CENTRAL RICE RESEARCH INSTITUTE

CUTTACK

केन्द्रीय धान अनुसंधान संस्थान

कटक

ANNUAL REPORT

1994 - 95

वार्षिक प्रतिवेदन

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Correction Citation : Central Rice Research Institute
Annual Report of the year 1994-95

The Central Rice Research Institute, located in the heart land of the rice growing region of the eastern India, is a unit of the Indian Council of Agricultural Research, New Delhi.

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Published by : Director, Central Rice Research Institute
Cuttack - 753006, Orissa
India 1995

Printed at : Capital Business Service & Consultancy,
Sahid Nagar, Bhubaneswar, Phone : 411484

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From Director's Desk

Of the 42.8 m ha. under rice cultivation in India nearly 63 per cent is confined to eastern India alone and contributing around 55 per cent to the total rice production has to grow faster than population growth and there has been a marginal decline in crop area and as such the research efforts continued for increasing grain productivity.

Focussing the research to priority farming situations in rainfed lowlands brought to attention the need to incorporate specific type of photoperiod sensitivity and thermoinsensitivity for different areas in eastern India. Assembling such materials for developing new breeding programmes has been initiated.

Our significant areas of research during the period under report include, varietal improvement for shallow, intermediate and semi-deep water depths, evaluation of hybrids for shallow situations, integrated nutrient management of lowlands, rice-fish farming for rainfed lowlands, quantification of methane emission from rice fields and devise ways to mitigate the efflux, molecular characterisation of rice blast , bacterial blight and gall midge, development of farm implements and quality characteristics of rice varieties etc.

This annual report embodies the results of research work organised by the erstwhile Director Dr. B. Venkateswarlu during his third year of stay at CRRI which represent the research contributions made by the Scientists during the period 1994-95.

I believe this annual report will be useful to rice scientists, research workers, policy makers, administrators and others to keep informed of the latest contributions in rice research made by CRRI.

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K. C. Mathur
Director (Acting)

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ABOUT OUR INSTITUTION

ABOUT OUR INSTITUTION

Brief background

The Central Rice Research Institute (CRRI) was set up in 1946 at Cuttack with 60 hectares farm provided by the Government of Orissa with Dr. K.Ramiah as the first Director. The administrative control of the Institute was subsequently transferred to the Indian Council of Agricultural Research (ICAR) in 1966.

Location

The CRRI is located in Cuttack (20°N, 86°E) 23 meters above mean sea level and about 410 km. south of Calcutta in the state of Orissa which is in the main rice growing tract of the country. The annual rainfall at Cuttack is about 1225-1575 mm and is mostly received during June to October from the south west monsoon. The institute is situated 35 km. from Bhubaneswar airport and 7 km. from Cuttack railway station on Cuttack-Paradeep road.

Organisational Set up

The ICAR is headed by the Director General who is also the Secretary to the Department of Agricultural Research and Education of the Government of India. Crops division of ICAR is headed by the Deputy Director General (Crops) who looks after crop institutes including CRRI at Cuttack has links with the Secretary, ICAR for the administrative purposes and the Agricultural Scientists Recruitment Board (ASRB) for the recruitment of scientific personnel.

The CRRI has been charged with the responsibility of conducting research on all aspects of rice and transfer of technology. The institute has a Management Committee for deciding the policies and administrative matters. The Institute is headed by the Director who is also the Chairman of the Management Committee. The Director executes the mandate of the institute through a full-fledged administrative set up and 10 divisions/sections viz; Genetic Resources, Plant Breeding and Genetics, Agronomy, Physiology Biochemistry, Soil Science and Microbiology, Plant Pathology, Entomology, Agricultural Engineering, Extension, Communication & Training, Agricultural Economics and Statistics, two sub-stations and three KVKs.

Sub Stations & KVKs

In order to involve directly in location specific research on rainfed rice, two substations, Central Rainfed Upland Rice Research Station at Hazaribag, Bihar in 1984 and Central Lowland Rice Research Station at Kharagpur, West Bengal in 1986 have been established to tackle the problems of rainfed drylands and lowlands respectively. It is also proposed to establish a substation in Assam for catering to its specific needs of rainfed rice. Further, for self propelling the technology transfer three Krishi Vigyan Kendras to function under this institute each in Cuttack, Dhenkanal and Angul districts of Orissa already been inaugurated and work is in progress.

Salient Achievements

The Institute has so far developed and released 48 high-yielding varieties of rice. Of these, 22 are suitable for irrigated lands, 11 for rainfed uplands and 15 for rainfed low lands. The varieties Ratna, Saket-4, Sarasa, Moti and Udaya are popular in irrigated areas; Kalyani II, Heera, Kalinga III, Annada and Vandana are popularly grown in rainfed uplands and Savitri, Dharitri, Gayatri, Tulsi, Panidhan, and Lunisree are popular in rainfed lowlands.

Present status

Since the establishment of the Institute, field, laboratory, administrative and residential facilities have progressively increased. From a mere 60 ha land, the area of the experimental farm has increased to 117 ha, of which the cultivated area is 70.05 ha while roads, buildings, office and orchard occupy 46.95 ha area. The major source of irrigation for the farm is from the nearby Taladanda canal. For supplemental irrigation two tanks-Kanori and Patnayaka with an area of 5.60 ha and 8 tube wells are available in the farm. The tanks are also used for fish culture. The farm is divided into 15 blocks with well bunded and levelled plots. Field plots for the respective ecosystems were developed with suitable bunding as per the known heights. Field experiments are conducted in these simulated plots representing irrigated, upland, shallow lowland and semi-deep water situations. Cemented tanks are constructed to simulate conditions of intermediate and semi-deep situations. A fish pond with a water area in two acres is developing in F block (F_2 and F_6) for studies on rice-cum-fish culture.

With the recruitment of scientific personnel, the demand for additional laboratory facilities grew, resulting in the addition of laboratory wing in 1958 and a new administrative and laboratory block in early 1980's. Simultaneously, the residential accommodation had also increased with the construction of staff quarters accommodating 300 families. The international Students Hostel was built in late 1950s to provide

accommodation to research workers visiting this Institute on a short term basis. Later a Guest House, Scientist Home, Farmers Hostel were added during 1980s.

The green house facility for conducting experiments under controlled conditions was also expanded for all the disciplines. The number at present is twelve.

The institute had started functioning with the scientists and the strength of the scientific personnel gradually increased to 40 in 1960s and then steeply to the present level of 170 which include principal scientists, Senior scientists, and scientists working on both applied and fundamental aspects of rice.

Our Mandate

- ☆ To increase productivity and sustainability of rice farmers by undertaking applied, strategic and basis research of rice ecosystems especially of eastern India
- ☆ To collect, preserve, evaluate and utilise the genetic resources for rice improvement
- ☆ To generate technology packages through interdisciplinary research and disseminate them
- ☆ To help strengthen and intensify local/ regional rice research systems
- ☆ To work in collaboration with international programmes so as to accomplish the goals desired

Central Rice Research Insittute, considering the cardianal issues of hydrology and its diversity, characterised the conditons into different ecologies and indicated the relevant Mega, Macro and Micro farming situtions. Research Programme is oriented suitably by addressing the sharp questions through multidisciplinary teams consisting of 15 to 25 scientists called 'Ecosystem Groups' with a Convenor for each. Thus, eight ecosystems are formed like rainfed upland, irrigated, shallow water (0-30 cm), intermediate lowland (30-50 cm), Semideep (50-100 cm) and deep Water (> 100 cm). Genetic resources, cropping systems and transfer of technology are added to support and strengthen them.

WEATHER

WEATHER

CRRI, CUTTACK

The total rainfall received during 1994 was 1358 mm which was deficient by 184 mm as compared to the average of previous 30 years (Table 1). Such deficiency occurred virtually in all months except April, June and August when it was slightly excess. Winter and post-monsoon periods experienced less rains. The lowest relative humidity during May (89 per cent) was associated with the highest pan evaporation (7.8 mm/day) and maximum sunshine (9.5 hours/day). As usual, relative humidity remained above 90 per cent during the remaining months of the year. The sunshine hours were lower in south-west

Table - 1 : Rainfall (mm) for the year 1994 as compared to average rainfall of 30 years from 1964-1994

Period	Month	Average rainfall from 1964-1993 (mm)	Rainfall during 1994 (mm)	Deviation from normal (mm)
Winter	January	11	0	-11
	February	34	18 (1)	-16
	Total	45	18	-27
Pre-monsoon	March	39	0	-39
	April	39	75 (4)	+36
	May	70	55 (4)	-15
	Total	148	130	-18
South-west monsoon	June	168	172 (13)	+4
	July	353	336 (19)	-17
	August	374	410 (20)	+36
	September	263	189 (10)	-74
	Total	1158	1107	-51
Post-monsoon	October	153	98 (9)	-55
	November	33	5 (1)	-28
	December	5	0	-5
	Total	191	103	-88
	Grand Total	1542	1358	-184

Figures in parenthesis indicate number of rainy days.

monsoon period, but increased gradually as rains became less frequent and long duration rice crop approached flowering and maturity. Pan evaporation, which is mostly related to temperature, was lower during the cooler post-monsoon and winter period than in summer months of the pre-monsoon period (Table-2).

Adequate pre-monsoon showers (39 mm) in April favoured early land preparation in upland and lowland areas, besides benefiting the dry season crops of greengram, cowpea, groundnut and sesam grown in rice fallows. Further, adequate rains in May and June facilitated early sowing of rice in rainfed lowlands followed by that in upland situation. No major drought or excess water stress was noticed in the early stages of rice growth. Water started accumulating in rainfed lowlands form July 6 onwards and rose abruptly by July 20,1994. Another peak of water depth was observed on August 20 (Fig.1).

In general, the rainfall during south-west monsoon period coinciding with the grand growth period of rice was evenly distributed and was quite favourable for rainfed lowland rice. However, early withdrawal of rains late in the rice growing season might have affected the performance of rainfed crop in shallow lowlands.

In the later part of the growing season approaching flowering of long duration photosensitive varieties grown in lowlands, weather conditions favoured a severe attack of stem borer causing large scale damage to rice crop (20-80 per cent). The varieties

Table - 2 : Weather data for CRRI, Cuttack, 1994

Period	Month	Relative humidity (%)	Sunshine (hours/day)	Pan evaporation (mm)
Winter	January	93	8.5	3.2
	February	95	7.8	3.6
Pre-monsoon	March	93	8.5	5.6
	April	90	7.3	5.6
	May	89	9.5	7.8
South-west monsoon	June	93	3.5	3.8
	July	92	4.1	2.8
	August	93	4.5	3.5
	September	93	5.9	3.3
Post-moonsoon	October	93	7.3	3.1
	November	93	7.7	2.9
	December	91	9.1	2.7

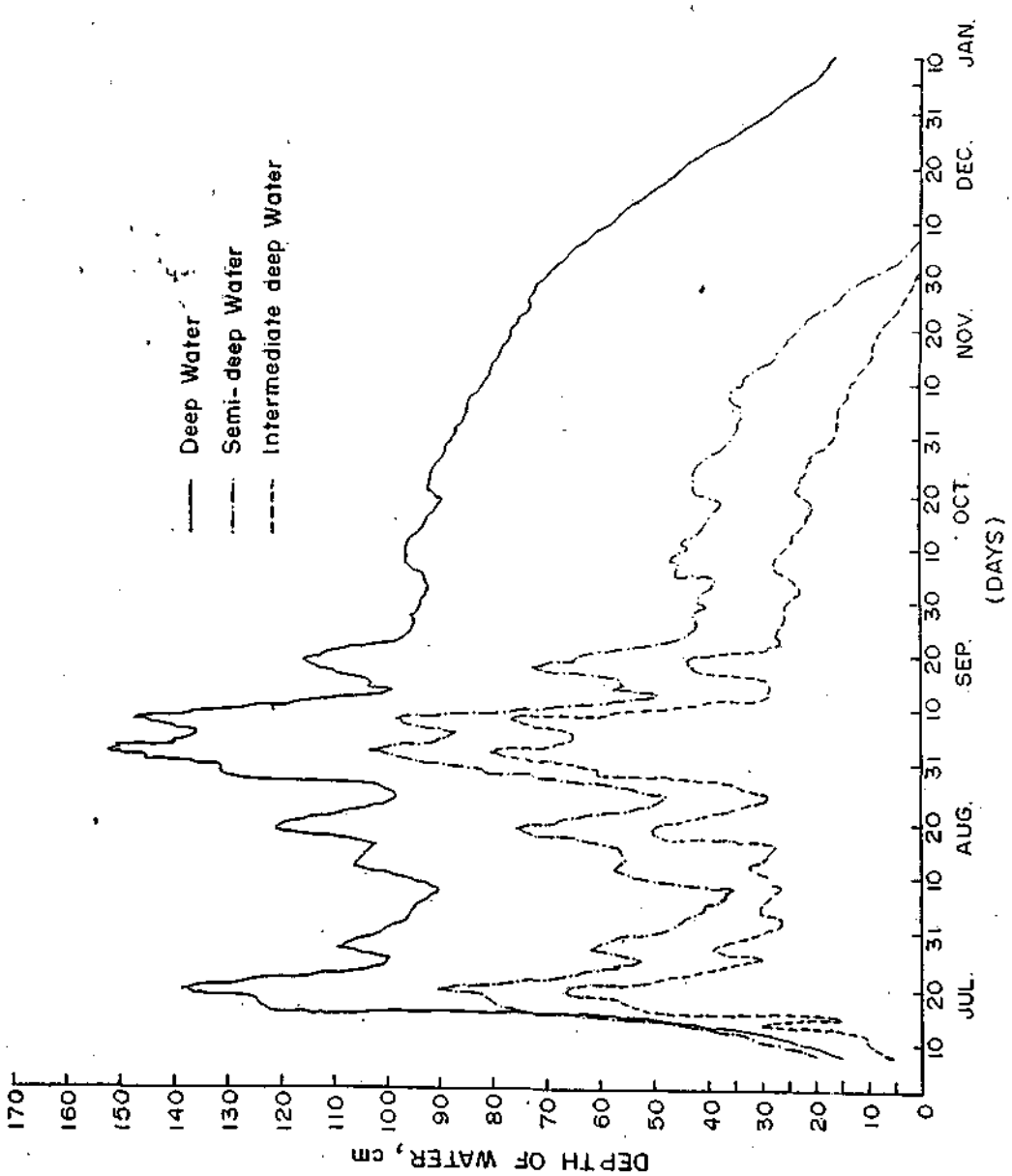

Fig. 1 : Daily variations in flooding patterns during growth period of rice under different lowland ecosystems at CRRI farm during 1994

Champaisali, Seema and Gayatri which flowered in the end of October were affected more than Panidhan and CR 260-77 which flowered in the first fortnight of November. Therefore the average rice yields were low, rarely exceeding 4 t/ha in intermediate lowland condition. The establishment of dry season crops like groundnut, maize, wheat, tomato and mustard grown with irrigation in rice fallows was satisfactory and yields were normal.

CRLRRS, Kharagpur.

The year 1994 experienced a total rainfall of 1527.6 mm (Table-3). The maximum rainfall was received in July (389.5 mm) which was followed by June (358.1 mm). Maximum temperature was observed in May (40.2°C) and temperature was observed minimum (12.9°C) in December. Relative Humidity (RH) was above 90 per cent in all months except April (88 per cent).

CRURRS, Hazaribag

The total rainfall received during 1994 was 1343 mm out of which the rainfall received during (July-September) was 769.9 mm. the winter and premonsoon period had less rains. The maximum temperature recorded was 98.2°C in June and the minimum temperature was 6.5°C in November months. maximum R.H. was 97.2% in july and minimum R.H. was 57.2% in May. (Fig.2)

Table - 3 : Weather data for CRLRRS, Kharagpur, 1994

Period	Month	Temperature (0C)		Relative humidity		Rainfall (mm)
		Max.	Min.	Max.	Min.	
Winter	January	29.6	12.7	93.0	32.2	3.4 (1)
	February	30.0	16.9	96.2	43.5	45.9 (4)
Pre-monsoon	March	38.6	21.8	92.9	24.8	21.2 (1)
	April	38.0	23.7	88.3	34.9	107.2 (10)
	May	40.2	26.3	95.2	38.9	72.0 (6)
South-West Monsson	June	35.6	26.0	97.7	63.2	358.1 (20)
	July	32.5	25.9	97.2	70.7	389.5 (22)
	August	33.3	25.9	96.0	70.6	329.5 (19)
	Sept.	33.2	24.6	95.2	59.6	140.1 (12)
Post-monsoon	October	32.7	22.6	95.0	50.6	58.1 (8)
	November	28.9	18.0	95.9	43.0	2.6 (2)
	December	27.0	12.9	91.3	32.7	Nil
Grand Total						1527.6

Figures in parenthesis indicate number of rainy days.

