist Award 2020',** by Society of Tropical Agriculture, New Delhi.

N Raju Singh, **'Young Scientist Award 2020',** by Society for Science of Climate Change and Sustainable Environment (SSCE), New Delhi.

Pankaj Kumar, **'Distinguished Scientist Award 2020'**, by Society for Scientific Development in Agriculture and Technology, Meerut

Pankaj Kumar, **'Gold Medal on Bovine Medicine (Shri Mathunga Jain Goraksha Mandali Gold Medal)'**, by Indian Society for Veterinary Medicine, Ludhiana.

PK Sundaram, **'TAFE Student Gold Medal Award'**, by Indian Society of Agricultural Engineers (ISAE), New Delhi.

Pradip Kumar Sarkar, **'SSCE Young Scientist Award 2020'**, by Society for Science of Climate Change and Sustainable Environment (SSCE), New Delhi.

Tarkeshwar Kumar, **'Young Scientist Award'**, by Green Agri Professional Society, Dhanbad.

Best Paper/Poster/Presentation Awards

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

Asit Chakrabarti, 'Certificate of Appreciation', by International Journal of Livestock Research.

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

DK Singh, 'Best Poster Award', by by Indian Potato Association, Shimla.

Jaipal S. Choudhary, 'International External Examiner of PhD Thesis Evaluation', by Macquarie University, Australia.

Jaipal Singh Choudhary, 'Best Oral Presentation Award', by CAU, Imphal.

Mali SS, 'Best Article Award', by Agriculture & Food: E- Newsletter.

Mali SS, '**Best Reviewer Award (Soil and Water Engineering)**', by Indian Society of Agricultural Engineers (ISAE), Delhi.

Mali SS, '**Innovative Article Award**', by Agriculture & Food: E-Newsletter.

Pradip Kumar Sarkar, '**Certificate of Appreciation**' for delivering a lecture as a resource person in one day webinar organized by Jharkhand Rai University, Ranchi, Jharkhand on 24th June, 2020.

Reena Kumari Kamal, '**Second Oral Presentation Award**', by Indian Society of Animal Production and Management, Hyderabad.

Sanjeev Kumar, '**Asian Journal of Soil Science and Plant Nutrition Certificate of Excellence in Reviewing** from Sciencedomain International, West Bengal.

24. Publications

Research Papers

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Chakrabarti A. 2020. A study on goat management practices in Ranchi District. Paper presented in National Symposium on Veterinary Research Priorities in Transitional Animal Health, Production and Food Safety organized by the Indian Association for the Advancement of Veterinary Research held in Madras Veterinary College, TNVASU, Chennai during 21-22nd February, 2020.

Chakrabarti A. 2020. Backyard poultry production – A source of family income for tribal farmers in Jharkhand. Invited lecture in the International Web- Conference on Climate smart agriculture for sustainable food and nutritional security Organized by Beni Singh College, Chenari, Rothas, Bihar and Society for Upliftment of Rural Economy, Varanasi, Uttar Pradesh during 10-11th July, 2020.

Chaudhary AK. 2020. Lecture on "Scientific cultivation of lentil and chickpea" under the training on "Management of Rabi Crops through Climate Resilient Farming Practices" on 23th December 2020 at ICAR RCER, Patna.

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Choudhary JS. 2020. Population Genetics and Phylogeography of Fruit Fly Species of Important Horticultural Crops in India, in the National webinar on "Recent Trends in Horticultural Entomology" organized by Department of Plant Protection, College of Horticulture, Sardarkrushinagar Dantiwada Agricultural University, Jagudan held on 27th August, 2020.

Dubey R. Delivered two lectures on (i) Importance of Bio-inoculants such as Phosphorous Solubilizers & Azospirilum and (ii) Importance of Bio-inoculants such as Blue Green Algae & Trichoderma in 15 Days Certificate Course on Integrated Nutrient Management for fertilizer Input Dealer of the district at KVK Buxar on 4th December, 2020.

G. G. Sonawane, Jyoti Kumar and C.P. Swarnkar. Haematobiochemical profile of sheep with emaciation and debility. Poster presentation. Abstract published in the compendium of XXVIII Annual Conference & National Symposium on "Physiological approaches to address environmental challenges for increasing animal productivity and farmer's income" (18-19th February, 2020), SAPICON 2020. S5-P-10 pp-151.

Jyoti Kumar, Rajiv Kumar, G. G. Sonawane, S. Jegaveera Pandian, Ashish Jain and S. R. Sharma. Poster presentation on Visceral Caseous lymphadenitis in a sheep caused by Corynebacterium pseudotuberculosis: a detailed case study. Abstract published in the compendium of XXVIII Annual Convention & National conference on "Challenges and threats of microbes to animals and humans", 6-7th February, 2020, IAVMICON 2020, at ICAR-IVRI, Bareilly. PP03-4, pp-108.

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Kumar Sanjeev. Invited lecture (virtual platform) on "Integrated farming System: A tool for doubling farmers' income and livelihood" for B.Sc. (Hons.) Ag Students, organized by Banaras Hindu University, Varanasi (B.H.U.) on 21st October, 2020.

Kumar Sanjeev. Presentation on "Integrated farming Systems for Sustainable Agricultural Development" in the National Webinar on A Multidisciplinary approach to COVID-19: Strategic opportunities for sustainable development. Organized by A. N. D. College, Shahpur Patori, Samastipur (LNMU) on 22nd August, 2020.

Kumar Sanjeev. Oral presentation on the topic "Integrated farming Systems for small and marginal farmers" in the 6th National Webinar on Kisan Mitr, Organized by CCS National Institute of Agricultural Marketing (NIAM) under the aegis of the Ministry of Agriculture & farmers' Welfare, New Delhi on 6th August, 2020.

Kumar Sanjeev. Presentation of Progress Report of AICRP on IFS (IIFSR, Modipuram) in the Biennial Workshop of AICRP-IFS *(online*) w.e.f. 15-18th December, 2020.

Kumar Santosh, Dwivedi SK, Mishra JS, Choudhary AK, Bhakta N, Dubey AK, Mondal S, Bhatt BP and Kumar A. 2020. Physiological and agro-morphological responses of rice genotypes grown under multi-stages drought conditions in eastern India. Paper presented in National Seminar on Crop Breeding for Wider Adaptation organized by Birsa Agricultural University (BAU), Ranchi, Jharkhand in collaboration with Indian Society of Genetics and Plant Breeding (ISGPB), Ranchi Chapter during December 12-13th, 2020 in virtual mode.

Kumar Santosh, Dwivedi SK, Mishra JS, Choudhary AK, Mondal S, Basu S, Kumar G, Bhakta N, Rao KK, Kumar S, Koley TK, Bhatt BP and Kumar A. 2020. Morpho-physiological and anatomical changes in rice genotypes under multi-stages drought conditions prevailed in eastern India. Paper presented in International Conference on Advances and Innovations in Agriculture & Allied Sciences (AIAAS-2020) held at Jawaharlal Nehru University (JNU), New Delhi, during 31st January to 1st February, 2020.

Kumar Santosh, Dwivedi SK, Mishra JS, Choudhary AK, Mondal S, Bhakta N, Bhatt BP and Kumar A. 2020. Physiological and agro-morphological responses of rice genotypes grown under multi-stages drought conditions prevailed in eastern India. Paper presented in International Web-Conference on New Trends in Agriculture, Environmental & Biological Sciences for Inclusive Development (NTAEBSID-2020) organized by Agro Environmental Development Society (AEDS) by Online Mode during 21-22nd June, 2020.

Kumar, Pankaj, Roy, R.K., Mahto, D., Sinha, B S., Kumari, R R., and Kumar, A. (2020) Disease Prevalence in Crossbreed Cattle of Bihar in Middle Indo-Gangetic Plains. In International Web conference of Global Research Initiatives for Sustainable Agriculture; Allied Sciences (GRISAAS-2020) held on 28–30th December, 2020 at Astha Foundation, Headquarter, Meerut (U.P.), pp. 23, ISBN: 978-93-88821-86-5

Kumari A. 2020. Land feasibility analysis for rainwater harvesting planning for efficient watershed management. Paper presented in International web-conference on "Climate Smart Agriculture for sustainable food and nutritional security" during 10-11th July, 2020.

Pan RS, Seth T, Shinde R, Srivastava A, Das B, Sarkar PK, Moanaro, Singh AK and Bhatt BP. 2020. Evaluation of selected wild musk melon (*Cucumis melo* var.*agrestis*/*callosus*) genotypes for yield and nutritional traits. Paper presented orally in National Seminar on "Crop Breeding for Wider Adaptation" organized by Birsa Agricultural University, Ranchi, Jharkhand and Eastern Chapter of Indian Society of Genetics and Plant Breeding, New Delhi at Birsa Agricultural University, Ranchi on 12th December, 2020.

Sarkar PK. 2020. Medicinal plant based integrated farming system: An option for entrepreneurship development. Invited lecture delivered as a resource person in webinar, organized by Jharkhand Rai University, Ranchi, Jharkhand on 24th June, 2020.

Saurabh K. 2020. Role of microbes in agricultural sustainability. Paper presented in the international web-conference on "Climate smart agriculture for sustainable food and nutritional security" during 10-11th July, 2020

Tamta, M.; Dubey, A.K.; Shivani; PawanJeet; Bharati, R.C.; Kumar, S.; Kumari, S.; Singh, N. R. and Mishra, J.S. (2020). Ensuring food security in the era of climate change: Addressing challenges of changing thermal and moisture regimes in agriculture. Paper presented in National Virtual Symposium (TROPMET-2020) on "Weather and Climate Services over Mountainous Regions" jointly organized by the North Eastern Space Application Centre & Indian Meteorological Society- Shillong Chapter during 14-17th December, 2020 at NESAC, Umiam, Shillong, Meghalaya.

Upadhyaya A. 2020. Prominent water management technologies for agricultural production. Lead Paper presented in National Web Conference on Technological Approaches for Resource Conservation and Management for Environmental Sustainability organized by the Academy of Natural Resources Conservation and Management (ANRCM), Lucknow during 16-17th August, 2020.

Upadhyaya A. and Singh, AK. 2020. Grow, Nourish, Sustain Together-Our Actions are Our Future. Paper presented on World Food Day at BSPC, Patna on 16th October, 2020.

Upadhyaya, A. 2002. Healthy Diets for A # Zero Hunger World. Paper presented during World Production Week at BSPC, Patna on 16th February, 2020.

Upadhyaya, A. 2020. Land allocation under different crops in Bhagwanpur distributary employing Simplex and Multi objective Fuzzy linear programming. Paper presented in 54th Annual Convention of ISAE and International Symposium on Artificial Intelligence Based Future Technologies in Agriculture. Pune, Maharashtra during 7-9th January, 2020.

Kharumnuid P, Pandey NK and Singh DK. 2020. Consumer preferences for potato attributes in Jalandhar and Ludhiana districts of Punjab, Poster presentation in Global Potato Conclave: Roadmap for a Better World at Gandhinagar, Gujarat during 28-31th January , 2020.

Webinar Delivered

Ahmed Akram. Webinar on "Shrinking of wetland and its vulnerability to climatwe change: A case study for Kanwar wetland, Begusarai, India" organized by Division of Land & Water Management, ICAR RCER Patna on 16th November 2020.

Jeet Pawan. Webinar on "Modelling for efficient storage and utilization of rainwater in watershed: A case study" organized by Division of Land & Water Management, ICAR RCER Patna on 17th October 2020.