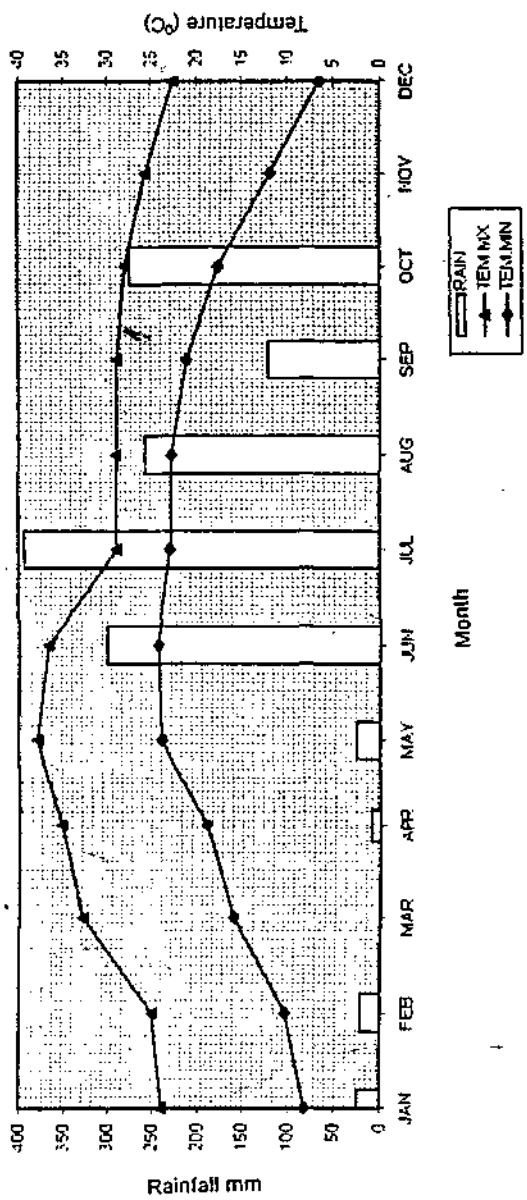

Fig. 2 : Rainfall and temperature, Hazribag 1994

RICÉ GERMPLASM

RICE GERMPLASM

EXPLORATION AND COLLECTION

CHARACTERISATION AND EVALUATION

- Yield potential
- Seed vaiability
- Screening of germplasm against flash floods
- Generation of breeding materials and selection in segregating populations
- Preliminary evaluation of fixed cultures
- Screening of germplasm against diseases

MAINTENANCE AND MULTIPLICATION OF SEED

- Rejuvenation and seed multiplication of early accessions
- Conservation of traditional rice varieties
- Gene conservation under storage
- Production and supply of breeder seed
- Production and supply of Nucleus seed
- Seed supply for indentors
- Documentation of germplasm

EXPLORATION AND COLLECTION

Two exploration and collection programmes were made during the harvesting period of wet season from 3 districts of Orissa. One trip was made to Koraput where 185 samples were collected while the other was made to Dhenkanal and Balasore districts from where 305 samples were collected. Besides, 50 accessions from Cuttack district were received from other agency aggregating to a total 540 samples in the year 1994-95.

One collection trip was made to Bhitarkanika mangrove forest to collect different populations of wild rice i.e. *Porteresia coarctata*. About 20 accessions of *P. coarctata* are being maintained at our Institute.

A set of 238 cultivars form Kalahandi district of Orissa were collected in collaboration with the Agriculture Department, Orissa. The varieties were grown in the field under transplanted condition. On preliminary assessment 63 varieties were found to be duplicates. The total duration of collected varieties varied form 60-165 days with four groups viz. extra early 26 percent, early 18 per cent , medium 20 per cent and late 36 per cent. The grain size fell into five groups viz. long bold 62 per cent, short bold 13 per cent, long slender 6 per cent, medium slender 7 per cent and short slender- 12 per cent. Husk colour showed black 6 per cent, brown 22 per cent, brown furrows 16 per cent and straw 56 per cent, Kernel colour had white 60 per cent and red 40 per cent. Test weight showed variability range of 12-35 g. belonging to 5 groups viz. (15 g-8 per cent, 16-20 g-22 per cent, 21-25 g - 29 percent, 26-30 g- 36 per cent and) 31 g. -5 per cent.

Fifty eight new upland rice germplasm from seven districts of Chotanagpur and Santhal pragans and ten local varieties viz., Bhimsail, Sandarjata, janglifata, Lohachur, Ranghusail, Indrasail, Bhuri, Debra Basmati, Mugi and Sankarsail were collected by CRURRS, Hazaribag. Five hundred and ninety three rice varieties were grown to regenerate fresh seeds. Three hundred and fifty local and high yielding varieties (collected upto 1993) has been handed over to Genetic Resources Division, CRRI. Out of which two hundred and fifty seven were rainfed upland varieties.

CHARACTERISATION AND EVALUATION

Yield potential

Characterisation of 240 accessions of new collections and about 500 accessions of exotic collections was done for their morphoagronomic traits. Several *japonica* varieties were grown during *Rabi*'1995 for assessing their yield potential.

Seed viability

During wet season, 1994 about 12,000 accessions were grown in the field for maintaining their viability, seed increase and supply to the researchers.

Screening of germplasm against flash flood

Twenty five days old seedling of 60 entries experiences flash flood during last week of August and during second week of October. Out of these 16 entries viz. Gayatri, Kabirajsail, Mugi, Savitree, Khejurchhor, Balasi, Bhuri, Sabita, CRK2-12, CRK 2-10, CRK 2-2, CRK5-1, CRK 10-5, Janglijata and Kumargore recovered and grew normally. The same set of material was screened for RTV and BLB. Except Mugi, Gayatri, CRK 2-12 and CRK 5-11 all were infected by RTV severely and for BLB, 20 entries viz. Gayatri, Sabita, Savitri, Mugi, Kabirajsail, Khejurchor, Batasi, CRK 2-10, CRK 2-2, CRK 5-1, CRK 10-5, CRK 11-115, Janlijata, Tilkachari, IR 42, Kumargore, Manasarovar, Raghusail, Sankarjata, Bhutamuri were moderately susceptible.

Regarding grain quality, all were medium and short bold except Kabirajsail, Sabita and Shandarjata.

Generation of breeding materials and selection in segregating population

F_1 seeds of nine crosses attempted during wet season 1993 were grown in pots and out of these F_2 seeds of CRK 1-21/IR 36 could only be harvested.

Two hundred fixed cultures obtained from the crosses during 1988, 191 had 140-160 days duration and the duration of the rest nine ranged from 90-130 days; 35 out of 191 had tolerance to RTV and 2 out of 9 among early groups were tolerant to RTV.

Preliminary evaluation of fixed cultures

Among 12 fixed cultures, IR 34/CR 149, Pankaj/Swarna, Pankaj/Jagannath, Cissadane/ CR 1018, CR 1102/IR 36, IR 42/ IET 11141, Pankaj/Kabirajsail, Cuttack Chandi/CR 1018 and CR 1006 selection recorded higher yield. None of the entries yielded less than 4 t/ha. Their performance is as follows :

Screening of germplasm against diseases

Sheath blight: Forty one rainfed lowland rice cultivars received from Kharagpur were evaluated for resistance to sheath blight fungus. Only two cultivars, Birakaka and Somalai gave a tolerant reaction of 3 and 4 respectively as against 7 in control.

MAINTENANCE AND MULTIPLICATION OF SEED

Rejuvenation and seed multiplication of early accessions

One hundred forty three early accessions were grown in 3-row-plots under transplanted condition for rejuvenation and seed multiplication. A collection of 155 traditional rainfed

rice cultivars from the plateau region of Bihar was evaluated for ten agromorphological characters. The characters showed wide variation. Secondary branches/panicle had the maximum variation (cv 39.5 per cent) followed by spikelets/panicle (cv 29.6 per cent). The lowest variation was for days to 50% flowering (Table-1). This collection offers a valuable gene pool and many donors were identified for their utilization in the breeding programme to improve yield, its components, grain size and shape. Characteristics and reaction to bacterial blight, brown spot and sealth rot of ten accessions with multiple desirable traits are presented in Table-2. Eighty three rice accessions were also characterised for 14 physico-chemical and cooking quality attributes.

Conservation of traditional rice variety

One thousand eight hundred eighty six traditional rice varieties collected from north-east India were grown in the fields under dibbled rows in the wet season of 1994 for rejuvenation, verification of genetic purity, seed increase, seed supply and deposition in the gene bank of national active germplasm collection. A duplicate set was deposited at the base collection centre, NBPGR, New Delhi.

Table - 1 : Range, mean and coefficient of variation (CV) for agromorphological charcters in 143 rainfed rice collections

Character	Range	Mean ± SEm	CV (%)
Plant height (cm)	79.2-154.7	112.5 ± 0.74	8.7
Days to 50% flowering	72.0 - 110.0	98.0 ± 0.50	7.3
Panicle length (cm)	16.5 - 32.0	23.0 ± 0.16	0.1
Primary branches pan^{-1}	6.0-13.2	9.6± 0.11	15.1
Secondary branches pan^{-1}	8.8-56.8	27.0 ± 0.80	39.5
Spikelets panicle^{-1}	34.0-177.0	104.0± 3.02	29.6
Fertility (%)	51.2- 96.7	77.5± 1.26	14.2
200 grain weight (g)	2.5 - 8.0	5.3 ± 0.06	14.1
Brown rice length (mm)	4.0 - 7.2	6.0 ± 0.23	9.2
L : B ratio	2.0 - 3.2	2.6 ± 0.02	9.6

Table - 2 : Characteristics of acessions with multiple desirable agronomic traits

Accessions	Reaction to BB	BS	ShR	50% flow	Height (Cm)	Pan. len.	Pri. br.							
Kalamdani	4	3	9	99	122	25.7	10.4	22.8	63.1	81.8	5.75	6.7	3.00	++
Tulsi-manjari	7	2	0	108	128	27.5	13.0	56.8	116.5	86.7	3.30	4.3	2.20	--
Sonachur	4	NA	0	98	132	30.0	11.2	34.8	152.5	65.2	4.00	NA	NA	NA
Lohasingh	8	NA	0	108	142	27.5	10.7	54.8	116.0	82.8	7.50	NA	NA	NA
Bhogana	2	4	0	111	133	27.7	12.5	48.2	155.0	66.1	5.75	6.0	2.40	+++
Goramalti	6	5	4	101	104	23.5	11.8	33.6	127.5	94.1	5.75	6.6	2.80	++
Radhakanka	3	9	0	105	112	23.9	10.9	18.2	165.6	86.1	5.75	-	-	+
Badnasal	8	3	2	105	120	24.5	11.7	22.0	150.3	93.1	5.00	6.9	2.90	++
Kalamkudh	12	7	7	100	116	23.7	10.6	29.2	127.8	87.8	5.35	6.8	3.21	++
Jhingasar	3	4	3	101	126	25.2	10.0	31.1	129.3	79.7	5.60	7.2	3.10	++

1. HRC 714; 2. HRC 719; 3. NIC 10550; 4. NIC 105505 5. NIC 105687; 6. 105699; 7. NIC105730; 8. NIC 105783; 9. NIC 105791; 10. NIC 105810

* *Figures underlined highlight the characteristics in the accessions.*

Gene conservation under storage

The seeds of three rice varieties belonging to three maturity groups viz., early (PTB 10), medium (T 141), and late (T 1242) were preserved at 5°C and 40 per cent R.H. during wet season, 1994. All varieties were found to be viable for last 30 years.

Production and supply of breeder seeds

About 6468 kg breeder seeds of 16 rice varieties viz. Annada(534), Basmati 358 (17). Basmati 370 (65), Basmati Ranbir (70), Pusa Basmati (49), Gaurav (18), Heera (667), IR 36 (165), IR 64 (1362), Kalinga 3(1638), Kasturi(76), PR 106(99), Ratna (1086), Savitri (195), Utkalprabha (155) and Vanaprabha (272) were produced during wet and dry seasons. The crops were certified by the monitoring team.

Four thousand three hundred forty five kg breeder seed was supplied to the National Seed Corporation, State Farm Corporation of India, State Seed Corporations of Orissa, West Bengal, Tamilnadu, Andra Pradesh, Maharashtra, Madhya Pradesh, Bihar, Rajasthan and Assam for production of foundation seeds.

Production and supply of nucleus seeds

A quantity of 209 kg of nucleus seed of 61 high yielding varities was produced.

About 136 kg nucleus seed of 47 rice varieties were supplied to NSC, BCKVV, OUAT, and other research organisations for production of breeder seeds and project works.

Seed Supply for indentors

A total of 32 requests for rice germplasm from different indentors all over the country were received and 137 varieties were supplied.

Documentation of germplasm

Data sheets for characterisation of germplasm were made and the data collected were fed to computer for making a catalogue.

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RAINFED UPLAND ECOSYSTEM

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CROP IMPROVEMENT

Advanced breeding lines

The Cultures RR 180-1 and Vandana were proposed for release in Madhya Pradesh and the culture RR 139-1 was recommended by the Rice Workshop for minikit trial in Bihar, West Bengal and Tamil Nadu.

Early generation progenies: Advanced lines derived from crosses RR 18-3/Bala, IRAT 112/Brown gora, IRAT 112/CR 143-2-2; Annada/RR 174-1 and CR 143-2-2/Ananda were found most promising and new breeding lines were generated by using *Aus* and japonica parents.

Early group: Nine promising cultures - RR 130-91-2, RR 137-88-1, RR 171-50-1, RR 203-16, RR 222-1-1, RR 225-1-5 AND RR 232-1-1, RR 288-1 and RR 303-5-3 were grown under transplanted conditions. Another set of 17 cultures were also grown under direct seeded condition alongwith Vandana, Aditya, Tulsi and Birsadhan 101 as checks. The cultures RR 232-1-1, RR 288-1, RR 222-1-1 and RR 254-2-14 gave higher yields than the checks. Two entries-RR 171-50-2 and RR 303-5-3 were nominated to IVT-VE and IVTIME respectively for testing under the DRR programme. RR 203-16, RR 222-1-1, RR 288-1, RR 215-2 and RR 217-1 were tested in multiloctional/adaptive trials.

Observational nurseries: Ninety two breeding lines derived from 25 crosses and irradiated mutants were grown under direct seeded condition with checks Vandana, Kalinga III. Birsadhan 101, Annada and Aditya. Seventeen bulks were prepared for yield testing. RR 241-170-B, RR 242-6-B, RR 242-9-B and IR38547-B-B appeared promising among the advanced breeding bulks under yield testing.

INGER nurseries: CT 7242-16-9, CT 7819-4-M-4, IR 53236-70-3 and IR 63372-14A were selected for testing from among the entries of IRDTN(44 entries), IURON(79 entries) and IIRON(197 entries).

An extra early line suitable for rainfed uplands

A semi-tall (110-120 cm) line CR 808-4 with long, panicles and long slender grains, was isolated from a natural cross of Heera and was found promising under direct seeding in wet season and transplanting in dry season. The yields obtained were specific as compared to other high yielding varieties of similar duration (Table 1) The new selection has built in tolerance to gall midge, blast and rice tungro virus.

Studies on agromorphological characters of rice

Genetic variability, phenotypic, genotypic and environmental correlations were studied

Table - 1 : Performance of early varieties under direct seeding

Variety	Yield t/ha	Duration (days)
CR 808-4 (Heera-NX)	4.0	97
CR 544-1-3-4	3.2	80
Kalinga-III	2.8	85
Vandana	3.5	90
Heera	2.2	70

for 11 morphoagronomic characters in 46 very early duration advanced cultures. The characters showed considerable range of variation and their manifestation was influenced by environmental factors as revealed by higher PCV than GCV. Grain yield/plant, biological yield/plant, spikelets/panicle and straw yield/plant had substantial genetic variability. Heritability in the broad sense was highest for 1000 grain weight (0.94) followed by harvest index. Grain yield/plant, panicle weight, spikelets/panicle, grain weight, biological yield and harvest index had high expected genetic advance associated with high heritability values suggesting the preponderance of additive gene effects in their expression and offering scope for selection. Growth parameters and their interrelationships were investigated using 14 elite breeding lines. Leaf area index, leaf are duration and cumulative growth rate and dry matter accumulation increased with advancing crop age while LAR decreased during the same period. RGR and NAR exhibited variable trend. Specific leaf weight decreased at 30 days after rice emergence (DARE) in most of the genotypes except RR 203-2-2, IET 10973 and IET 10980. Grain yield had positive and significant relationship with dry matter at 50% flowering (r=0.424*), biological yield (r=0.793*). Growth parameters *per se* appeared not to influence grain yield. Their direct and indirect contributions through dry matter production and other components should further be investigated.

Drought: Growth and development of two rainfed upland rice cultivars, Brown Gora and Vandana were studied under four moisture regimes- at water holding capacity (WHC) (29.2% soil moisture content-SMC), 80% WHC (23.44SMC), 60% WHC (17.62

SMC) and 40% WHC (11.81 SMC). Vandana had higher diffusive resistance and transpired less water than Brown Gora under stress conditions. Effects of stress were more pronounced at 40 and 60 % of WHC at 35 days stage.