Kumar Ajay. Webinar on ''Enhancing water productivity of a canal command through technological advancement in water management'' organized by Division of Land & Water Management, ICAR RCER Patna on 28th November 2020.

Kumari Arti. Webinar on"Budgeting and auditing of water for its efficient use and management" organized by Division of Land & Water Management, ICAR RCER Patna on 18th September 2020.

Manibhushan. Webinar on "Decision Support System in Agriculture" organized by Division of Land & Water Management, ICAR RCER Patna on 14th December 2020.

Mridusmita D. Webinar "Concept on Virtual Water for its Efficient Use" organized by Division of Land & Water Management, ICAR RCER Patna on 31th August, 2020

Rahman A. Webinar on "Dielectric properties and its application in agriculture" organized by Division of Land & Water Management, ICAR RCER Patna on 31th October 2020.

Upadhayay A. Webinar on "Status of Floods in Bihar and Management Strategies" organized by Division of Land & Water Management, ICAR RCER Patna on 10th August 2020.

25. Personnel

Division of Crop Research

Scientists

Dr. J.S. Mishra, Pr. Scientist (Agronomy) & Head upto 25.11.2020
Dr. A.K. Choudhary, Pr.Scientist (Plant Breeding)
Dr. Sanjeev Kumar, Pr. Scientist (Agronomy)
Dr. Shivani, Pr. Scientist (Agronomy)
Dr. Md. Monobrullah, Pr. Scientist (Entomology)
Dr. Narayan Bhakta, Pr. Scientist (Plant Breeding)
Dr. Santosh Kumar, Sr. Scientist (Plant Breeding)
Dr. Rakesh Kumar, Scientist (Agronomy)
Dr. S.K. Dwivedi, Scientist (Plant Physiology) upto 06.08.2020
Dr. Surjit Mondal, Scientist (Soil Science)
Mr. Ved Prakash, Scientist (Agril. Meteorology)
Mr. Karnena Koteswara Rao, Scientist (Soil Science) (on study leave)
Mr. Abhishek Kumar Dubey, Scientist (Plant Pathology)
Dr. N. Raju Singh, Scientist (Agroforestry)
Ms. Manisha Tamta, Scientist (Agricultural Meteorology)
Dr. Kumari Shubha, Scientist (Vegetable Science)
Dr. Rachna Dubey, Scientist (Environmental Science)
Mr. Govind Makarana, Scientist (Agronomy) w.e.f. 04.040.2020
Mr. Saurabh Kumar, Scientist (Microbiology) w.e.f. 06.04.2020

Division of Livestock and Fishery Management

Scientists

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

Technical Officer

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

Division of Land and Water Management

Scientists

Dr. A. Upadhyaya Pr. Scientist (SWCE) & I/c Head
Dr. A. Rahman, Pr. Scientist (Physics)
Dr. Anil Kumar Singh, Pr Scientist (Agronomy)
Dr. Bikash Sarkar, Pr. Scientist (FMPE)
Dr. Ajay Kumar, Pr. Scientist (SWCE)
Dr. Manibhushan, Sr. Scientist (Comp. App.)
Dr. P.K. Sundaram, Scientist (FMP)
Dr. Pawan Jeet, Scientist (L&WME)
Er. Akram Ahmed, Scientist (L&WME)
Dr. Kirti Saurabh, Scientist (Soil Science)
Mrs. Mridusmita Debnath, Scientist (L&WME)
Mrs. Arti Kumari, 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. Tanmay Kumar Koley, Scientist (Horticulture)
Dr. Dhiraj Kumar Singh, Scientist (Ag. Extension)
Dr. Anirban Mukherjee, Scientist (Agril. Extension)
Dr. Rohan Kumar Raman, Scientist (Agil. Statistics)

Technical Officer

Mr. Sanjay Rajput, Technical Officer

Prioritization Monitoring & Evaluation Cell

Dr. A. Dey, Pr. Scientist (Animal Nutrition) & 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, Assistant Chief Technical Officer
Mr. P.K. Singh, Sr. Technical Officer
Mr. R.K. Tiwari, Technical Officer
Mr. A.S. Mahapatra, Technical Officer

Workshop and Estate Section

Sh. M.L. Swarnkar, Chief Technical Officer

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

Scientists

Dr. A.K. Singh, Pr. Scientist (Horticulture) & Head
Dr. R.S. Pan, Pr. Scientist (Horticulture)
Dr. B.K. Jha, Pr. Scientist (Horticulture)
Dr. Bikash Das, Pr. Scientist (Horticulture)
Dr. S. K. Naik, Pr. Scientist (Soil Science)
Dr. V.K. Yadav, Pr. Scientist (Ag. Extension)
Dr. P.R. Kumar, Pr. Scientist (Seed Technology) upto 30.05.2020
Dr. Asit Chakrabarti, Sr. Scientist (LPM)
Dr. S.S. Mali, Sr. Scientist (SWCE)
Dr. P. Bhavana, Sr. Scientist (Plant Breeding)
Dr. Ajit Kumar Jha, Sr. Scientist (Plant Pathology) w.e.f. 06.10.2020
Dr. J.S. Choudhary, Scientist (Entomology)
Ms. Reshma Shinde, Scientist
Mr. P.K. Sarkar, Scientist (Agroforestry)
Mr. M.K. Dhakar, Scientist (Fruits Science)

Technical Officers

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

ICAR RCER, Research Centre for Makhana, Darbhanga

Dr. I.S. Singh, Pr. Scientist (Soil Science) & I/c Head
Dr. B.R. Jana, Scientist (Horticulture)
Dr. Manoj Kumar, Scientist (Soil Science)
Mr. Shailendra Mohan Raut, Scientist (FRM)
Mr. Padala Vinod Kumar, Scientist (Agronomy) w.e.f. 04.04.2020