Mass screening for drought tolerance and analysis of genetic control (Upland rice research consortium) : Root characteristics imparting tolerance to drought were examined in nine upland rice genotypes grown in cement tubes filed wit equal amounts of upland soil and maintained at field capacity fr 51 days. There were four sets and three replications. Roots were sampled 12 and 18 days afte sowing in two sets. Watering was withheld in the third set at 51 DAS. Roots were sampled in the third ad fourth sets 66 DAS. Root length, number, root fresh weight and shoot length were recorded and the stress induced changes, computed and expressed as ratio of the characteristics in stressed over saturated conditions.

Root fresh weight and number (Table-2) had high sensitivity to drought stress, drought susceptible Co 13 and Cauvery recorded maximum reduction in both characters while drought tolerant Kalakeri and Vandana had minimum reduction. High root weight ratio was not associated with root number in IRAT 112 indicating that roots thickened in this genotype under stress. Root length was not

Table - 2 : Changes in root and shoot characters due to drought stess in nine upland rice genotypes

Genotypes	Varietal group	Reduction		Ratio		Drought score
		Root len.	Shoot len.	Root fresh wt. (g)	Root No.	
Vandana	0	7.86	4.50	0.6961	0.9708	MR
Kalakeri	Aus	16.23	8.37	0.7188	0.9174	R
IRAT 112	Japonica	19.75	12.62	0.7692	0.5373	R
Moroberekan	Japonica	22.80	11.54	0.6088	0.7821	R
CR 143-2-2	Indica	8.57	3.61	0.5360	0.8395	R
Birsadhan 101	Indica	13.18	16.52	0.5164	0.8750	MR
Heera	Indica	27.34	24.02	0.5189	0.6383	R
Cauvery	Indica	30.93	26.71	0.3274	0.5351	S
Co 13	Indica	31.26	29.17	0.4943	0.6571	S

* *Based on leaf rolling*

significantly affected by drought in most genotypes.

CROP MANAGEMENT

Effect of tillage system on soil properties and plant growth

Three methods of tillage, namely minimum tillage were compared to understand the relationship between the tillage methods, changes in soil properties and upland rice productivity. Rice productivity was comparable in deep and conventional tillage while the crop growth was very poor in minimum tillage. Most of the root biomass was in plough layer. Rice grain yield was maximum in conventional tillage followed by deep tillage.

Effect of P application on rice productivity

This experiment was initiated in 1994 to generate improved data sets on availability and fate of P for validation of diagnostic, recommendation and predictive fools for long term P management in the uplands. Phosphorus was applied @ 0, 15, and 45 kg P_2O_5/ha. Root, shoot weight and grain yield was maximum at 15 kg P_2O_5/ha. Root development upto 45 cm depth was observed with maximum concentration between 0-15 cm.

Soil fertility management of acid soils for upland rice

The long term fixed plot experiment was continued to monitor the effects of different fertility levels and combinations on sustaining upland rice productivity. There were eight combinations with 60 kg N, 40 kg P_2O_5, 30 kg K_2O and 1.0 t lime/ha. Except in one of the control treatments, crop residue was returned to respective plots after harvest of rice for each treatment.

Incorporation of crop residue, i.e. entire quantity of rice straw into the soil significantly increased the grain yield consistently (Table 3). Application on N alone recorded significantly lower yield than combination of N with P, K or lime in first and second year. It was further noted that application of N in conjunction with K and crop residue yielded similar to those recorded with NL, NPK and NPKI, combined with crop residue in all the years.

Utilization of VAM for dryland rice improvement

Enhancement of native VAM population: Estimates of colonization by VAM from rhizosphere soils in the different cropping systems during the year revealed that (i) rice-pigeonpea intercropping led to substantial increase in native VAM population over other systems, (ii) no-off season ploughing slightly increased VAM population, but no synergism was noticed when long duration

Table - 3 : Effect of different fertility levels and combinations on grain yield

Treatment	Grain yield (t/ha)			
	1992	1993	1994	Mean
Control without RCR	0.35	0.53	0.94	0.62
Control + RCR	1.43	0.98	1.20	1.20
N + RCR	1.56	1.59	2.08	1.74
NP + RCR	2.40	1.76	1.94	2.03
NK + RCR	2.57	1.92	2.14	2.21
NL + RCR	2.69	1.91	2.27	2.29
NPK + RCR	2.16	1.94	2.05	2.05
NPKL + RCR	2.64	2.07	2.16	2.29
LSD 0.05	0.65	0.17	0.13	0.23

pigeonpea was intercropped with rice and (iii) sequence cropping of toria (*B.campestris var. toria*) after rice reduced VAM population.

Effect of soil nutrients on native VAM colonization as a function of rice varietal interaction: Differential varietal sensitivity to VAM was detected earlier. An attempt was made to work out how soil nutrient status, particularly P, influenced such differential sensitivity. A set of 15 upland rice genotypes (9 indigenous, 6 exotic) were tested under four fertilizer level, viz. $N_{40}P_0K_{20}$, $N_{40}P_{30}K_{20}$, $N_{40}P_{30}K_{20}$ and FYM (2.5 t/ha). All the indigenous genotypes had decreasihg colonization with increased fertilizer levels, particularly P. No such changes were noticed no exotic cultivars.

Identification of suitable crop after upland rice to enhance native VAM: Colonization pattern in five potential post wet season crops viz. linseed, bengal gram, niger and toria grown after upland rice (Vandana) was examined at maturity of the respective crops. Linseed and toria did not show any colonization. Horse gram had the maximum colonization followed by niger and bengal gram.

Long term manurial trial

An experiment was conducted to understand the nutrient dynamics on a long term basis and its relationship with rice crop growth and productivity. The experiment had 16 combinations of inorganic and organic fertilizers (manures) with Vandana as the test variety. Crop growth was better with 2.5 t/ha of FYM

and 40:30:20 kg NPK. Maximum rice grain yield (1.8 t/ha) was obtained with this treatment, consistently for the last three years.

CROP PROTECTION

Weed Management

Effect of weed control practices on upland rice (FSRE)

Upland rice loses its grain yield to the extent of 95 per cent if not weeded and hence weed infestation is one of the major factors that limit the production in upland rice. Weeds need to be controlled before the crop is 3 weeks old or earlier, through hand weeding, mechanical weedling or weedicide application. Since the human labour is expensive, adopting chemical weed control or combination of mechanical+chemical methods is cheaper. An experiment was conducted in the farmers fields at Bhairpur village during 1994 with a well adopted upland variety. Annada (105 days duration). The weeded crop of farmer's practice increased the grain yield by 66 per cent over unweeded crop. Hand weeding with a finger weeder, two times at 3 week intervals enhanced the grain yields by 106 per cent than unweeding check. In the absence of these weeders, a narrow space could be used for loosening the soil and removing weed in Inter-row spaces. There was an increase in grain yield by 56 per cent when compared with farmers practice of weed control. It was found that chemical weed control with butachlor @ 1.5 kg ai/ha followed by a hand weeding, 25 days after sowing produced the highest grain maximum number of panicles/m^2 recorded and large panicles size (22 cm). The chaff content in the grain was indicating minimal (11.3 per cent) that chemical weed control @ 1.5 kg ai/ha of butachlor and a hand weeding 25 days after seeding helped the crop to its maximum capacity for the sink. Spraying of liquid formulations (1.5 kg ai/ha) in 500-1,000 liters of water of thiobencarb (Saturn) or butachlor (Machete, Punch, Delchlor, Tee) within 2-3 days after the first sowing, if the seeds are sown in dry soil or within 5-6 days of sowing, when the crop but not the weeds has just germinated an effective. To avoid patchy growth, spraying of the weedicide was done uniformly throughout the rice field as per the treatments. The success and high production of rainfed upland rice depends upon the effective weed control.

Economic threshold level of weeds in upland rice

A study was carried out in wet season to find out the threshold level of weeds in direct seeded upland rice (cv. Annada). The field was infested with the weeds *Cyperus iria*. The dry weight of this weed under unweeded condition was estimated to be 2.4 t/ha. Taking this quantum of weed bio-mass as standard (100), different levels of biomass of this

weed-0, 10, 25, 50 and 75 per cent were maintained through periodical weedings. It was observed that maintaining weeded conditions - 10, 25 ,50 and 75 per cent of weed biomass in control (100 per cent) reduced the grain yield by 8.6, 20.0, 24.5, 36.6 and 40.3 per cent respectively over the plots which were maintained with 10 per cent weed incidence (weed biomass around 0.24 t/ha) weed control measures need not be taken since yield reduction is marginal. Beyond this level weed control measures have to be initiated.

Chemical weed control

A field experiment was carried out to evaluate three liquid herbicides viz. anilophos 30EC @ 0.4 and 0.6 kg a.i./ha, butachlor 50EC @ 1.0 and 1.5 kg a.i./ha and pendimethalin 30 EC @ 1.0 and 1.5 kg a.i./ha alone was well as in conjunction with application of 2,4 DNa 80 WP at their lower doses. Anilophos, butachlor and pendimethalin were applied at emergence of rice as early post emergence whereas 2, 4 D Na 80 WP was applied after a month of sowing. Four additional treatments namely, stale seed bed, weed free, hand weedling twice and no weeding were also included in the experiment to compare the efficiency of herbicides *vis* a *vis* other treatments.

Anilophos and pendimethalin yielded equally both at their lower and high doses. But the efficiency of butachlor was significantly better at higher dose. Efficiency of the butachlor, anilophos and pendimethalin was significantly higher when their lower dose was followed by application of 2,4 D Na and had yields similar to that obtained in two hand weedings.

Identification of weed competitive cultivars (URRC) :

Nineteen upland rice cultivars originating from diverse geographies and belonging to different isozyme groups (aus, indica, japonica) wee grown under late sown condiions in four sets (field capacity, irrigated; weed free, unweeded to identitify characters that confer weed competitiveness and to rank characters which fonfers weed competiiveness.

A set of traits ranked by competive abilty among aus indica and japonica were identified, Early sprouting, quick emergence, early seedling vigour, leaf length and breadth, plant height and tiller number varied among genotypes but correlations for weed competitiveness were strong for early seedling vigor and less so for spread of emergence, sprouting and plant height in that order. Leaf length and breadth varied among within isozyme groups (Table 4). Varieties with better weed competitive ability had long, broad leaves which remained green for longer periods.

Growing conditions did not affect plant height in weeded or unweeded conditions but tiller number improved significantly under weeded conditions in stressed as well as irrigated conditions. Japonica cultivars having low

Table - 4 : Percent reduction in growth parameters and yield of upland rice due to weed infestation

Genotypes	Leaf/ plant #	Leaf len. cm.	leaf bre. cm.	Tillers plant #	Shoot wt/pl g.	Grain wt/pl g.	Grain y./m² g.
Azucena	0.00	15.29	4.08	14.71	15.24	48.72	25.00
OS 6	5.00	13.63	14.02	0.00	22.79	32.76	13.04
IR 55548-05	2.70	18.28	2.83	8.00	4.14	16.10	43.66
Br gora	0.00	5.32	19.19	28.13	4.96	3.70	3.03
Birsa 102	11.76	2.05	4.44	10.71	23.48	41.54	0.00
Saita	8.82	0.20	13.46	30.00	46.06	56.76	62.26
VHC 1253	10.00	0.98	12.15	15.63	0.93	2.54	23.26
RR 174-1	13.89	26.48	7.86	22.22	42.79	19.78	35.45
Vandana	9.09	7.93	19.61	8.82	34.00	35.84	45.45
Laloo 14	8.33	12.85	12.50	5.56	13.13	10.57	7.69
Kalinga III	12.55	1.43	21.74	13.51	25.86	20.86	40.59
Cauvery	0.00	10.76	12.77	32.14	33.99	22.67	10.71
Birsa 101	0.00	16.39	1.30	31.58	48.51	28.03	48.89
RR 51-1	0.00	23.65	11.69	13.16	49.40	53.52	51.37
RR 180-1	2.94	7.57	2.41	5.88	26.81	41.31	4.29
RR 139-1	8.33	2.20	3.09	28.95	12.34	36.14	24.93
RR 2-6	0.00	6.89	7.37	6.67	29.76	20.61	13.79
RR 20-158	10.00	1.65	17.71	2.78	12.90	23.65	33.46
CR 143-2-2	0.00	1.37	3.74	10.71	10.64	3.81	11.11

tillering had higher weed infestation. Grain and straw yield reduction due to weed infestation was higher in the indica cultivars. Indica genotypes had higher yield potential which was expressed only under weeded conditions. Laloo 14, Vandana, RR 2-6, Brown gora, RR 20-158, RR 139-1 and RR 51-1 were weed competitive. Among the gorups aus cultivars had better weed competive ability.

Competitiveness of major weeds (Upland rice research consortium) :

Rice yriety Vandana was grown with natural and sole stand of *Ageratum conyzoides* L., annual Cyperus species, *Echinochloa colona* (L.) Link, *Setaria glauca* (L.) and an unidentified broad leaved weed. These were compred with no weeding and weed free. There was 80.9% yield reduction due to weeds under no weeding as compared to weed free (Table 5). Yield reduction by weeds were ranked as *Ageratum conyzoides*> UW> *Cyperus species*> *E. colona* > *Setaria glauca*. Critical limit of E. colona population (Upland Rice Consortium) :

Population level at which yield reduction is significant with *E. colona* was estimated by growing rice var Kalinga III in association with 0, 75, 188, 375, 563 and 750 plants of E. colona per m^2 as sole weed. Grain yield of rice decreased linearly with increasing stand of E. colona. A response curve for grain yield (Y) was worked out as Y = 2.21 - 0.08 (# E. colona/m^2). Based on this it was estimated that beyond 262 plants of *E. colona* cause signficant reduction in grain yield.

Weed community stratification in relation to location and fertility management (URRF)

The study was conducted in two parts viz., location and soil fertility management. Weed observation for soil fertility was taken in a fixed plot experiment with different fertilizer levels. For location effect weeds were sampled periodicaly from the research station and a farmers field in Meru. Weed growth

Table - 5 : Grain yield of upland rice in association with mixed weed stand, weed free and sole stand of major weeds

Treatments	Grain yield (t/ha)	Yield redn. (%) *
Weed free	2.78	–
Weedy	0.50	80.9
Ageratum conyzoides	2.29	17.5
Unidentified weed (UW)	2.38	14.5
Annual Cyperus sp.	2.54	8.4
Echinochloa colona	2.59	6.8
Setaria glauca	2.59	6.8

invariably increased at higher fertility levels and the differences between treatments were not discernible. There was higher number of weed species at the research station and differences in weed species at different locations.

Disease Management

Blast

Varietal evaluation against blast

A set of International blast differential, near isogenic lines and IR 50 mutants were evaluated against blast under uniform blast nurseries. The entries C 105A51, CRM 49,51,59, Basmati 370 and IR 64 gave a consistently resistant reaction. The prevalent race group was IE. Among the different natural and exotic cultivar/varieties tested Dalbao, Lunishree, Nagheri, Panidhan and Moroherekan showed 0.1 to 0.2 per cent average mean leat are damage, Jaladhi-1 and IET 3264 were found tolerant to blast with 0.1 to 3 per cent average mean leaf area damaged.

Collection of blast isolates and characterization of their virulence pattern

Leaf and neck blast infected samples were collected from varieties, Annada, RR 50-1, Karuna, HR 12 from CRRI rice fields and the isolations were made under artificial inoculation, the physiological races identified were. IC-2, ID-3, IC-1 and IE-1. The identified races were inoculated back to the susceptible varieties Karuna and HR 12 separately. It was observed that the disease pressure was more in Karuna when inoculated with race IC-1, indicating the virulence of the race. The highly susceptible varieties Karuna and HR 12 were grown throughout this year to see the presence of the disease and the identification of the races, it was found that the disease incidence was more in March-April and October-November. The race IC, ID and IE groups were prevalent during this period.

Genetics of blast

Inheritance of leaf blast resistance was investigated in F_2, F_3 generations of two crosses (Annada/Prasanna and BG 367-4/RR 149-177) using generation mean analysis. The significance of sealing test 'D' and joint scaling test showed the presence of nonallelic interactions in the inheritance of this trait. Additive and dominance gene effects were large and predominant. Blast resistance was found to be highly heritable. However, the presence of large dominance gene effects with non-allelic interactions limits te usefulness of early generation selection. It is therefore, suggested that instead of single plant selections in F_2 progeny selection in F_3/F_4 should be adopted to improve blast resistance.

Components of slow blasting resistance

Rice genotypes were evaluated for 10 compo-

nents of slow-blasting resistance like the incubation period (ICP), latent period (LP), infectious period (IP), infection frequency (IF), infection efficiency (IE), lesion number (LN), necrotic zone area (NZA), chlorotic zone area (CZA), sporulation capacity (SP) and finally the area under disease progress curve (ADPC). The estimation of genetic parameters like the genotypic coefficient of variation, genotypic variance, heritability genetic advance and genetic gain revealed that each of the component was genetic and heritable in nature. Maximum correlated response and relative selection efficiency could be expected through indirect selection for LN followed by IE. There was a strong association among the components both at genotypic and phenotypic levels except for IF, in terms of the number of penetration points which was not considered as an important component. Path coefficient analysis revealed highest direct effect of LN followed by NZA on the ADPC both at genotypic and phenotypic levels. Indirect effects of fairly high magnitude were also exerted by other components through LN and NZA towards ADPC (Fig.1). The LN and NZA were identified as the most important genetic and heritable components for indirect selection of slow-blasting resistance in rice.

Genetic diversity among slow blasting rice genotypes

Fifteen rice genotypes, originating from eight countries of widely different eco-geographical regions, were subjected to multivariate analysis, for assessing the nature and degree of inta-specific divergence with regard to their slow blasting resistance. Based on the 14 component characters of slow blasting resistance, these genotypes formed 9 constellations (Table-6)

Seven of the 15 genotypes formed a single cluster, while the remaining 8 were single genotype clusters. The grouping of the genotypes form different eco-geographic regions to the same cluster and from the same eco-geographical region into different clusters, indicated the non-parallelism between geographical distribution a genetic diversity. The component characters like infection frequency, infection efficiency and chlorotic zone area exhibited highest contribution towards genetic diversity; the necrotic zone area and infectious period being the second ranking contributors. The use of genotypes like Lien Tsan-50, DM-27 and Surajmukhi, belonging to genetically diverse clusters (Fig.2), as parents in a hybridization programme would generate broad spectrum of recombinants and facilitate selection of desired slow blasting lines.

Selection index for blast

The construction of selection indices from the estimate of genotypic and phenotypic variances and covariances of 10 components

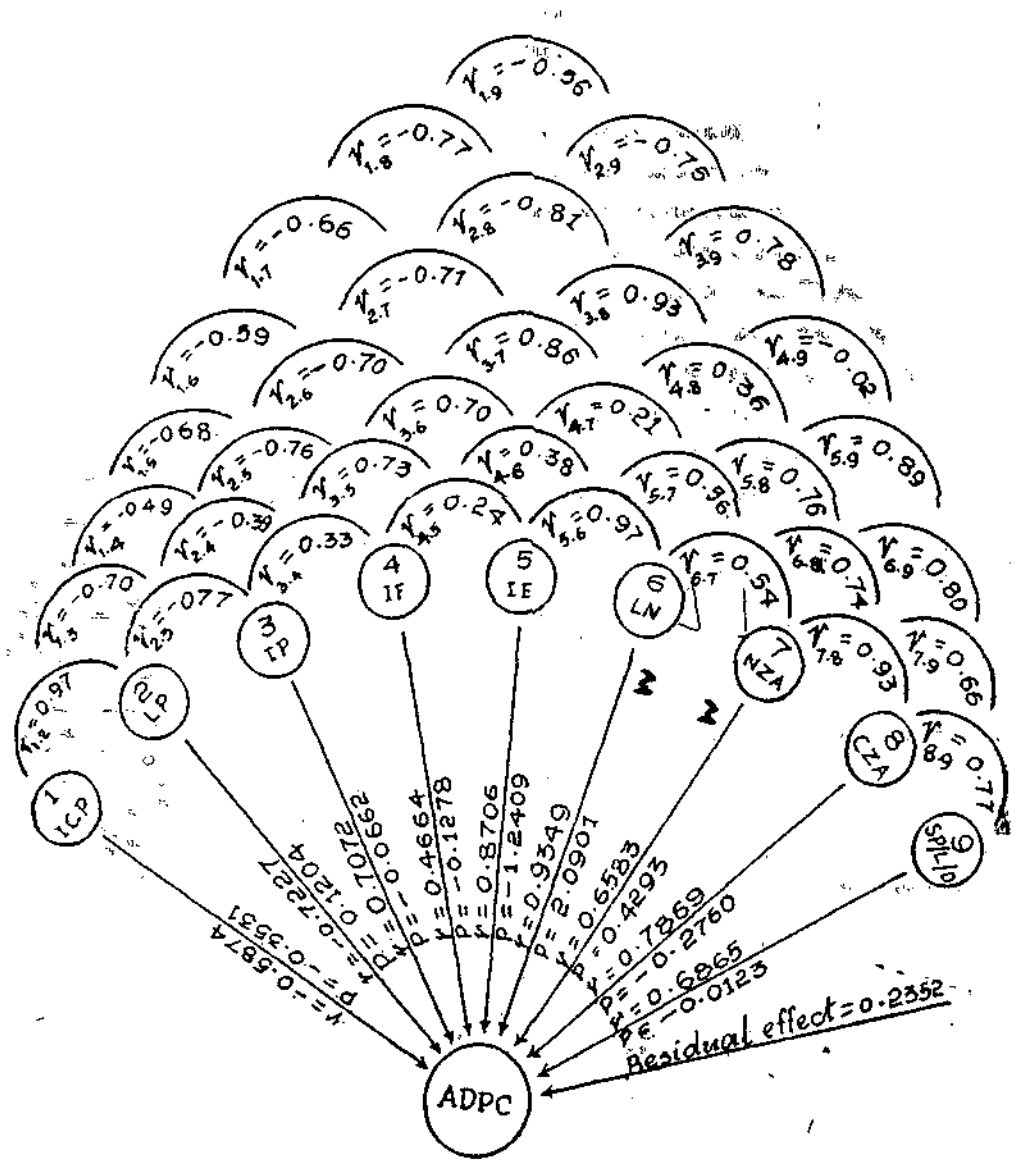

Fig. 1 Path diagram showing the genotypic corrrelation between the components of slow blasting resistance and their direct effects on ADPC

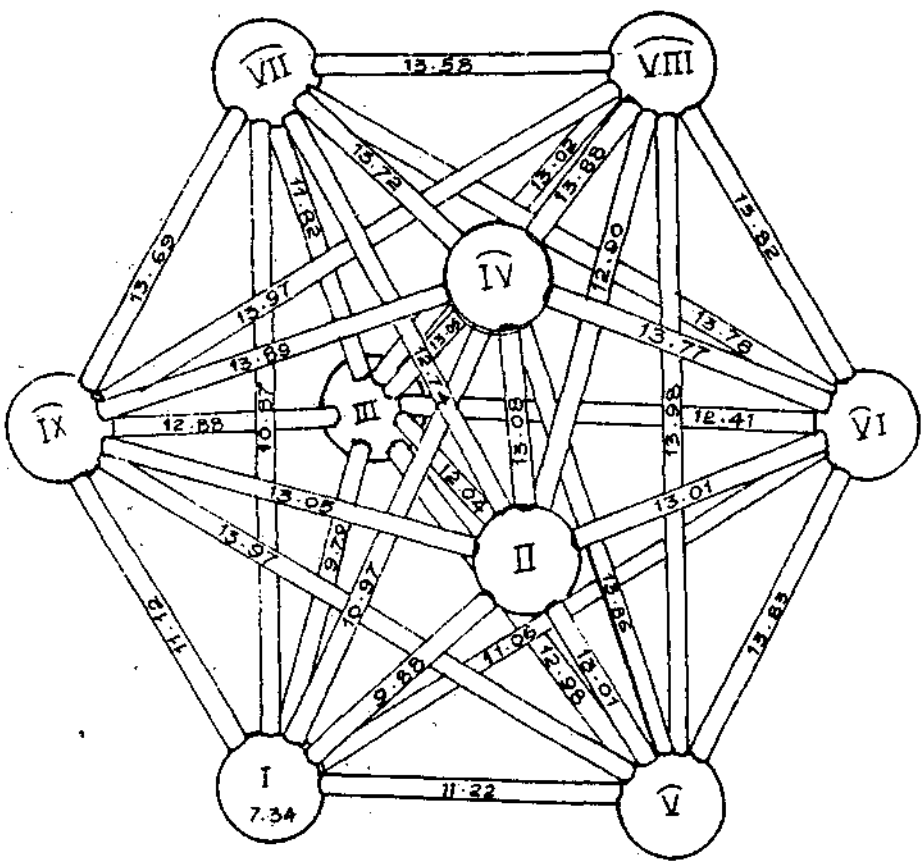

Fig. 2 : Cluster diagram showing the inter and intra-cluster distances (D2-values) among nine groups of 15 rice genotypes

Table - 6 : Composition of the clusters based on the D^2 values

Cluster	No. of genotypes	Genotypes (Origin)
I	7	Sakai (Malaysia) DJ-88 (Bangladesh) Dahanala (Sri Lanka) Laurent-TC (Source-Philippines) Chiang-Tsene-Tao (Brazil) DNJ-155 (Bangladesh) DZ-192 (Bangladesh)
II	1	Lien-Tsan-50 (China)
III	1	DM-27 (Bangladesh)
IV	1	Surjamukhi (Bangladesh)
V	1	E-425 (West Africa)
VI	1	N-22 (India)
VII	1	CR 570 (India)
VIII	1	CR 389-1045-16 (India)
IX	1	Karuna (India)

of slow blasting resistance, the estimate of the economic weight each component and the comparison of the expected genetic advance (GA) and relative selection efficiency (RSE) revealed the superiority of the single component index 6.4 LN and the two component index 5.61 LN+14.67 NZA over rest of the multiple component indices. The sequential addition of the components to the index one by one did not result in appreciable gain in terms of predicted GA and RSE (Table-7). Comparison of the index scores estimated by the single component index involving LN, the tow component index involving LN+NZA or the multiple component index involving all the components, did not result in any appreciable deviation in ranking order of the 15 rice genotypes from those by direct selection through the parameter ADPC. Hence the use of the single component index involving LN

Table - 7 : Selection indices, expected genetic advance (GA) and relative selection efficiency (RSE) over straight selection

Index content	Slection indices	GA	RSE
ADPC	$1.000X_{10}$	283.79	100.00
LN	$6.408X_1$	264.74	93.29
IE	$28.17X_2$	246.89	87.00
NZA	$44.53X_3$	186.00	65.54
CZA	$27.90X_4$	222.53	78.42
SP	$140.93X_5$	193.88	68.32
SP	$140.93X_5$	197.11	69.46
IP	$18.81X_6$	188.76	66.51
LP	$-65.12X_7$	128.41	45.25
ICP	$-51.59X_8$	128.41	45.25
IF	$349.66X_9$	128.85	45.40
IN+IE	$9.77X_1 + 16.37X_2$	267.23	94.17
LN+NZA	$5.61X_1 + 7.29X_4$	267.60	94.30
LN+SP	$7.16X_1 - 28.67X_5$	265.85	93.68
LN+IP	$5.95X_1 + 2.60X_6$	265.47	93.55
LN+LP	$5.96X_1-9.83X_7$	265.62	93.60
LN+ICP	$6.30X_1 - 3.87X_8$	264.88	93.34
LN+IF	$6.10X_1 + 92.42X_9$	266.62	93.95
LN+ADPC	$-0.02X_1+1.00X_{10}$	283.78	100.00
IN+IE+NZA	$9.87X_1 - 21.45X_2 + 17.93X_3$	273.77	96.47
LN+IE+NZA+CZA	$10.06X_1-19.28X_2+30.44X_3-9.44X_4$	274.25	96.64
LN+ .... + SP	$8.28X_1-2.68X_2+40.87X_3-13.77X_4-59.99X_5$	275.86	97.21
LN+ .... + IP	$8.3X_1-3.66X_2+39.62X_3-9.02X_4-54.31X_5-3.55X_6$	276.22	97.33
LN+ .... +LP	$8.75X_1-6.91X_2+39.20X_3-9.86X_4-49.67X_5-4.24X_6-8.8X_7$	276.64	97.48
LN+ .... +ICP	$7.68X_1+0.12X_2+39.66X_3-9.28X_4-71.70X_5-4.02X_6-19.53X_7+15.57X_8$	277.24	97.69
LN+ .... +IF	$6.35X_1+7.58X_2+48.72X_3-15.57X_4-64.41X_5-4.25X_6-15.85X_7+16.49X_8+74.64X_9$	277.53	97.79
LN+ .... +ADPC	$-0.09X_1-0.62X_2-0.97X_3+0.38X_4+4.47X_5-0.06X_6+1.92X_7-1.69X_8+0.23X_9+1.022X_{10}$	283.80	100.00

X_1 = Lesion number

X_2 = infection efficiency

X_3 = Mean necrotic zone area,

X_4 = Mean chlorotic zone zrea

X_5 = Space production ability

X_6 = Infectious period,

X_7 = Latent period

X_8 = Incubation period

X_9 = Infection frequency

X_{10} = Area under disease progress curve

as well as the two component index involving LN+NZA are advocated for easy and quick identification of slow blasting rice genotypes from large screening populations.

Durable resistance to blast

Attempts were made to identify durable resistance through analysis of stability of slow blasting resistance in 25 rice genotypes tested over a period of 4 years. The analysis of variance revealed highly significant genotype (G) as well as environment (E) mean square (MS) thus indicating that both represented an array of diverse conditions for disease development.

The pooled analysis of variance revealed that G x E interactions were a linear function of the additive environmental component. The G x E linear MS was due to the differences in fitted regression lines and indicated that each genotypes had its characteristic response to the environmental changes. The 14 genotypes from serial 1 to 14, with low mean disease score, least response in their disease reactions to environmental changes (i.e. b_i=o) and minimum deviation from regression (S_d^2=0) were identified as possessing above average stability for resistance (Table-8). The genotypes, Surajmukhi and N.22, with moderately low mean disease score, unit regression coefficient (b_i=1) and minimum deviation from regression (S_d^2=0) were identified as possessing average stability. Rest of the genotypes from serial; 17 to 25, with high mean disease score, variable bl values and deviation from regression significantly greater than zero (S_d^2>0) were considered as possessing below average stability. Thus the genotypes from serial 1-16 with average to above average stability for resistance could be considered as possessing durable resistance.

Leaf and neck blast relationship

Response of 34 breeding lines and six traditional *(aus)* cultivars were consistent in the second year qualitatively; the amount of disease (neck blast) however varied quantitatively. Aus cultivars in general had tolerance to panicle blast (Brown gora, Kalakeri), while some of the indica genotypes (RR 51-1, Vandana) had increased susceptibility at flowering.

Effect of drought on blast

Soil moisture tension did not exceed 0.33 MPa during 1994. Leaf and neck blast in the dry, normal and wet nurseries were similar except for minor variations. Comparison of the results over seasons showed that drought predisposed upland rice to blast with pronounced effect at neck blast stage.

Epicuticular wax content was estimated in drought/blast susceptible (Cauvery), drought and blast resistant (Moroberekan) and drought susceptible/blast resistant geno-

Table - 8 : Mean disease score (% severity), phenotypic index (Pi), regression coefficient (bi), deviation from regression (S^2d) in respect of 25 rice genotypes exposed to 4 environments (seasons)

Sl. No.	Genotypes	Mean disease score		F_i	b_i	S_d^2
1.	Sakai	2.96a	(9.87)	-24.45	0.24	-6.92
2.	DZ-191	3.13ab	(10.03)	-23.37	-0.28	-7.61
3.	Dahanala-2014	3.13ab	(10.03)	-25.61	0.73	-7.18
4.	DNJ-155	3.33ab	(10.53)	-23.97	0.01	-7.91
5.	UCP-188	3.331b	(10.51)	-23.96	0.00	-7.96
6.	DM-27	4.83c	(12.59)	-23.03	0.38	-6.43
7.	DJ-88	3.88ab	(11.17)	-23.33	-0.29	-7.51
8.	Laurent-TC	4.44bc	(12.00)	-24.19	0.04	-6.73
9.	Goda Heenati	4.99c	(12.76)	-23.98	0.05	-7.37
10.	Chiang-Tsene-Tao	4.08ab	(11.60)	-21.83	0.01	-5.71
11.	Lien-Tsan-50	4.50c	(12.13)	-23.03	-0.47	-7.44
12.	CR 570	4.80C	(12.56)	-22.15	-.020	-7.25
13.	E-425	5.83c	(13.80)	-22.79	-0.60	-7.66
14.	Jumi-i	5.33c	(13.22)	-23.03	0.43	-6.85
15.	Surjamukhi	15.83d	(22.33)	-14.98	2.11*	-6.45
16.	N-22	20.83e	(26.88)	-4.84	2.66**	-7.19
17.	Bakka Biasa	49.37f	(47.34)	24.89	11.21*$	67.40++
18.	Kalubalawee	57.78g	(52.26)	24.89	-10.76	156.02++
19.	CR 289-1045-16	57.08g	(53.86)	19.39	13.52*$	143.48++
20.	Ratna	73.75i	(64.27)	49.03	-0.28	74.78++
21.	ARC 7046	66.12h	(57.12)	34.63	6.65	53.64++
22.	Riace	89.79j	(76.41)	49.03	0.28	74.79++
23.	Indian Dular	97.50k	(83.54)	49.03	0.53	72.96++
24.	Warangal 1253	97.69k	(82.55)	48.46	-0.64	22.31+
25.	Karuna	97.50k	(83.58)	49.19	-0.34	70.31++
	Mean	31.27	(32.51)	-	1.00	-
	LSD (P=0.05)		1.97	-	-	-

* & ** Significantly different from zero at P = 0.05 and 0.01, respectively.

$ Significantly different from 1.0 at P = 0.05

\+ & ++ Signficantly different from zero at P = 0.05 and 0.01, respectively

Figures in the parentheses are transformed angular values.

types (RR 203-16). Leaf blast tolerance was correlated with EW content in drought tolerant genotypes. However the relationship was variable with deep rooted genotypes. Leaf age differences also influenced estimation of the wax content necessitating refinements in the protocol for wax extraction.