ICAR RCER, Krishi Vigyan Kendra, Buxar

Subject Matter Specialists

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

Technicals

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

ICAR RCER, Krishi Vigyan Kendra, Ramgarh

Subject Matter Specialists

Dr. Dushyant Kumar Raghav, SMS (Plant Protection)
Dr. Indrajeet, SMS (Ag. Extension)
Dr. Dharmjeet Kherwar, SMS (Agroforestry/ Horticulture)

Technical

Shri Sunny Kumar, Farm Manager

Administration & Finance Section

Mr. Pushpanayak, Chief Administrative Officer
Mr. Ajay Kumar Soni, Senior Administrative Officer
Mr. Vipul Raj, Administrative Officer upto 23.08.2020
Mr. K.K. Lal, Junior Account Officer
Mrs. Prabha Kumari, AAO (P)
Mr. Dayanand Prasad, AAP
Mr. Ravi Shankar, Assistant
Mr. Rakesh Mani, Assistant
Mr. Md. Sajid Mustaque, Assistant (on deputation w.e.f. 19.12.2020)
Mr. Madan Paswan, Assistant
Ms. Divyadarshini, Assistant
Mr.. Nagendra Kumar, Assistant

New Joining

Dr. Ujjwal Kumar, Pr. Scientist (Agril. Extension) & Head joined as Director (Acting) w.e.f. 01.10.2020 (A/N)

Scientists

Mr. Govind Makarana, Scientist (Agronomy) w.e.f. 04.040.2020

Mr. Padala Vinod Kumar, Scientist (Agronomy) w.e.f. 04.04.2020

Mr. Saurabh Kumar, Scientist (Microbiology) w.e.f. 06.04.2020

Dr. Ajit Kumar Jha, Sr. Scientist (Plant Pathology) w.e.f. 06.10.2020

Promotion

Scientists

Dr M.K. Dhakar, Scientist (Fruit Science) promoted to Scientist (Level-12) w.e.f. 01.01.2018

Dr T.L. Bhutia, Scientist (Vegetable Science) promoted to Scientist (Level-12) w.e.f. 01.07.2018

Transfer

Dr. J.S. Mishra, Pr. Scientist (Agronomy) & Head joined as Director, ICAR-DWSR, Jabalpur w.e.f. 26.11.2020

Dr. P.R. Kumar, Pr. Scientist (Seed Technology) transferred to ICAR-IARI, Hazaribagh w.e.f. 31.05.2020

Dr. S.K. Dwivedi, Scientist (Plant Physiology) transferred to ICAR-CITH, Lucknow w.e.f. 07.08.2020

Dr. S. Maurya, Scientist (Plant Pathology) transferred to ICAR-IVRI, Varanasi w.e.f. 13.12.2019.

Mr. Vipul Raj, Administrative Officer transferred to ICAR-MGIFRI, Motihari w.e.f. upto 24.08.2020

Dr. B.P. Bhatt, Director transferred to NRM Division, ICAR, New Delhi w.e.f. 02.10.2020

Retirements

Sh. Tipa Mahli, SSS w.e.f. 31.01.2020

Sh. Y.N. Pathak, ACTO w.e.f. 31.01.2020

Sh. Babulal Mahto, SSS w.e.f. 29.02.2020

Sh. Sarju Mahto, SSS w.e.f. 29.02.2020

Sh. Mangal Lakra, SSS w.e.f. 29.02.2020

Sh. Pradeep Kumar Singh, TO w.e.f. 30.06.2020

Sh. Sukhna Oraon, SSS w.e.f. 30.09.2020

Sh. Somra Munda, SSS w.e.f. 30.09.2020

Sh. Ganga Ram, STO w.e.f. 30.11.2020

Sh. Chandra Kant, STO w.e.f. 31.12.2020

26. On-going Research Projects

Theme wise Ongoing and New Institute Research Projects 2020

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, Ujjwal Kumar, N. Chandra, K.K. Rao, Kamal Sarma, Shivani	June 2010	Mar. 2022	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, S.K. Naik, A. Chakrabarti, P.K. Sarkar	June 2011	July 2020 Extd. 2023	ICAR RCER
1.3	ICAR-RCER/ RC Makhana/ 2014-15/ 157	Introduction of sweet flag and tuber vegetable crop under wetland ecosystem with makhana crop for north Bihar	B.R. Jana	July 2014	June 2020 Extd 2021	ICAR RCER
1.4	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 (Associate)	Sept. 2014	Sept. 2020 Extd. 2023	ICAR RCER
1.5	ICAR-RCER/ DCR/2019/ 204	Structure and functioning of agro-forestry systems in middle IGP	N. Raju Singh, A. Raizada	2018	2021	ICAR RCER
1.6	ICAR-RCER/ RC Ranchi/2019/225	Evaluation of Zero Budget Natural Farming (ZBNF) for Eastern Plateau and Hill Region	B.K. Jha, P.K. Sarkar, Associates:, S.K. Naik, J.S. Choudhary	2019	2024	ICAR-RCER
1.7	New	Development of multipurpose trees and medicinal plants based agroforestry models for Eastern Plateau and Hill Region	P.K. Sarkar, Reshma Shinde, M.K. Dhakar	2020	2025	ICAR-RCER
1.8	New	Optimum land allocation of different Integrated farming systems components to maximize resource use efficiency and net return.	Manibhushan, A. Upadhyaya, Sanjeev Kumar, Bikas Das, S.S. Mali, M.K. Dhakar	Sept. 2020	Aug. 2023	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, B. K. Jha, S. K. Naik, S.S. Mali, Rakesh Kumar, Rachana Dubey	2015	2021	Consortium Research Platform on CA (ICAR)
2.2	ICAR-RCER/ DCR/EF/2016/	Cereal Systems Initiative for South Asia (CSISA) Phase III	J.S. Mishra, Rakesh Kumar, S.K. Dwivedi S. Mondal, Rachana Dubey	2016	2020	CIMMYT
2.3	ICAR-RCER/ RC Ranchi/2011/ 196	Evaluation of leaching loss of nutrients in acidic soils of Jharkhand under different cropping systems	S. K. Naik, S. S. Mali	Oct 2018	Sept, 2021	ICAR RCER

2.4	-	Network project on Conservation of lac insect genetic resources (NPCLIGR)	M. Monobrullah	Jan 2019	Mar 2021	ICAR
2.5	New	Impact of long- term conservation agriculture on greenhouse gas fluxes from middle Indo-gangetic plains of India.	Rachana Dubey, J.S. Mishra, K.K. Rao	Aug. 2020	July 2023	ICAR RCER
3	**Climate Resilient Agriculture**					
3.1	ICAR-RCER/ DCR/EF/2016/	Development of climate resilient farming system models for livelihood improvement	M. Monobrullah, Bikash Das, Ravi Kumar, Dhiraj Kumar Singh, A. Raizada, Manisha Tamta	Nov. 2016	Dec. 2021	NMSA, DAC & FW, Ministry of Agriculture & Farmers' Welfare, Govt. of India
3.2	ICAR-RCER/ RC Ranchi/ 2018/ 214	Diversification of existing upland production systems with tuber crops in eastern Plateau and Hill region	R.S. Pan, S.K. Naik,	July 2018	June 2021	ICAR RCER
3.3	ICAR-RCER/ DCR/ 2018/ 208	Effect of drought and heat stress on wheat : changes in plant physiologi-cal traits and yield attributes	S.K. Dwivedi, Santosh Kumar, Manisha Tamta, Rachana Dubey	2018	2021	ICAR RCER
3.4	ICAR-RCER/ DCR/ 2018/ 213	Simulating production potential of rice and wheat under changing climate over Bihar	Manisha Tamta, R.C. Bharati, Shivani, Pawan Jeet S.K. Dwivedi (Associate)	2018	2021	ICAR RCER
3.5	-	Scaling up Climate Smart Agriculture (CSA) through Mainstreaming Climate Smart Villages (VSVs) in Bihar	J.S. Mishra, Abhay Kumar, P.K. Sundaram, A. Mukherjee, K.K. Rao, Manisha Tamta, N. Raju Singh	2018	2021	Ministry of Environment & Forests, GoI
3.6	-	Long term conservation agriculture impact on micro biome and soil health indicators for resource efficiency and resilience in maize systems	K.K. Rao, Rakesh Kumar	Nov. 2018	2021	NASF
3.7	-	Climate Resilient Agriculture Programme	Ujjwal Kumar, Abhay Kumar, P.K. Sundaram Rakesh Kumar, Surajit Mondal, Dhiraj Kumar Singh, R.K. Raman	Nov. 2019	Mar. 2024	Govt. of Bihar

4	**Varietal Development**					
4.1	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	2001	Long term	ICAR RCER
4.2	ICAR-RCER/ RCM/ 2015/	Evaluation of different genotypes of water chestnut	B.R. Jana, I.S. Singh, Manoj Kumar	2015	2020 Extd. 2021	ICAR RCER
4.3	ICAR-RCER/ RC Ranchi/ 2017/215	Genetic resource management in vegetable crops	A.K. Singh, P. Bhavna, R. S. Pan, V.K. Yadav, J.S. Chaudhary	Sept 2017	Long term project	ICAR RCER
4.4	ICAR-RCER/ DCR/EF 2017/	Identification of traits, genes, physiological mechanisms to develop climate smart varieties for unfavourable environment	S.K. Dwivedi, Santosh Kumar	2017	2022	IRRI
4.5	-	Development of nutrient rich lines of pulse legumes for eastern India	A.K. Choudhary, Kirti Saurabh	Sep. 2019	Aug. 2022	ICAR-RCER