Seed treatment to control blast

Various systemic (Carbendazim and Beam 75) and non-systemic (Mancozeb) fungicides were evaluated for seed treatment for controlling blast. In blast susceptible variety Karuna, seed treatment with Mancozeb (Dithane M-45) showed 30-50 per cent infection as compared with Carbendazim (Bavistin 50WP) treatment which recorded only 5-10 per cent infection. Seed treatment with Beam 57 WP resulted in negligible blast infection with significant increase in yield over untreated check plots.

Identification and characterisation of blast pathogen lineages (URC-ARBN)

Characterisation of *pyricularia grisea* population from upland rice areas of Eastern India using virulence analysis and DNA fingerprinting was initiated. *Pyricularia grisea* samples from upland rice areas of the plateau region (45 locations) were collected and isolated for pathotyping using differentials (Fig. 1). serve to design sampling strategies for eastern India.

Popular upland rice variety Vandana was crossed with two near isogenic lines (C 101 A 51 and C 101 Lac) found resistant at Hazaribag (Table-9) and Moroberekan for recurrent selection using pathotyping and market aided selection.

Effect of plant products against blast

Effectiveness of two botanical extracts from *A.marmelos* and *O. sanctum* in ethanolic, aqueous and essential oil preparations were tested for the control of rice blast disease in the field. All the treatments (Table-10) had remarkably lower level of incidence of foliar blast when compared to control except extracts of essential oil of *O. sanctum* because of some extraneous factor that effected this particular treatment.

A mixture of Carbendazim and essential oil and essential oil alone from *O. sanctum* were tested along with steamed aqueous and ethanolic extract produced varying degree of increased of decreased fungitoxic performance (Table-11).

Brown Spot

Genetics of brown spot

Two recessive genes were identified controlling resistance to brown spot in RR 35-4-1, RR 20-5 and RR 36-141. The gene present in RR 20-5 and RR 36-141 were same but the R gene in RR 35-4-1 was different.

Table - 9 : Reaction of Near Isogenic lines exposed to a population of *Pyricularia grisea* blast nursery, Hazaribag 1994

Varieties	Blast reaction			
	Set 1 lesion type	DLA	Set 2 lesion type	DLA
C 103 TTP	3	1	4	1
C 101 Lac	2	0	4	1
C 101 TTP-1	4	25	4	50
C 101 Lac	1	0	3	0
C 101 A 51	1	0	1	0
C 101 PKT	4	50	4	75
C 102 PKT	4	40	4	75
C 104 PKT	4	60	4	75
C 105 TTP-4-L23	4	50	4	75
WHD1575-1-127	--	--	1	0
Moroberekan	1	0	1	0
Brown gora (ch)	4	25	4	30

Table - 10 : Demonstration of the effectiveness of *Aegle marmelos* and *Ocimum sanctum* extracts for rice blast control in field, 1994-95

Replications	Foliar blast (%) 4 days after 3rd spraying of weekly interval					
	Control	Aegle marmelos (Aq.)	A. marmelos (Eath.)	O.sanctum* (Essential oil)	O. sanctum (Eth.)	Carbendazim
R_1	60	15	15	40*	25	20
R_2	80	15	15	25	30	20
R_3	65	15	15	25	20	20
R_4	60	15	15	25	20	15
R_5	55	15	15	20	20	25
R_6	60	20	15	20	25	15

*1 = Owing to execessive rain of spray fluid due to leakage in sprayer, detected once the plant showed phytotoxicity, hence the spraying was abandoned.

Table - 11 : Fungitoxic performance of *O.sanctum* (Krishna) leaves steamed aqeous, ethanolic, essential oil extracts and/or carbendazim mixture against conidial germination of rice blast fungus

Concentration	TREATMENT						
	SAE	SAE+ Carbendazim	Exthanolic extract conidial	Ethanolic extract + Carbendazim germination (%)	Essential oil (%)	Essential oil + Carbendazim	Carbendazim
0.0001	98 (81.8)	582,4,5 (40.6)	98 (81.8)	522,3,5 (46.1)	881,3,5 (69.7)	981,4,5 (81.8)	24 (8.1)
0.001	791,5 (62.7)	302,4,5 (33.2)	781,3,5 (62.0)	182,3,5 (25.1)	252,5 (30.0)	901,2,4,5 (71.5)	24 (8.1)
0.01	284,5 (31.9)	24,6 (8.1)	402,3,5 (39.2)	24-6 (8.1)	24-6 (8.1)	26 (8.1)	26
0.1	24-6 (8.1)	26 (8.1)	24-6 (8.1)	26 (8.1)	26 (8.1)	26 (8.1)	26 (8.1)
Control	98 (81.8)	98 (81.8)	98 (81.8)	98 (81.8)	98 (81.8)	98 (81.8)	98 (81.8)

Date in parenthesis represent transformed angular values
SAE = Steamed aqueous extract.

Management of brown spot (URC)

Effect of nutrients and drought on brown spot: Influence of phosphorus and potash nutrition in reducing brown spot intensity and positive effect of Ca, Mn, Mg and Zn in reducing brown spot disease in upland soils with low organic matter content was confirmed. Interactive effect of drought an micronutrients in relation to brown spot development was examined in a pot study using Co, Zn, Mg and Mn. Disease intensity was relatively high (48.25 per cent) in lower moisture regimes whereas it was less (30 per cent) in higher moisture regimes.

Effect of potassium: Six levels of K were examined for their efficacy in reducing brown spot Kalinga III and Brown gora. Nitrogen and phosphorus were applied @ 40:40kg/ha of N and P_2O_5 respectively. Potassium levels upto 30 kg K_2O reduced disease intensity while higher levels enhanced disease. Minimum disease of 7 and 15 per cent were recorded on Kalinga III and Brown gora respectively at 30 kg K_2O/ha.

Upland rice soils from ten locations nearby Hazaribag were collected and incidence of brown spot examined in pots using a susceptible cultivar. Significant differences were observed among the soils for disease intensity; minimum disease was recorded in the Krishi Vigyan Kendra soil form village Sakhia (farmers' field).

Host resistance: (URC) Association of resistance to brown spot and tolerance to drought was examined in 77 upland rice genotypes. Drought tolerant genotypes had lower brown spot incidence.

Seventy eight resistant (scores 0,1) and 86 moderately resistant breeding lines were indentified from among 480 test lines evaluated in the nursery. Out of 549 lines evaluated in NSN II, 82 were resistant (0,1) and 125 moderately resistant (2-4). Twenty four lines of NSN I (total 146 entries) and 13 lines of DSN (total 94) were also resistant.

Effect of grain infection by *Helminthosporium oryzae* on speed germination and seedling growth was examined in selected upland rice genotypes. Seed germination was not significantly affected by brown spot infection but speed of germination was significantly reduced in infected seed lots Root length, root dry weight, shoot dry weight, root shoot ratio and root shoot dry matter per unit length were affected. Delay in germination and reduced seedling vigour in the field would lead to poor crop establishment.

Sheath Blght

Effect of pesticides on sheath blight pathogen

Various chemicals (fungicides, insecticides and herbicide) were evaluated against *Rhizoctonia solani* sheath blight pathogen. Insecticides and herbicides showed enhanced fungal growth at lower concentration of 2.5 ppm or below. However, an insecticide (Chlopyriphos) and a herbicide (argold) were identified as potential pesticide for inhibition of sclerotia formation and germination of selerotrial.

Bacterial blight

Management of bacterial blight

Host resistance: Two hundred forty six gora collections of Chotanagpur plateau and 230 breeding lines derived from different crosses were evaluated for their resistance to bacterial blight under transplanted conditions in bunded uplands. Twenty seven gora collections were resistant. HRC 28, 38, 55, 56, 57, 58 and 66 were the most promising among them. Advanced breeding lines derived from the cross CR 149-3244/Mahsuri and the natural outcross of open floret mutant of CR 314-5-10 were found resistant in the third year.

IRRIGATED RICE

IRRIGATED RICE

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- Screening of rice germplasm to white tip and root-knot nematodes
- Chemical control of insect pests
- Studies on reservoir hosts of rice pest parasitoids
- Scent and cooking quality with progress of storage of scented and non-scented rice varieties

CROP IMPROVEMENT

Breeding for photo-insensitive varieties

Twenty rice varieties collected from different sources were evaluated for their suitability in wet and dry seasons. The varieties IR.64, Ratna, Kiran, Swarna Prabha, IR 36, IET 8586 in wet season and CH 988 in dry season performed better. These are being utilised in crossing programme.

Twentyfive early duration fixed lines were evaluated for their yield potential during dry and wet seasons. The cultures CR 691-61, CR-3, CR 691-209 and CR 749-26-2 performed better in both the seasons.

Under direct seeding in wet season the cultures CR 691-31, CR 691-253 based on their performance were entered in all India coordinated trials of DRR (Directorate of Rice Research).

Breeding for scented rice

Twentyfive newly collected scented accessions were evaluated in dry and wet seasons for morphological characters, yield potential, plant stature, duration etc. They were of semi-dwarf to semi-tall stature, duration etc. with 85-125 days flowering duration. Among long slender grained varieties, Basmati 385 and Basmati 370 in wet season and Pusa 33-308 and Gaurav gave better yields in dry season. These lines will be utilised in future breeding programmes.

Selection and evaluation in segregation populations

F_2 population from six cross combinations were grown and selections were made. 1700 F_3, F_4 and F_5 progenies from 15 cross combinations were grown and selections were made based on flowering, plant height, single plant yield, grain type and scent.

Evaluation of promising breeding lines

Twentyfive promising lines developed through hybridization and mutation were evaluated for yield in wet and dry seasons. CRM 8-30 and CR 689-15-34 gave yields than Pusa Basmati-1 in both the seasons. These were included in BRVT trial.

Inheritance of scent and grain quality

F1s from a 11 x 11 diallel set involving 8 scented varieties viz. Pakistan Basmati, Basmati 370, Karnal Local, Basmati 133, T 412, Sitabhog, Tulasimanjari and M. Sung Song and 3 non-scented varieties Ratna, Savitri and Gayatri were grown. Observation on scent, grain size and shape were recorded. Biochemical characters like gel consistency (GC), gelatinization temperature (GT) are being evaluated on single plant basis.

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Method for gel consistency test has been modified to suit analysis of small samples (10 mg). The protocol developed by Company (1973) has some deficiencies like the time for mixing the contents in cyclomixer, time period and temperature of ice water treatment. The classification of rice was also modified according to the results of the known controls viz. hand (6-10 mm), medium (11-20 mm) and soft (more than 20 mm).

Mutation breeding for bacterial blight resistance

Selections were made in 800 M4 progenies of PR 106 and Pusa Basmati-1 for bacterial blight resistance and single plant yield.

CROP MANAGEMENT

Studies on yield maximization of rice

A field experiment with nine treatments comprising different combinations of normal plant stand (spacing 15 cm x 15 cm), 33 per cent extra plant stand (spacing 20 cm x 20 cm), optimum fertilizer (90 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha), 33 per cent extra fertilizer (120 kg N, 53 kg P_2O_5 and 53 kg K_2O/ha), green manuring *in situ* and insecticide-treated robust seelings raised from high density grains was conducted using rice variety Gayatri. The highest grain yield of 6.85 t/ha was recorded in treatment where insecticide-treated robust seedlings were transplanted using 33 per cent extra plant stand following green manuring and the crop given 33 per cent extra fertilizer. The grain yield in this treatment was 36 per cent higher than that of treatment with normal plant stand and optimum fertilizer application. This even gave 7 per cent extra yield over the treatment comprising of a combination of green manuring + 33 per cent extra plant population + 33 per cent extra fertilizer without robust seedlings. Thus the grain yield could be maximized by agronomic practices like higher plant population and use of thick robust healthy seedlings (particularly when the crop experiences submergence at seedling stage) and conjunctive use of organic and inorganic fertilizers (Table -1).

Crop growth modelling on the effect of nitrogen application on growth and yield of rice

Three field experiments were conducted during wet season, 1991 and dry seasons, 1992 and 1993 to study the growth, yield and N uptake by irrigated rice. The treatments were of different timing and rates of fertilizer N application. The values of crop and soil input parameters for the model Oryza-0 of ten Berge et al. (1994) with modifications were derived from these experiments. These parameters were combined with a few time and weather parameters to optimize N fertilizer application at Cuttack. It yielded a fertilizer N response curve and fertilizer N recom-

Table - 1 : Grain yield and ancillary characters of rice as affected by different agromic practices, wet season 1994

Treatment		Grain yield (t/ha)	Panicles m^2	Panicle weight (g)
T1	Normal plant sland (20 cm x 15 cm) and optimum fertilizer (90:40:40 NPK kg/ha)	5.03	294	2.01
T2	33 % extra plant stand (15 cm x 15 cm) and optimum fertilizer	5.31	325	1.85
T3	Normal plant stand + 33 per cent extra fertilizer (120:53:53 NPK kg/ha)	5.45	320	2.05
T4	33% extra plant stand + 33 % extra fertilizer	5.85	343	2.15
T5	Green manure in situ & normal plant stand optimum fertilizer	5.35	310	2.21
T6	Green manure in situ (15 kg N/ha) + 33% extra plant stand + 33 % extra fertilizer	6.41	350	2.30
T7	Normal plant stand + optimum fertilizer + robust insecticide treated seedlings	5.62	331	2.05
T8	33% in situ (15 kg N/ha) + 33% extra fertilizer + robust insecticide treated seedlings	6.85	365	2.31
T9	Green manure in situ (15 kg N/ha) + 33% extra plant stand + 33 % extra fertilizer + insectiticide treated robust seedlings	6.85	365	2.31
	C.D. (P=0.05)	0.36	13	0.09

mendation curve. From these response curves a total input level was selected on the basis of environmental and economic considerations. Accordingly a fertilizer recommendation curve for the selected N input level of recommendation was constructed from which the split doses and timing of application were obtained. The model was used to analyse the yield gap. The performance of the model was tested for several other varieties grown in wet season every year 1987-93.

The native soil fertility and the season were found to influence the N uptake capacity of rice under conditions of ample N supply. The site specific match factor (FSV) which reflects the overall efficiency of light and N utilization by the rice crop was lower in wet season than in dry season. An application of 90 kg N/ha in 3 equal splits at 46, 54 and 67 days after sowing for the variety IR 36 in the wet season and 120 kg N/ha in 3 equal splits at 45, 60 and 70 days after sowing in the dry season was found optimum to produce grain yields of 5.0 and 7.0 t/ha during wet and dry seasons respectively. The model does not suggest any basal application of fertilizer N which is otherwise a conventional practice in these soils. There is also a fair agreement between simulated biomass, after optimization, and observed biomass for 35 cultivars grown at the same site with 4 N application levels in wet season during the years 1987-93.

Response of scented long slender grain rice varieties to potassium

The grain yield performance of five long slender grain sccented rice varieties - Kasturi, Pusa Basmati-I, Ranbir Basmati, Pakistan Basmati and Gaurav were tested under 3 levels of potash (K_2O) - O, 50 and 100 kg/ha during wet season. Among the varieties - Pakistan Basmati was the highest yielder (2.38 t/ha) closely followed by Ranbir Basmati (2.32 t/ha) and Kasturi (2.27 t/ha). There was progressive increase in yield upto 100 kg K_2O/ha.

Evaluation of promising rice cultures for nitrogen use efficiency

Twelve elite cultures/cultivars were screened for their nitrogen use efficiecy at 4 levels of N, viz. 0, 30, 60 and 90 kg N/ha in wet season in a lowland site having clay loam soil with pH 6.1, 32 per cent clay, cation exchange capacity 26.0 cmol (P^1) kg^{-4} soil, 0.780 per cent organic carbon and 0.071 per cent total N. Results obtained from the field experiment revealed that the cultures, CR 683-123 and CR 626-7-3 absorbed largest amounts of N (54-56 kg N/ha) at zero level of applied N as against the lowest N absorption (37 kg N/ha) recorded with CR 629-526. Thus the former two cultures utilized soil nitrogen better and produced higher grain yields (2.71-2.74 t/ha) at no application of N

than the other then cultures (1.16-2.40 t/ha). Only six cultures showed response to N upto the levels of 30-60 kg N/ha. Among these cultures, CR 673-43 was the best giving a grain yield of 3.70 t/ha at 60 kg N/ha. The cultures BKS-13 and CR 673-431 showed higher apparent recovery of applied N (58-67 per cent at 30 kg N/ha and 38-47 per cent at 60 kg N/ha) than the other cultures/cultivars.

At the end of October when the rice plants were either at the stage of panicle emergence or flowering, four cultures viz. BK 7-275, CR 673-431, CR 629-526 and Gayatri were observed to be non-lodging even at the N level of 90 kg/ha, whereas the other eight cultures lodged completely or partially. With no N control, however, five more cultures in addition to the above mentioned four cultures did not lodge.

Activity of associative nitrogen fixing bacteria in rhizosphere of 3 rice cultures widely differing in uptake was also studied. The cultures, BKS-13 was found to have highest N_2 fixation in its rhizosphere.