4.6	ICAR-RCER/ DCR/2019/227	Evaluation, characterization and identification of rice genotypes for combine tolerance to drought and submergence	Santosh Kumar, N. Bhakta, S.K. Dwivedi,	July 2019	June 2023	ICAR-RCER
4.7	ICAR-RCER/ RC Ranchi/ 2019/ 226	Development of multiple disease resistant hybrids in solanaceous vegetables	P. Bhavana, A.K. Singh	2019	2024	ICAR-RCER
4.8	New	Genetic enhancement of pigeon pea for yield and biotic stress resistance	P. Bhavana, Kishor Tribhuvan, J S Choudhary	June 2020	Dec 2025	ICAR-RCER
Theme- 3. Improved Production and Protection Technologies for Agri-Horti Crops						
5	**Production Technologies**					
5.1	ICAR-RCER/ DCR/ 2017/ 212	Diversification of rice-wheat system with vegetables	Shivani, Kirti Saurabh, Shubha Kumari, Akram Ahmed	2017	2021	ICAR RCER
5.2	--	Creation of seed hubs for increasing indigenous production of pulses in India	A.K. Choudhary, Hari Govind (KVK, Buxar)	2016	2021	ICAR
5.3	ICAR-RCER/ RC Ranchi/ 2018/206	Development of year round seed production techno-logies in chillies (Capsicum annum L.) for Jharkhand	P. Bhavana,	Apr 2018	Oct 2020	NABARD (Externally funded)
5.4	ICAR-RCER/ DSEE/ 2018/	Performance evaluation of medicinal and aromatic plant in EIGP	T.K. Koley, N. Raju Singh, N.A. Gajbhiye (DMAPR, Anand)	July 2018	June 2021	ICAR-RCER
5.5	ICAR-RCER/ RCM/ 2019/	Response of nutrients on productivity of water chestnut and Indian lotus	I.S. Singh, Manoj Kumar	Aug 2019	July 2022	ICAR-RCER
5.6	ICAR-RCER/ RCM/ 2019/	Effect of different intercultural practices on biochemical constituents of makhana seed	B.R. Jana, Manoj Kumar	Aug 2019	July 2022	ICAR-RCER
5.7	ICAR-RCER/ RCM/ 2019/	Effect of secondary and micronutrients on yield and quality of makhana in field condition	Manoj Kumar, I.S. Singh, S.M. Raut	Aug 2019	July 2022	ICAR-RCER
5.8	ICAR-RCER/ DCR/ 2019/ 228	Enhancing nutritional security of rural households through vegetable based Nutri garden in Bihar	Kumari Shubha T.K. Koley	Oct. 2019	Sep. 2022	ICAR-RCER
5.9	New	Standardization of basin enrichment in bearing orchards of Bael, Mango and Guava under eastern plateau and hill region	Bikash Das, P.K. Sarkar, M. K.Dhakar	2020	2025	ICAR-RCER
5.10	New	Standardization of agro-techniques in nutri-cereals for enhancing the productivity in eastern Indo-gangetic plains	Rakesh Kumar, K.K. Rao, Reshma Shinde	July 2020	Dec. 2025	ICAR-RCER
5.11	New	Development of clonal seed orchard of Kusum (Schleichera oleosa)	Pradip Kumar Sarkar	July 2020	June 2030	ICAR-RCER
5.12	New	Improving nutrient use efficiency and productivity by customizing nutrient application methods in Makhana	Manoj Kumar, I.S. Singh	June 2020	May 2023	ICAR-RCER
5.13	New	Studies on soils in relation to makhana production in North Bihar	Manoj Kumar, I.S. Singh	June 2020	May 2023	ICAR-RCER
6	**Protection Technologies**					
6.1	ICAR-RCER/ RC Ranchi/ 2018/199	Management of wilt complex in leguminous and cucurbitaceous crops of eastern region	A.K. Dubey	2018	2021	ICAR-RCER
6.2	ICAR-RCER/ RC Ranchi/ 2018/198	Seasonal incidence and evaluation of management strategies against insect- pests of cauliflower and chilli	J. S. Choudhary, D.K. Raghav, M. Monobrullah, Rakesh Kumar	2018	2021	ICAR-RCER
6.3	ICAR-RCER/ DCR/ 2018/217	Development of native Trichoderma based bioformulations for management of soil-borne diseases	A.K. Dubey, A.K. Choudhary	2018	2021	ICAR-RCER

6.4	ICAR-RCER/ DCR/ 2019/ 229	Studies on weed and seed bank dynamics in different cropping systems in the middle Indo Gangetic Plains	Sanjeev Kumar, Rakesh Kumar, N. Raju Singh	Nov. 2019	Oct. 2022	ICAR-RCER
Theme- 4. Integrated Land & Water Management						
7	**Land & Water Management**					
7.1	ICAR-RCER /RC Ranchi/ 2014/150	Rehabilitation of coal mine affected areas through agroforestry interventions	M.K. Dhakar, S.S. Mali, Bikash Das, P.K. Sarkar, D. Kherwar	Sept 2014	Aug 2020 Extd 2023	ICAR RCER
7.2	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
7.3	ICAR-RCER/ RC Ranchi/ 2018/210	Design, development and performance evaluation of solar powered agricultural equipment	S.S. Mali, P.K. Sundaram J.S. Choudhary (Associate)	2018	2021	ICAR-RCER
7.4	ICAR-RCER/ DLWM/2018/205	Water productivity assessment in major cropping systems of Eastern India	M. Debnath, Rakesh Kumar, Santosh Kumar, N. Bhakta, Akram Ahmed	July 2018	June 2021	ICAR-RCER
7.5	ICAR-RCER/ DLWM/ 2018/	Design and development of peripatetic fish vending cart with solar aerator	P.K. Sundaram, Bikash Sarkar, A. Rahman, S.K. Ahirwal	July 2018	June 2021	ICAR-RCER
7.6	ICAR-RCER/ DLWM/ 2018/	Improving rabi/ summer maize productivity through efficient land and water management	Anil. K. Singh, A. Upadhyaya	July 2018	June 2021	ICAR-RCER
7.7	ICAR-RCER/ DLWM/ 2018/211	Assessment of land use and land cover change for crop planning using remote sensing and GIS of East and West Champaran district.	Manibushan, A. Raizada, Anil K. Singh	2018	2021	ICAR-RCER
7.8	ICAR-RCER/ DLWM/ 2018/	Water conser-vation under different irrigation and tillage management in rice based cropping system	Surajit Mondal, Rakesh Kumar (Associate)	Oct. 2018	Sep. 2021	ICAR-RCER
7.9	ICAR-RCER/ DLWM/ 2018/219	Optimization of cropping pattern to maximize water productivity	A. Upadhyaya, Akram Ahmed, Anil K. Singh, S. Mondal	Jan. 2019	June 2022	ICAR-RCER
7.10	ICAR-RCER/ DLWM/ 2018/218	Studies on irrigation water pricing and influencing factors	A. Upadhyaya, Pawan Jeet, M. Debnath,	Jan. 2019	June 2022	ICAR-RCER
7.11	-	Evaluation of irrigation system and improvement strategies for higher water productivity in Sone Canal Command (AICRP on Water)	Ajay Kumar, Akram Ahmed, A.Upadhyaya, A. Rahman, Manibhushan, Pawan Jeet, Mani Kumar (WALMI)	Dec 2014	Mar 2020	ICAR
7.12	ICAR-RCER/ DLWM/ 2019/ 233	Standardization of fertigation schedule in high density guava under middle Gangetic plains	Akram Ahmed,	Oct 2019	Sep 2022	ICAR-RCER
7.13	New	Evaluation of existing solar pump for irrigation potential in eastern region of India	A. Rahman, Anil K. Singh, N. Chandra	June 2020	May 2023	ICAR-RCER
7.14	New	Budgeting and auditing of water for better planning and management in agriculture.	Arti Kumari, A. Upadhyaya, Manisha Tamta	2020	2023	ICAR-RCER
7.15	New	Land feasibility analysis for rainwater harvesting planning at watershed level in Nalanda, Bihar.	Arti Kumari, A. Upadhyaya, Pawan Jeet	2020	2023	ICAR-RCER
7.16	New	Refinement of indigenous plough and weeding rake in Eastern Hill and Plateau region	Bikash Sarkar, P.K. Sundaram, D.K. Raghav (As Associate)	2020	2023	ICAR-RCER
7.17	New	Umbrella project on floodplains of E. India		July 2020	June 2024	ICAR-RCER

7.17 (i)		Collection, evaluation and characterization of popular rice landraces in flood-plains of eastern India.	N. Bhakta, Scientist from NRRI			
7.17 (ii)		Resource inventorization of floodplain wetlands in eastern India	R. K. Raman, S.M. Raut, P.K. Bharti			
7.17 (iii)		Flood mapping and mitigating strategies	Akram Ahmed, Arti Kumari, Anil K. Singh			
7.18		Assessing uptake of arsenic by winter crops from organic amended soils	S. Mondal			
Theme- 5. Livestock & Fisheries Management						
8	**Livestock and Avian Management**					
8.1	ICAR-RCER / DLFM / 2011/ 106	Formulation of area specific mineral mixture for Bihar based on Soil-plant-animal continuum	A. Dey, J.J. Gupta, S.K. Naik, P. K. Ray	Aug. 2011	July 2019 Extd 2021	ICAR RCER
8.2	ICAR-RCER / DLFM/EF/ 2011/ 31	Network project on Buffalo improvement	P.C. Chandran, Pankaj Kumar, R.K. Kamal, P.K. Ray, A.Dey (Associate)	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, R.K. Kamal	July 2013	June 2019 Extd 2021	ICAR RCER
8.4	ICAR-RCER/ DLFM/ 2015/175	Characterization and evaluation of duck germplasm in Eastern region.	R.K. Kamal, P.C. Chandran, P.K. Ray	Aug 2015	Aug 2020	ICAR RCER
8.5	ICAR-RCER/ DLFM/ 2018/202	Assessing genetic variability in ducks of eastern states	Rajni Kumari, P.K. Ray, R. K. Kamal (Associate)	2018	2022	ICAR RCER
8.6	ICAR-RCER/ DLFM/ 2018/209	Molecular epidemiology and therapeutic management of bovine Theileriosis	Pankaj Kumar, P.K. Ray, NIAB, Hyderabad, IIT, Guwahati	2018	2021	ICAR RCER
8.7	--	Studies on development of method for early pregnancy diagnosis in buffalo	Rajni Kumari, P.C. Chandran, Scientist from BASU, Patna	2018	2022	ICAR RCER
8.8	--	Outreach programme on zoonotic diseases	P.K. Ray, Rajni Kumari, Scientist from BASU, Patna	2018	2021	IVRI (Externally funded)
8.9	ICAR-RCER/ DLFM/ 2019/ 231	Development of meat and egg strains of duck suitable for backyard farming	P.C. Chandran, R.K. Kamal, A. Dey, Rajni Kumari A.R. Sen	2019	2024	ICAR-RCER
8.10	ICAR-RCER/ DLFM/ 2019/ 232	Effect of genetic and non-genetic factors on prolificacy of Bengal goat	R.K. Kamal, A. Dey, P.C. Chandran Rajni Kumari P.K. Ray	Aug. 2019	July 2023	ICAR-RCER
8.11	--	AICRP on Goat Improvement	A. Dey, R.K. Kamal, P.C. Chandran, P.K. Ray	July 2019	Mar 2025	ICAR
8.12	--	Evaluation of different tree leaves as fodder for goats	A. Chakrabarti, P.K. Sarkar	2019	2022	ICAR-RCER
8.13	New	Evaluation of traditionally used growth promoters on production performances in pig and poultry	A. Chakrabarti, A.Dey (Associate)	July 2020	June 2023	ICAR-RCER
8.14	New	Assessment of antimicrobial drug resistance in bacteria of animal origin	Jyoti Kumar	July 2020	June 2025	ICAR-RCER
9	**Fisheries Management**					
9.1	--	National Surveillance Programme for Aquatic Animal Disease (NSPAAD)	Kamal Sarma, T. Kumar , P.K. Ray, S.K. Ahirwal,	Nov. 2015	Sep. 2019	NFDB