Effect of silver ethylene diguanidine nitrate on rice growth and yield

The experiment was repeated during 1994 wet season with 0, 30 and 60 kg N/ha over a basal dose of each of 30 kg P_2O_5 and K_2O under direct seeded condition with IR 36 and T 141 as test varieties. The seeds were treated with silver ethylene diguanidine itrate before sowing in the field.

In general, both varieties gave very low grain yield of only 0.97 to 1.46 t/ha for IR 36 and 2.13 to 277 t/ha for T 141 under different treatments. There was no significant difference in yield between the treatments while varietal difference in yield was noticed. The interaction was also not significant(Table-2.)

The straw yield ranged from 2.45 to 3.79 and 3.74 to 6.01 t/ha for IR 36 and T. 141, respectively. Varietal and treatmental differences were significant. The interaction was also significant. But the chemical treatment did not increase the straw yield significantly.

The nitrogen content in grain varied from 0.99 to 1.2 per cent for IR 36 and 0.86 to 1.13 per cent for T 141. The straw nitrogen content varied from 0.69 to 0.80 per cent for IR 36 and 0.52 to 0.63 per cent for T 141, respectively. The chemical treatment did not increase the nitrogen content of grain and straw.

In general the chemical silver ethylene diguanidine nitrate was not effective in enhancing the rice yield.

Use of fertilizers and organic materials for higher N use efficiency

The effect of different organic and inor-

Table 2. Effect of silver ethylene diguanidine nitrate on grain and straw yield (t/ha) of rice

Treatment	VARIETIES		
	IR 36	T 141	Mean
	Grain Yield		
N_0	0.974	2.131	1.553
N_0 + chemical	0.965	2.626	1.795
N_{30}	1.166	2.468	1.817
N_{60}	1.242	2.321	1.782
N_{30} + chemical	1.464	2.457	1.961
N_{60} + chemical	1.212	2.776	1.994
Mean	1.171	2.463	
C.D. (P = 0.05)			
Treatment	NS		
Variety	0.233		
Variety x treatment	NS		
	Straw Yield		
N O	2.515	3.763	3.139
N O + chemical	2.449	3.737	3.093
N 30	3.646	5.070	4.358
N 60	3.445	6.009	4.727
N 30 + chemical	3.364	4.717	4.040
N 60 + chemical	3.788	5.894	4.841
Mean	3.201	4.865	
C.D. (P = 0.05)			
Treatment	0.398		
Variety	0.230		
Variety x treatment	0.564		

ganic nitrogen sources alone or in combinations was studied in the field during the wet season of 1994 using Savitri as the test cultivar. Nitrogen was applied either as urea or in the form of farmyard manure (FYM) or green manure *Sesbania aculeata* (GM) at the rate of 70 kg N/ha. It was observed that there was significant respons to the application of nitrogen both in terms of grain and straw yields. Grain yield ranged from 3.22 t/ha with control to 4.44 t/ha with the best split of urea (i.e. 50+25+25) whereas the straw yield

ranged from 3.22 t/ha with control to 4.44 t/ha with the best split of urea (i.e., 50+25+25) whereas the straw yield ranged from 4.52 t/ha in control to 7.05 t/ha with the treatment receiving 50 percent N as GM and the rest 50percent in two equal splits respectively at AI and PI. The grain and straw yields were minimum among the treatments when the entire amount of nitrogen was applied basal as 50% percent green manure + 50 per cent FYM. Application of GM alone or in combination of organic manures (FYM + GM) as basal gave comparable grain yield with that of the best split of fertilizer nitrogen. In case of non-availability of sufficient organic nitrogen sources, 50 per cent N as organic (basal) and the rest 50 per cent as urea can be applied in two equal splits at active tillering and panicle initiation stages. Similar trend was also observed in the case of straw yields and uptake of nitrogen.

The effect of application of nitrogen through FYM alone or different combinations of FYM and urea were compared with that of the best split of chemical nitrogen (urea). All the treatment combinations, excepting full FYM gave significantly better yields over that of the control. The combinations where 25 per cent to 33 per cent of the applied nitrogen was substituted with organic source (FYM) and the rest as urea in one or two splits at different stages gave comparable grain yield with that of the chemical nitrogen. More or less similar trend was observed in the case of straw yield. Maximum grain yield of 4.44 t/ha and straw yield of 6.85 t/ha were obtained with the best split of chemical nitrogen. Similar trend was observed in the case of N uptake by rice.

Management strategies to increase the efficiency of applied nitrogen

A green house study was conducted to determine the effect of different combinations of organic (FYM) and green manure *(Sesbania aculeata)* and fertilizer nitrogen (urea) sources under two input levels on the utilization of applied nitrogen by rice. Application of 50 per cent of N as FYM and 25 per cent N as urea based and the rest 25 per cent at active tillering stage gave grain yield comparable to that of the treatments receiving full N as green manure or urea incubated with boric acid under low rate of nitrogen application whereas application of 50 per cent N through green manure and the rest 50 per cent N as urea in two equal splits at active tillering and panicle initiation or urea incubated with boric acid gave grain yields comparable to that of the best split (50+25+25) under low input management. The treatments receiving 50 per cent N through green manure and the rest 50 per cent through urea in two equal splits and the best splits of nitrogen as urea gave significantly more yield than that of the treatment where nitrogen was supplied through FYM supplemented with urea.

Under optimum input management, the grain yield in treatment receiving FYM and urea combination was significantly less than that in all other treatments receiving nitrogen. The treatments receiving urea incubated with boric acid or full green manure were on par and were significantly inferior to that of the best splits and the treatment receiving 50 per cent N through green manure and the rest 50 per cent as urea in two equal splits. The latter two treatments, however, gave comparable grain yield.

The straw yield and N uptake followed almost a similar trend as that of the grain yield excepting the treatments receiving full nitrogen as green manure, urea incubated with boric acid and the best splits of urea which gave comparable straw yield.

Application of simulation models for N limited rice production (SARP)

The Oryza-O model has been used for optimizing N fertilizer application programme to irrigated rice. The soil and crop input parameters for this model were derived from yield experiments conducted at this institute. The N uptake capacity of rice variety IR 36 under conditions of ample N supply was very much influenced by radiation and native soil fertility (Table 3). The maximum daily nitrogen uptake rate is 3.6-5.5 kg N/ha/day and is usually higher in the dry season than in the wet season for a given variety. However, the maximum fraction of total crop nitrogen in leaves before flowering is usually 0.55 and does not change from wet to dry season conditions, but the recovery of fertilizer N is higher in the dry season than in the wet season.

The response of rice crop as found by numerical optimization represented the maximum attainable biomass calculated on the basis of radiation, crop and soil parameters for given N input levels for optimum yield, an application of 90 kg N/ha in 3 equal splits at

Table - 3: The influence of radiation on the biomass accumulation, grain yield and N uptake by rice cv IR 36 under irrigated condition

Season	Radiation MJ/m²				Maximum biomass production (t/ha)	Maximum grain yield (t/ha)	Maximum N uptake (kg/ha)
	Preflowering		Post-flowering				
	Total	Mean	Total	Mean			
Wet season	900.2	14.5	517.5	14.4	9.6	4.9	128.1
Dry season	1208.6	18.6	627.2	20.9	13.4	7.6	171.6

16,24 and 37 days after transplanting is recommended for wet season. Similarly, for dry season an application of 120 kg N/ha in 3 equal splits at 15-30 and 40 days after transplanting is recommended. The model does not suggest a basal application of fertilizer N for this experimental site.

Effect of P nutrition on growth, yield and nutrient contents of rice in a problem soil of Orissa

Symptoms of bronzing appeared on plants, after maximum tillering stage, and remained till flowering. P levels showed significant effects on yields of dry matter, straw and grain. Treatments (50-200 ppm P) significantly increased dry matter by 10-24 per cent over 25 ppm P. Grain yield was significantly high by 7-30 per cent in treatments (50-200 ppm P) as compared to 25 ppm P. Straw yield was significantly ;enhanced by 7-32 per cent in treatments (75-200 ppm P) over 25 ppm P. Contents and total uptake of P.S.Ca and Mn increased and Fe, Zn and Cu decreased significantly with rise in levels of P fertilizer. The rate of significant increase over 25 ppm P was 10-85 per cent, 10-35 per cent, 10-35 per cent and 17-115 per cent for P.S.Ca and Mn respectively. For Fe, Zn and Cu the range of significant decrease was 47-6 per cent, 54-7 per cent and 65-12 per cent, respectively, as compared to 200 ppm P. Total uptake of P.S.Ca and Mn increased significantly by 20-126 per cent, 15-66 per cent, 15-66 per cent and 29-168 per cent, respectively over 25 ppm P. The rate of significant reduction of total uptake was respectively at 18-6 per cent, 24-10 per cent and 34-28 per cent for Fe, Zn and Cu over 200 ppm P.

Sulphur and phosphorus interaction in rice

The interaction effect of sulphur (0, 10, 25 and 50 ppm) and P (0, 25, 50 and 100 ppm) was studied in a pot experiment under flooded conditions using an Inceptisol soil suspected to be deficient in these two nutrients.

Application of 25 ppm S increased the grain yield by 9 per cent. In the case of P, the grain yield increased from 16.9 at 0 ppm P to 42.5 g/ppm at 1200 ppm P. The interaction showed that irrespective of S addition, the grain yield increased with increasing levels of P. The straw yield declined at 50 ppm S; however, it was not significant. There was a significant increase in straw ;yield due to P addition upto 50 ppm, whereas it decreased with increasing levels of both the nutrients. Sulphur content in grain was maximum (0.08) at 25 ppm S, while straw S content showed only marginal increase. Phosphorus content in grain and straw significantly increased with P levels.

The significant interaction between S and P will be beneficial for rice in such soils.

Effect of time of rice transplanting on growth and N_2 fixation of *Azolla* and yield of rice

This experiment was conducted during the wet season using rice variety IR 36. Seedlings of equal age were transplanted on July 1, 16 and 31 and August 16. The crop was fertilized with 30 kg N/ha through urea. *Azolla caroliniana*, *A. Pinnata* and *A. mexicana* were affected at 1.0 t/ha 10 days after transplanting and grown with 10 kg P_2O_5/ha applied in three equal splits at weekly intervals. Fresh weight and N-yield of all the *Azolla* species decreased gradually with delay in transplanting, the highest being under July 1 planting and the lowest under August 16 planting (Table 4). However, July 16 and

Table 4. Influence of time of rice transplanting on fresh weight and N-yield of Azolla and yield of rice

Date of planting and Azolla species	Azolla fresh weight (t/ha)	N-yield (kg N/ha)	Grain yield t/ha	Straw yield (t/ha)
JULY 1				
A. caroliniana	18.1	36.6	4.06	4.84
A. pinnata	19.2	38.2	3.94	4.87
A. mexicana	17.6	34.8	3.88	4.77
JULY 16				
A. caroliniana	12.1	26.3	3.46	4.45
A. pinnata	10.6	24.0	3.39	4.57
A. mexicana	10.1	22.4	3.35	4.47
JULY 31				
A. caroliniana	10.7	24.1	3.21	4.02
A. pinnata	8.5	20.3	2.98	3.93
A. mexicana	10.8	24.8	3.17	3.88
AUGUST 16				
A. caroliniana	6.9	15.1	2.85	3.60
A. Pinnata	5.3	12.0	2.68	3.57
A. mexicana	6.9	15.3	2.61	3.24
C.D. (P = 0.05)				
Azolla species	NS	NS	NS	NS
Date of planting	1.7	2.5	0.28	0.33
Interaction	NS	NS	NS	NS

31 planting were comparable. Fresh weight of *A. caroliniana, A. pinnata* and *A. mexicana* under July 1 planting was 49.6, 81.1 and 74.4 per cent higher than that under July 16 planting, respectively, possible due to higher solar radiation and more sunshine hours in the former treatment. Grain and straw yields of rice were also the highest under July 1 planting and the lowest under August 16 planting.

Performance of P-enriched *Azolla* under varying nitrogen levels

The performance of P-enriched *Azolla caroliniana* vis-a-vis the unenriched *Azolla* under varying levels of urea-N (0, 30 and 60 kg N/ha) was assessed during the dry season. The two types of *Azolla* were grown at 1.0 t/ha 10 days after transplanting of IR 36 seedlings, either without further application of P during dual cropping or with 10 kg P_2O_5/ha applied in three equal parts, P-enriched *Azolla* and difference between them were wider when no P was applied during dual cropping (Table 5). At all the urea-N levels, fresh weight and N-yield of P-enriched *Azolla* grown without P were comparable to that of the unenriched *Azolla* grown with the recommended dose of 10 kg P_2O_5/ha. Grain and straw yields of rice were significantly higher with P-enriched than with unenriched *Azolla*. Application of P during dual cropping also increased fresh weight and N-yield of both unenriched and P-enriched *Azolla* as well as the grain and straw yields of rice.

Effect of Zn on growth of rice and its uptake in combination with compost, *Azolla* and green manure

A pot experiment was conducted to study the effect of different organic manure in the presence of added Zn on rice growth and yield. The soil used in this study was collected from Maitapur sasan and it contained 0.70 ppm of DTPA Zn.

There was significant difference in grain and straw yields due to different treatments and Zn application (Table 6). The interaction between treatment and Zn application was also significant. Application of 50 ppm Zn increased grain yield by 18 per cent over noZn treatment. In the absence of added Zn, the highest grain yield (24.35/pot) was obtained for *Azolla* treatment. Grain yield with Zn + urea and Zn + *Azolla* were at par followed by dhaincha. Compost + Zn was the least effective in enhancing the grain yield. The straw yield was highest in *Azolla* and dhaincha treatments both with and without Zn.

The Zn content in grain was maximum in the NPK treatment irrespective of Zn application and was least in the dhaincha treatment. Zinc application increased Fe content

Table 5. Fresh weight and N-yield of unenriched and P-enriched *Azolla* at varying urea-N levels and their influence on grain and straw yields of rice

Phosphorus treatments during dual corpping and urea-N levels	Azolla fresh weight (t/ha)		N-yield (kg N/ha)		Grain Yield (t/ha)		Straw yield (t/ha)	
	Unenriched *Azolla*	P-enriched *Azolla*	Unenriched *Azolla*	P-enriched *Azolla*	Unenriched *Azolla*	P-enriched *Azolla*	Unenriched *Azolla*	P-enriched *Azola*
No-phosphorus								
No-nitrogen	6.0	11.5	11.9	24.5	3.34	3.68	2.80	4.25
30 kg N/ha	5.0	10.6	11.3	22.2	3.68	4.01	4.26	4.70
60 kg N/ha	5.3	8.9	10.1	17.4	4.26	4.66	4.82	5.12
10 kg P_2O_5/ha								
No-nitrogen	11.8	14.1	24.5	30.7	3.72	3.99	4.34	4.59
30 kg N/ha	10.7	12.5	22.0	26.8	4.25	4.47	4.76	5.03
60 kg N/ha	9.3	10.9	18.5	22.9	4.69	4.97	5.23	5.48
LSD (P=0.05)*								
Type of *Azolla* or phosphorus treatment during dual cropping	0.9		1.9		0.24		0.27	
Urea-N levels	1.1		2.3		0.29		0.33	
Type of *Azolla* X phsphorus treatment during dual cropping	1.3		27		NS		NS	

The remaining interactions were not significant

Table 6. Effect of different organic manures and Zn application on grain and straw yield (g/pot)

Treatments	Levels of Zn		
	NoZn	Zn (50ppm)	Mean
	Grain Yield		
Control	4.08	4.35	4.22
NPK	21.83	26.69	24.26
Compost	13.36	15.00	14.18
Azolla	24.35	26.48	25.42
Dhaincha	19.65	25.97	22.81
Mean	16.65	19.69	
C.D. (P + 0.05)			
Treatments	1.18		
Zn	1.20		
Zn x treatment	2.43		
	Straw Yield		
Control	5.21	5.39	5.30
NPK	20.38	25.25	22.82
Compost	14.94	14.00	14.47
Azolla	25.81	26.03	25.93
Daincha	25.96	26.29	26.13
Mean	18.46	19.39	
C.D. (P= 0.05)			
Treatment	3.91		
Zn	0.97		
Zn X treatment	2.23		

in straw while Mn content decreased over other treatments. In case of grain a decreasing trend was observed both for Fe and Mn due to Zn application.

Zinc addition decreased Fe in the post harvest soil while a reverse trend was observed for Mn. Organic carbon content of the soil was highest in the dhaincha treatment. After fractionating the soil Zn into different pools of Zn, it was found that in all the treatments either with or without Zn application, residual fraction contained the highest amount of Zn followed by complexed organically found, occluded exchangeable and the least was found in the water soluble form.

Performance of *Azolla* sp. in response of P-enrichment

This experiment was conducted during the wet season using *Azolla caroliniana, A. pinnata, A. mexicana* and *A. rubra*. Unenriched and P-enriched *Azolla* were grown at 1.0 t/ha 10 days after transplanting of IR 36 seedlings, either without any P fertilizer during dual cropping or with 10 kg P_2O_5/ha applied in three equal splits at weekly intervals. Irrespective of the *Azolla* species, P-enriched *Azolla* grown subsequently without P produced fresh weight and N-yield comparable to that of the unenriched Azores grown with 10 kg P_2O_5/ha when unenriched *Azolla* was used and no P was applied during dual cropping, *A. pinnata* and *A. caroliniana* produced more biomass and N-yield than *A. mexicana* and *A. rubra*. Grain and straw yields of rice increased sigificantly with both P-enrichment of *Azolla* inoculum and application of P during dual cropping.

Influence of pesticides on growth and N_2 fixation of *Azolla* and yield of rice

The experiment was conducted during the dry season with two pre-emergence herbicides (butachlor and thiobencarb) and three insecticides (furadan, thimet and metacid) applied at their recommended doses for rice 3 herbicides and 15 days insecticides after transplanting of IR 36 seedlings. *Azolla caroliniana* at 1.0 t/ha was applied 10 days after transplanting and phosphorus at 10 kg P_2O_5/ha applied in three equal splits at weekly intervals. Urea at 30 kg N/ha was uniformly applied in all the plots. Application of butachlor or benthiocarb decreased the fresh weight and N-yield of *Azolla* significantly. The fresh weight and N-yield in both untreated and herbicide-treated plots increased significantly due to the application of any of the three insecticides which also increased the grain and straw yields of rice. Yields were lower in herbicide-treated plots than in untreated plots.

Response of *Anabaena*-free and *Anabaena*-containing *Azolla* to magnesium

Anabaena-free and *Anabaena*-containing *Azolla filiculoides* and *A. pinnata* were grown in mineral medium at varying levels (0-75) of magnesium. The growth (fresh and dry weight) of *Anabaena*-containing *Azolla* was the highest at 30 ppm of manganese in case of *A. filiculoides* and 45 ppm in case of *A. innata*, while the growth of *Anabaena*-free *Azolla* was the highest at 15 ppm in case of *A. filiculoides* and 30 ppm in case of *A. pinnata*. The higher magnesium requirement for *Anabaena* containing Azolla is suggestive of its role in N_2-fixation.

Biological N_2 fixation by free living bacterial in rice soils

The effect of field applied herbicides on the rhizomic nitrogenase activity was investigated. Nitrogenase activity associated with

rice rhizosphere under the impact of herbicides over the period of plant growth indicated a general decline towards the harvest (Table 7). Pretilachlor and anilofos, at two application levels had no substantial effect on nitrogenase activity. Application of thiobencarb and butachlor showed a marginal influence. On the other hand, Cinmethylin consistently stimulated the nitrogenase activity almost throughout the plant growth period. Cinmethylin is composed of carbon hydrogen and oxygen ($C_{18}H_{26}O_2$) and is easily biodegradable. Either the parent compound and/or the degradation product might have been involved in the stimulation of nitrogenase. Interestingly, anilofos when applied singly had no substantial effect or the nitrogenase while in combination with 2,4-D particularly at 0.30, 0.40 kg a.i./ha stimulated the activity. Likewise a combination of two herbicides, viz. Anilofos and 2,4-D stimulated the nitrogenase associated with the rhizosphere. Evidence suggested that the direct and indirect influences of herbicides resulted in the enhanced nitrogenase activity associated with the rice rhizosphere.

Table 7. Influence of field applied herbicides on the rhizosphere associated nitrogenase activity

Treatment	Dose (kg a.i./ha)	n moles of C_2H_4 formed/g soil/24 h				
		Days after sowing				
		40	50	60	70	80
Pretilachlor	1.0	106±30	285±18	138±12	163±26	41±13
Pretilachlor	1.25	80±3	296±7	190±17	88±4	44±19
Thiobencarb	1.00	159±32	320±5	136±5	153±6	48±17
Butachlor	1.80	72±16	269±19	181±19	113±19	63±12
Cinmethylin	0.1	207±16	378±16	269±3	236±32	116±13
Anilofos	0.4	112±15	243±2	132±3	117±7	73±8
Anilofos	0.6	87±3	286±58	183±4	128±4	70±15
Anilofos+2, 4-D	0.30+0.40	179±32	416±9	281±4	249±6	125±12
Anilofos+2, 4-D	0.4+0.53	100±10	309±7	112±15	82±5	50±13

Means of 5 replicates ± SD

To determine whether the effects of the combined application of anilofos and 2,4-D were related to alterations in the nitrogen fixing populations associated with rice rhizosphere, the populations of nitrogen fixing *Azotobacter* sp., *Azospirillum* sp. and anaerobic nitrogen-fixing bacteria were enumerated in herbicide treated and untreated plots (Table 8), the combination of herbicides clearly enhanced the populations of nitrogen fixing bacteria. More specifically and conspicuously the population of anaerobic nitrogen fixing bacteria were stimulated followed by *Azotobacter* and *Azospirillum* sp. It is concluded that the candidate herbicides exhibited differential response in relation to nitrogenase activity in rice rhizosphere. Further, anilofos when applied singly had no substantial effect, but in combination with 2,4-D a considerable stimulation of nitrogenase and anaerobic nitrogen fixing bacterial populations occurred.

Studies on germination of *Fischerella muscicola akinites*

Akinetes of *Fischerella muscicola*, a heterocystous and N_2 fixing blue-green alga, collected locally from the rice fields, were isolated by the Lysozyme method. The influence of pH, light quality, nutrient deficiencies, N sources, growth hormones and sodium acetate on their germination was studied under controlled conditions (Tables 9 and 10). The akinetes did not germinate when pH of the growth medium was below 6 and showed the maximum germination of 83.5 per cent at pH 9. Per cent germination of akinetes at pH 7, 8 and 10 was 32.7, 46.6 and 57.3, respectively. Red and white light favoured the akinete germination, while there was no or very little germination under blue, green and yellow light. A deficiency in phosphorus or calcium decreased the germination while magnesium deficiency increased

Table 8. Nitrogen-fixing bacterial populations in the rice rhizosphere amended with a combination of herbicides

Treatment	Azospirillum SP (x10 4/g dry soil)	Anaerobic N_2 fixers (x10 5/g dry soil)	Azotobacter (x10 3/g dry soil)
Without herbicide	11+- 2	1.1+- 0.3	3 +- 0.5
Anilofos + 2,4-D	24 +- 4	12 +- 3.0	15 +- 2.0

Means of 5 replicates +- SD for azospirillum and anaerobic N2 fixers; 3 replicates +- SD for Azotobacter.

Table 9. Influence of pH of the growth medium, light quality and deficiency of some nutrients on germination of *Fischerella muscicola* akinetes (10 days after incubation)

pH of the medium	Percentage of germination (Angular value)	Light quality	Percentage of germination (Angular value)	Nutrient deficiency	Percentage of germination (Angular value)
5	0.00	Dark	0.00	Control	31.50
6	28.70 (23.2)	White Light	35.55 (33.8)	Phosphorus (17.1)	24.43
7	34.88	Red	38.59	Calcium	24.43
8	43.05 (46.6)	Yellow Light	10.63 (3.4)	Magnesium (40.3)	39.41
9	66.03 (83.5)	Green Light	6.55 (1.3)		
10	49.20 (57.3)	Blue Light	0.00		
C.D. (P= 0.05)	6.0	4.1	5.1		

Figures in parenthesis are percent germination

it. N sources increased the akinete germination significantly. Of them, ammonium chloride recorded the highest germination (99.5 per cent) followed by calcium nitrate (69.6 per cent), potassium nitrate (63.4 per cent) and urea (48.6 per cent). Increasing concentrations of IAA upto 0.5 ppm and GA upto 5.0 ppm enhanced the germination. Sodium acetate at 100 and 500 ppm also simulated their germination.

Biodegradation of pesticides in tropical rice soils

The effect of temperature-moisture interaction on the persistence of the factor causing

Table 10. Influence of different nitrogen sources (20 ppm), growth hormones (IAA and GA) and sodium acetate on germination of Fischerella musciola akinetes (10 days after incubation)

Nitrogen sources	Percentage of germination (Angular value)	IAA (ppm)	Percentage of germination (Angular value)	GA (ppm)	Percentage of germination (Angular value)	Sodium acetate (ppm)	Percentate of germination (Angular value)
Control	30.79 (26.2)	Control	32.39 (28.7)	Control	33.09 (29.8)	Control	30.20 (25.3)
KNO_3	52.77 (63.4)	0.01	46.83 (53.2)	0.01	36.03 (34.6)	10	32.27 (28.5)
$Ca(NO_3)_2$	56.54 (69.6)	0.05	57.92 (71.8)	0.05	40.63 (42.4)	100	35.61 (33.9)
NH_4Cl	85.95 (99.5)	0.50	67.94 (85.9)	0.50	52.00 (62.1)	500	40.51 (42.2)
Urea	44.20 (48.6)	5.0	54.82 (66.8)	5.00	59.41 (74.1)	1000	25.03 (17.9)
		10.0	49.26 (57.4)	10.0	51.94 (62.0)	1500	0.0
C.D (P = 0.05)	8.2		6.3		4.2		3.2

Figures in parenthesis are percent germination

accelerated degradation of HCH in commercial-HCH-treated soil was studied. Commercial HCH acclimatized soil, continuously kept moist and held at 20, 25 and 35 OC, retained the capacity of accelerated degradation of HCH even at 40 days (Table 11). Temperature did not seem to have an appreciable impact on the survival of the factor causing accelerated degradation of HCH when soil was maintained under moist conditions. However, if water loss was not compensated by regular additions of water during the incubation of commercial HCH acclimatized soil and the soil was allowed to undergo moisture stress, the factor causing acclerated degradation of HCH was inactivated, more rapidly at 35°C than at 25°C and 20°C. Thus, in commercial-HCH-acclimatized soil not replenished with water for evaporation loss, the factor was inactivated in about 10 days at 35°C and 30 days at 25°C however, at 20°C, soil not replenished with water retained the capacity for accelerated degradation of HCH even at 40 days, as in soil continuously kept moist.

The commercial-HCH-acclimatized moist soil (20g) used for incubation at different temperatures contained 12.5g of soil and 7.5 ml of water at the start. During the first five days incubationof the most soil, the amounts of water lost by evaporation were 0.21 ml at 20°C, 2.9 ml at 25°C and 5.7 ml at 35°C. Thus when the soil is not replenished with water to compensate for the loss by evaporation during the 40-day incubation, the soil could become somewhat dry in about 10 days at 35°C, in 15 days at 25°C and in 20 days at 20°C. The inactivation of the factor that caused accelerated degradation of HCH in about 10 days at 35°C in soil ot replenished with water (Table 11) and in dry field soil after rice harvest, in contrast to the distinct survival of this factor at 35°C even at 40 days in soil continuously kept moist suggests that the adverse effect of 35°C on the factor in soil not replenished with water is due to high temperature-induced moisture stress and not to the direct effect of high temperature on the microorganisms involved in accelerated temperature-induced moisture stress and not to the direct effect of high temperature on the microorganisms involved in accelerated degradation.

Diurnal variation in methane efflux from rice paddy

In studies on diurnal variation of methane efflux CH_4 emission from rice fields (planted with cv. IR 36) at panicle initiation stage, reached the maximum around midday and declined to minimum levels at midnight. The atmospheric methane emission is influenced by many factors, such as solar radiation, temperature and pH. In the present study, solar radiation and soil and water temperatures peaked between 12 noon and 2 p.m.. The soil temperature increased from 28°C at 6 a.m. to 30°C at midday while the tempera-

Table 11. -HCH Recovered from uninoculated medium and from the medium additionally inoculated with commercial HCH-acclimatized soil suspension that had been preincubated at 20, 25 and 35 °C with and without replenishment of water

Period of Preincubation of commercial-HCH acclimatized soil samples	Uninoculated medium	HCH recovered (% of initial)					
		Medium inoculated with commercial HCH-acclimatized soil samples that had been preincubated					
		20°C		25°C		35°C	
		Unreplenished	Replenished	Unreplenished	Replenished	Unreplenished	Replenished
5	84.4[a]	0	0	0	0	0	0
10	83.9	0	0	0	0	46.5	0
20	75.7	0	0	0	0	77.2	0
30	81.8	0	0	57.6	0	83.3	0
40	72.5	17.8	0	65.1	0	72.5	0

a. Moist soil samples (showing accelerated degradation of >-HCH) from commercial -HCH-treated pot were incubated at 20,25 and 35 °C with and without replenishment of water lost by evaporation for indicated number of days and then used for inoculating the mineral salts medium.

b. Uninoculated and inoculated medium were incubated at room temperature.

c. Commercial-HCH-acclimatized soil samples, used for inoculation, preincubated without replenishment of water lost by evaporation.

d. Commercial -HCH-acclimatized soil samples, used for inoculation, preincubated under continuously moist conditions with regular replenishment of water lost by evaporation.

ture of the standing water the rice fields measured from 27°C at 6 a.m. to 32° at midday. Diurnal variation in CH_4 emission has been strongly correlated with soil temperature. The pH of the standing water of the rice paddies increased from 7.0 at 6 a.m. to as high as 9.5 at 2 p.m.. Possibly, peak CH_4 emissions at midday were favoured by higher levels of solar radiation, soil temperature and pH.

In a repeat experiment on diurnal variation in methane efflux as affected by growth stage of the rice plant, CH_4 emission at different growth stages of the rice crop (cv. IR 36) was measured (Fig. 1). Methane emission at seedling stage was negligible and no clear-cut variation in diurnal methane emission values was noticed. But a definite CH_4 emission maxima and minima could be observed at tillering stage of the crop and onwards.

Rice plants are known to help in passive transport of several gases including methane through its foliage. During the seedling stage, the plant biomass was very low and definite build-up of plant biomass started with the initiation of primary and secondary tillers. Thus, highly oxidised state of the rice rhizosphere (as evidenced by high oxidised state of the rice rhizosphere due to high root oxidase activity) coupled with low biomass could be the reason for low CH_4 emission values and lack of definite diurnal fluxes at the seedling stage of the rice crop.

Chlorophyll analysis of individual leaves with respect to their ontogenesis

A hot experiment was conducted with two varieties IR 36 and Swarnaprabha to analyse the chlorophyll of individual leaves. The total chlorophyll content of the leaves was estimated in three day intervals. Whenever there was a decrease in chlorophyll content nitrogen was applied. Thus (1) control - basal with no booster nitrogen, (2) Treatment-2 basal with single booster nitrogen, and (3) treatment-2 basal with single and double booster nitrogen was maintained.

It was observed that individual leaves senesced in a stipulated time period. In IR 36 unlike Swarnaprabha upto the grain formation period, the flag leaf, showed higher levels of chlorophyll than in any other leaves irrespective of different N applications. The age related chlorophyll degradation pattern reversed as grain development phase (70-80 days) started. At this stage the chlorophyll contents of the flag leaf was minimum. During this period the loss of chlorophyll in the flag and the third leaf from top processed at a faster rate, resulting in partial senescence of these leaves at 80-90 days. The most significant event was the period of chlorophyll degradation in the flag leaf which was found to coincide with grain development phase. However, the senescence of the second leaf was delayed more compared to other leaves at 90 days. Thus, the senescence of rice leaves

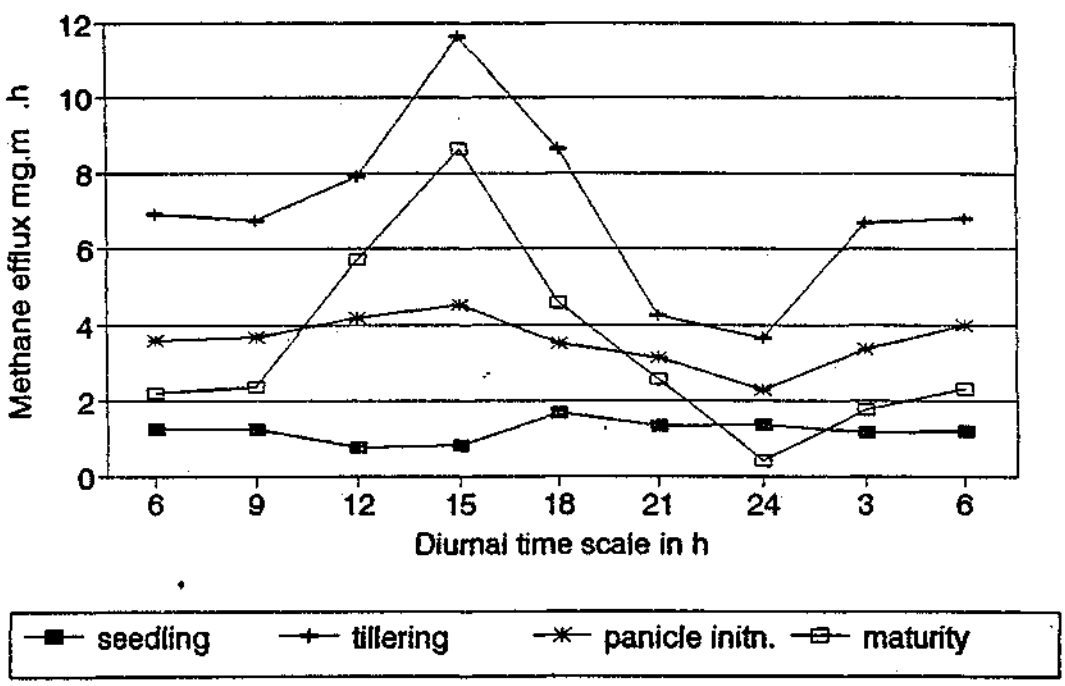

Fig.1 : Diurnal flux in methane emission as affected by the growth stages of paddy

may not be a simple function of chronological leaf age at the grain development period.