9.2	ICAR-RCER/ DLFM/ 2018/201	Culture potential of selected Indian minor carp	S.K. Ahirwal, T. Kumar, Ravi Kumar, Kamal Sarma, Jaspreet Singh	2018	2021	ICAR RCER
9.3	ICAR-RCER/ DLFM/ 2019/ 221	Biofloc technology: Exploring production optimization and economic viability for the Eastern region	Jaspreet Singh, Bavithra R	Sep 2019	Aug 2022	ICAR-RCER
9.4	--	Economic feasibility of integrated prawn cum fish farming in Polyculture system in Eastern region	Bavithra R. Jaspreet Singh	Sep. 2019	Aug. 2022	ICAR-RCER
9.5	--	Assessment of fish diversity and production potential in lentic inland ecosystems of North Bihar	S.M. Raut, I.S. Singh, Ravi Kumar, Jaspreet Singh	Aug 2019	July 2022	ICAR-RCER
9.6	New	Effect of different manures on fish productivity	Kamal sarma, T. Kumar, Jaspreet Singh, Jyoti Kumar, A. Dey, S. Mondal (Associate)	July 2020	June 2023	ICAR-RCER
9.7	New	Assessment of fish production potential in makhana-periphyton system in North Bihar	S.M. Raut, Jaspreet Singh	June 2020	May 2023	ICAR-RCER
Theme- 6. Socio-Economics, Extension and Policy Research						
10	**Socio-economic Research**					
10.1	ICAR-RCER/ DSEE/ 2014/184	Growth and instability in production of principal crops in Eastern India	Abhay Kumar, N. Chandra, R.C. Bharati, Dhiraj Kumar Singh	July, 2017	June, 2021	ICAR RCER
10.2	--	Socio-economic characterization of farmers in Bihar & Jharkhand	V. K. Yadav, Pankaj Kumar, Ujjwal Kumar, R. C. Bharati, R.K. Raman	2017	2020 Extd 2022	ICAR RCER
10.3	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
10.4	ICAR-RCER/ DSEE/ 2018/207	Transfer and adoption of improved agricultural technologies	Ujjwal Kumar, D.K. Singh, Sanjeev Kumar, M.K. Dhakar, J.S. Choudhary	2018	2021	ICAR RCER
10.5	--	Enhancing food, nutritional and livelihood security of marginal and tenant farmers in Jharkhand through need based agricultural technologies	Bikash Das, V.K. Yadav, A. Chakrabarti, R.S. Pan	June 2018	Mar 2020	Farmer FIRST Project (Externally funded)
10.6	ICAR-RCER/ DLWM/ EF/ 2018/ 41	Evaluation of farm implements and tools for small land holders	Bikas Sarkar, Ujjwal Kumar, P.K. Sundaram, S.S. Mali, Ramkewal, D.K. Raghav	2018	2020 Extd June 2021	ICAR RCER
10.7	--	Value addition of principal food grains by farmers of Bihar	N. Chandra, Ujjwal Kumar, Dhiraj Kumar Singh, P.K. Sundaram, R.C. Bharati	2018	2021	ICAR RCER
10.8	ICAR-RCER/ DSEE/ 2018/216	Status of food and nutritional security of rural households in Eastern India	A. Mukherjee, Shubha Kumari, V.K. Yadav,	Oct. 2018	Sep. 2021	ICAR-RCER
10.9	--	Establishment of Biotech-KISAN Hub at ICAR RCER	Bikash Das Pawan Jeet, S. Mondal, A. Mukhrjee, N. Raju Singh, P.K. Ray, R.K. Kamal, J.S. Choudhary, A. Chakrabarti, D.K. Raghav, Indrajeet, D. Kherwar, KVK Ramgarh; R.K. Singh, S.K. Singh, S.L. Yadav, KVK, Hazaribagh; Ajit K. Singh, B. Mahto, KVK, Ranchi	July 2019	June 2021	DBT

10.10	ICAR-RCER/ DSEE/ 2019/ 230	Status of utilization of digital tools in agriculture sector in Eastern India	R.C. Bharati, Ujjwal Kumar, N. Chandra, R.K. Raman, PC, KVK Buxar, Indrajeet, SMS, KVK Ramgarh	Oct. 2019	Sep. 2024	ICAR-RCER
10.11	New	DBT Biotech KISAN project on Improvement of livelihood through establishment of value chain of horticultural crops in seven Aspirational districts of Jharkhand and Bihar	Bikash Das, A.K. Singh, Bikas Sarkar, Pawan Jeet, A. Mukherjee, J.S. Choudhary Kaushalendra	2020	2022	DBT
10.12	New	Agri-Business Incubation Project	Bikash Das, V.K. Yadav S.S. Mali	2020	2025	NAIF
10.13		Development and validation of need based technology delivery model through farmers' producer organization for eastern region of India	A. Mukherjee, Ujjwal Kumar, Dhiraj Kumar Singh, Shubha Kumari, V.K. Yadav, R.S. Pan, D.K. Raghav	Dec. 2019	Nov. 2022	NASF

New and on-going activities 2020

S. No.	Title of Activities	PI
New Activities		
1.	Breeding for submergence tolerance in rice	N. Bhakta
2.	Evaluation of lentil genotypes	N. Bhakta
3.	Evaluation and development of drought tolerant rice for Eastern region	Santosh Kumar
4.	Evaluation of different production system for Carbon sequestration potential	S.K. Naik
5.	Impact of tillage, residue manage-ment and crop rotation on soil health and crop productivity in rice-fallow system of Eastern India	Kirti Saurabh
6.	Ergonomic study of farmers' friendly farm implements in Eastern region.	Bikash Sarkar
7.	Scope of low cost vertical farming with particular reference to microgreens	T.K. Koley
8.	Formulation of mineral mixture for Indian Major carps based on soil-water and fish continuum	T. Kumar
Ongoing Activities		
1.	Evaluation and identification of rice genotypes for tolerance to drought stress at different growth stages.	Santosh Kumar
2.	Fe and Zn fortification in rice (Oryza sativa L.) varieties under drought condition for nutritional security in Eastern India	Kirti Saurabh
3.	Effect of seed size of makhana with respect to its production potential	I.S. Singh
4.	Maintenance of advance breeding lines of cool season pulses	A.K. Choudhary
5.	Seed production and evaluation of T&D breeds of pigs in Jharkhand	A. Chakrabarti
6.	Evaluation of backyard poultry farming	A. Chakrabarti
7.	Genetic enhancement of Tomato for nematode and bacterial wilt resistance through Molecular markers	P. Bhavana
8.	Assessment of soil health under different land use systems	S. Mondal
9.	Design and development of makhana grader	P.K. Sundaram
10.	Design and development of low cost irrigation system for smart farming	Akram Ahmed
11.	Multi-objective optimization of integrated farming system	Akram Ahmed

भाकृअनुप
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