Effect of seedling age and time of planting on yield and phenological growth stages of the photosensitive varieties

Yield attributes : Eleven rice cultivars were evaluated for their photosensitivity. The cultivars were planted in the field with 30 days and 45 days old seedlings at three different dates viz., July 1st (First planting), July 15 (2nd planting), August 1st (Third planting), 1994. Of these only four varieties (IET 12875, Lunisree, CR 629-256, CR 683-195) were found to be highly photosensitive. In general rice cultivars when transplanted with 30 days old rice seedlings on second planting gave higher grain yield (4.2 t/ha) than the first (3.7 t/ha) and third (3.49 t/ha) planting. However, cultivars IET 12875 and Lunisree when planted with 45 days old seedlings of first sowing gave higher grain yield (3.3 and 3.51 t/ha) than those of the same cultivars planted with 30 days old seedlings (3.18 and 3.49 t/ha). Sterility percentage corresponded with the yield potential of cultivars.

Phenological growth of plants : Studies on the phenological growth of plants showed that the active tillering stage of plants from 30 days old seedlings was achieved around 40-50 days after transplanting. However, the primordial initial of the first planting was delayed by 10-15 days and it was enhanced by 10-15 days in plants of third planting compared to those of second planting. Changes in the pheology of plants between the 30 and 45 days old seedlings later to flowering stage were negligible. The grain maturity in all the cultivars was achieved by about 28-30 days after flowering irrespective of the cultivars, age of seedlings and days of planting.

Evaluation of maintenance respiration : Maintenance respiration(MR) was evaluated for scented and non-scented long slender grain type varieties with Ratna as check. Three scented varieties viz., Basumati 370, Debraj and I + KR 228 and two non-sented but long slender grain type were taken.

No difference in maintenance respiration rate was observed amongst scented and non-scented varieties. In general maintenance respiration in these varieties was found to be less in comparison with high yielding varieties but the proportion of MR consumption per day in relation to total photosynthetic assimilates was found to be higher (18 per cent) in long slender varieties than in high ;yielding varieties (15 per cent).

Chlorophyll system studies : Chlorophyll was estimated at every three days interval commensurating with primordial initiation to mid dough stage with the objective to retain chlorophyll status and to observe its effect on productivity.

IR 36 and Swarnaprabha exhibited chlo-

rophyll degradation after a week of PI which when applied with 30 kg N per ha indicated 15 to 20 per cent higher productivity through less abscissions and degradation of spikelets.

The second degradation was noticed during 5 days after anthesis which when applied with another 30 kg N per ha resulted in delaying of apparent senescense of leaves but rather acted adversely on the productivity by reducing yield by 15 per cent. Application of N beyond anthesis although effective in retaining chlorophyll status but not in terms of increasing yield. However, IR 36 responded better than Swarnaprabha more particularly at PI stage.

Evaluation of photosystem I and II : Analysis of Photosystem I and II under saturated and limiting light conditions (50 per cent NL) was studied in variety Swarnaprabha adding $MgCl_2$ to the chloroplast suspension. Photosystem I activity increased by additionof cl^- anion under both the light intensities, but the values were more in saturated light than limiting light intensity. However, effect of cl^- anion on photosystem II photochemistry was not much influenced under both the light intensities. Hence further studies on Mg^{2+} and cl^- induced fluorescence of photosystem I and photosystem II, redistribution of energy transfer etc. is continuing.

Influence of nitrogen on biomass production and yield in aromatic fine rice cultivars

In wet season, 1994, two aromatic fine varieties, HKR 228 and Basmati 370, and one non-aromatic fine variety, Ratna ws taken to assess their 'N' response (0, 30 and 90 kg/ha) in relation to yield and biomass production. Nitrogen was applied by top dressing in three splits (20 DAT, PI and anthesis). Though there was no significant variations at different N levels in terms of yield, test grain weight, and total spikelet number, significant variations were present in total biomass production panicle number, sterility percentage and harvest index. At 90 kg N/ha the HKR-228 produced more biomass than Basmati 370 and Ratna. Ratna produced more dry matter at 30 kg N/ha than 90 kg N/ha., Though all varieties produced more panicles at 90 kg N/ha than 30 kg 'N' ha, HKR 228 responded well to the former by producing more panicle number than other two cultivars.

Unlike Basmati 370 and Ratna, HKR 228 showed a leaf area index value of two from heading to harvest owing to its more biomass production. All three varieties exhibited less specific leaf weight after anthesis.

Development and testing of puddle seeder for rice

The six row drum type puddler seeder was tested in the field during wet season 1994 and dry season 1995.

The field was prepared with two operations of tractor operated rice disc harrow followed by planking by bullock operated leveller. The excess water was drained out from the field. The puddle seeder was operated one day after the puddling operation. The three separate seed boxes were filled upto 50 per cent capacity to get seed rate of 60-70 kg per hectare. The machine was pulled by one person for sowing pregerminated rice seeds with row spacing of 20 cm.

In wet season the complete removal of excess water from the field was not possible. So about 15 per cent lines were disturbed due to floating of seeds. In dry season seeds could be sown in line as there was no standing water in the field. When germination length was more than 2 mm, free flow of seeds was difficult through 10 mm holes in the drums. The hill placement of seeds was not possible with the machines and seeds dropped in continuous lines.

The average seed rate was 65.6 kg/ha. The draft of the implement varied between 17-22 kg. The rice variety Heera of 65-70 days duration was used in the experiment. By increasing ground wheel diameter from 30 cm to 40 cm reduced draft by 10-12 per cent. Average yield of 2.48 t/ha was obtained. The field capacity of the machine was 0.49 ha/day (8 hrs.) (Table 12).

Development and testing of rice transplanter

The power operated self propelled root washed transplanted that was fabricated earlier had to the bush bearing at rotating junction to save cost. In test run it was seen that more power was wasted in friction at the bushes, hence they were changed to ball bearings. The power could be transmitted

Table - 12 Performance test of 6 row drawn seeder

No. of Observations	Seed rate (kg/ha)	Draft (kg)	Speed of operation (km/hr)	Field capacity (ha/B.hr)	Plant population per meter row	Yield (t/ha)
1	63	18	0.8	0.46	80	2.3
2	68	20	1.2	0.55	65	2.8
3	72	17	0.7	0.63	74	2.2
4	55	22	0.9	0.38	90	2.6
5	70	19	0.8	0.42	110	2.5
Average	65.6	19.2	0.88	0.49	84	2.48

through the power chord to the oscillating mechanism from where the power to the transplanting fingers is through the chain drive.

While transportation of the machine to the field and during turn at the headland the machine is to be idle for which a clutch is provided. The fabrication of the machine is complete.

Design and development of the 4-row manual rice transplanter using mat type seedlings

A 4-row manual operated rice transplanter using mat type seedlings was designed, fabricated and tested in the farm field.

Machine specification :

Power requirement : One person

Planting finger : Fixed fork type with 30° angle and bend at the tip

Row spacing : 20 cm

Tray displacement per stroke : 1.1 to 1.3 cm

Weight of the machine without mat seedlings: 27 kg.

Weight of the machine with mat seedlings : 31.4 kg

Sinkage of wooden float in the field : 4.3 cm

Depth of setting : 2 cm below the depth of sliding

Angle of tray with respect to soil surface: 68°

Draft : 10 kg.

Planting depth : 3 to 5 cm.

Seedling preparation

Seeds of variety Moti were put into the water for 24 hours. Soaked seeds were put into a moist sack with a press over it for 24 hours or till their germination. The sprouted seeds were sown over the tray (18 x 50 cm) where thin layers of soil with manure were spread earlier. The water is sprinkled alternately for a period of 20 to 25 days.

Tray specification : (185 x 500 x 20 mm).

To keep the proper density of the seedlings in the mat, the seed rate was maintained at 100 gms/100 sqm. of tray area. The tray is having the side holes in order to pass the excess water at the time of irrigation.

The average number of seedlings were found to be 2 to 3 (Table 13).

Table - 13 : Testing of transplanter from taking up seedlings.

Test No.	No. of Fingers			
	1	2	3	4
1	3	3	2	3
2	4	2	3	4
3	3	2	3	4
4	3	2	4	2
5	2	4	3	3

Missing hills : The missing hills depend upon the seedling density as well as the tray displacement. It was found that missing hill percentage was below 10 per cent. To increase the number of seedlings per hill, it requires 130 g/1000 m² of area. Hence the seed rate per hectare is 40 kg for (18.5 x 50 cm) tray 20 m² of seeds. No. of trays per ha. is 400. Average age of seedlings is 20 to 25 days.

Field capacity :

Nursery data : (i) Variety - Moti, (ii) Seed rate - 200 g/tray.

Seed soaked 24 hours and then kept under gunny bag for 24 hours. Sprouted seeds were sown in the tray.

a) Leaf stage : 4 to 5
b) Height of seedlings : 8.5 to 9.5 cm
c) Stem diameter of the seedling : 1.2 mm to 1.5 mm.
d) Soil type : Sandy clay loam
e) Age of seedlings : 22 days
f) Depth of soil/mat : 15 mm depth of soil
g) Depth of soil cover over seed : 5 mm
h) No. of seedlings/m² : 2 to 3

Field preparation

Length of area : 40 m
Width of area : 35 m

After summer ploughing, the field was puddled by tractor drawn paddy disc harrow with 8 to 10 cm depth of standing water and then levelled by leveller

Depth of operation and puddling : 10 cm
Depth of water : 2 to 3 cm
Depth of hard pan : 10 cm
Sinkage of the worker in the field: 8 cm
Average field capacity of machine : 23.6 hr/day (including loading of the seedlings) (Table 14)

Table 14 : Test of field capacity.

Test No.	Time (min.)	Area (sqm)	Missing hill(%)	Field Capacity (hr/ha)
1	13	105	9.1	21.6
2	15	105	10.2	25
3	30	210	9.3	25
4	14	105	10.1	23.3
5	14	105	9.5	23.3

Average field capacity of machine : 23.6 hr/ha/ (including loading of the seedlings)

Sinkage of machine in the field : 2.5 cm

Planting observation :

1. Average no. of hills/m^2 : 35
2. Average seedlings/hill : 2
3. Field efficiency : 75 per cent
4. No. of times machine stopped during operation : 8
5. Reason for stop : Mainly due to loading of seedlings
6. Area covered : (40 x 35m) 1400 m^2.

Design and development of rice weeder

The fabrication of the weeder was taken up according to the design. It was designed on the principle of cone weeder where the force required to operate the machine is less and churching of young succulent weeds and soil is done at the top layer. The soil churching component that is the cone was fabricated. The cone is a tapering hollow drum of 22 cm diameter at the wide bend and 13 cm long. Straight and serrated blades were welded alternatively on the cone. The height of the straight blades are 3.5 cm and serrated ones are 2 cm respectively. A shaft passing through the cone was to move on the frame for which bushes were provided. A wooden handle was provided for the operation whose angle could be changed. A star wheel of 15 cm dia was assembled infront of the cone.

The fabrication was completed. The preliminary test was satisfactory.

Testing of tractor drawn reaper

A tractor mounted commercial reaper and a self-propelled commercial reaper were tested extensively in CRRI farm and farmer's field. The crop parameters like height of plant, number of tillers per hill, number of hills per m^2 were studied. The study of height of plant was necessary for effective handling of plant during conveyance and laying in the window. The height of plants were less than 110 cm. average number of hills were 38 per m^2. The crop was harvested at 38 per cent moisture content.

The tests were carried out in plot size of 0.08 ha and 0.16 ha and farmer's plots were nearly of the same size.

The capacity of tractor drawn harvester ranged from 0.3 to 0.34 ha per hour and the capacity of self propelled harvester was 0.25 ha/hr (average) (Table 15).

The field loss for both the harvester was below 0.5 per cent at 23 per cent moisture content. The cost of manual harvesting was Rs.675/- per hectare, while the cost of tractor harvesting was Rs.575/- per hectare inclusive of cost due to gathering and transport. The cost of harvesting by self propelled reaper was Rs.500/-. Besides the lower operating cost the work is done early, hence losses are prevented.

Table-15 : Field capacity and skilled labour requirement of tractor drawn harvester.

Test No.	Field Capacity (ha/hr)	Skilled labour (hr/ha)	Harvest loss (%)
1	.30	3.3	0.2
2	.34	2.9	0.3
3	.32	3.1	.02
4	.31	3.2	.03
5	.33	3.0	0.3

Development of a dryer (500 kg) suitable for small and medium farmers

A batch dryer of 500 kg holding capacity has been developed. The unit comprises of the following main components : (i) drying chamber, (ii) blower with motor and (iii) solid fuel fired furnace with heat exchanger. The dryer works on the principle of thin layer (12 cm) drying. Air from the blower gets indirectly heated while passing through the heat exchanger pipes before entering in to the drying chamber. The whole unit is mounted on a wheeled base to make it movable.

While performing the preliminary trials, it was felt to make two additional arrangements so that the unit can operate with varying capacities. This was done by (i) providing a gate to control the inflow of hot air to one of the plenum chambers. By these arrangements, the holding capacity of the dryer can be reduced to 250 kg and to 150 kg.

Testing of the dryer was further carried out taking mixture paddy, to find out the total drying time, fuel requirement, labour requirement and final milling qulity of dried product.

The detailed specifications and summary of test results of the dryer are given as follows

Specifications

Type		:	Batch
Holding capacity kg/batch		:	500 (rough rice)
Drying principle		:	Thin layer (12 cm)
Dimensions :	Length (mm)	:	3560
	Breadth (mm)	:	970
	Height (mm)	:	1400
Fuel to be used		:	Any solid fuel (coal, wood, briquets)
Blower type and capacity		:	Centrifugal, 85 cum per min.
Motor		:	Induction 3, 3.25 A 1.5/2 KW/HP
Cost of dryer		:	Rs.25,000/- (1994)

Influence of processing conditions on milling quality of rice

Threshing by tractor treading was compared to that with hand beating, and using mechanical thresher (pedal and motorised) on milling quality of three rice varieties viz. CR-1014, Tulasi and Kalasree. Only tractor treading revealed 4-5 per cent higher breakage as compared to the control. Other methods of threshing did not have any adverse effect on milling quality.

As for as the cleaning is concerned, there was no difference in the head rice recovery whether the grain was cleaned manually or using a mechanical cleaner. But there was difference in total rice recovery. Mechanically cleaned sample showed 6-8 per cent higher rice recovery than manual method. This was mainly due to better cleaning with mechanical cleaner.

Summary of the test results of the dryer is as follows :

Parameters	Observations		
	Test I	Test II	Test III
Variety	Mixture	Mixture	Mixture
Mean ambient air temp.°C	26	25	25.5
Drying air temp. °C	42 ± 2	42 ± 2	42 ± 2
Maximum grain temp. °C	40 ± 2	40 ± 2	40 ± 2
Initial moisture contact (w.b.) of paddy %	24	24.5	24.2
Final moisture contact (w.b.) of paddy %	14.2	14.5	13.8
Loading time, man hr	0.5	0.5	0.5
Unloading time, man hr	0.5	0.5	0.5
Labour requirement, man hr	3	3	3
Total drying time, hr	7	7	7
Tempering time, hr (After 3hr of initial drying)	1	1	1
Fuel (coal) consumption, kg	15	15	15
Head rice recovery %	62	63.4	62.8
Cost of drying (Rs/ton)	52	52	52

Advantages of the new dryer over commercially available dryers

* Cost of this dryer is much less than commercial dryer
* It is easy to operate and it requires less maintenance.
* The varying capacity without affecting the thin layer drying principle helps uniform drying
* Use of solid fuel for heating air makes it suitable for rural use.
* Since it is movable, it can be installed easily at different locations.

CROP PROTECTION

Weed management

Chemical weed control in puddle-seeded rice

An experiment was conducted during dry season to identify a suitable herbicide for controlling weeds in puddle-seeded rice (cv. Annada). The herbicides tested were anilofos (EC) at 0.4 and 0.6 kg/ha, anilofos + 2,4-DEE (EC) (at 0.3 + 0.42 and 0.4 + 0.53 kg/ha), butachlor (EC) at 1.0 and 1.5 kg/ha, pendimethalin (EC) at 1.0 and 1.5 kg/ha and cinmethylin (EC) at 0.1 kg/ha. Unweeded and weed free controls and hand weeding twice treatments were kept for comparison. The problem weeds of the experimental site were *Cyperus difformis* L., *C. iria* L. and *Fimbristylis miliacea* (L.) Vahl. (sedges); *Sphenochlea zeylanica* Gaertn. and *Marsilea quadrifolia* L. (dicots).

Among the test herbicides, anilofos (0.4 and 0.6 kg/ha), and anilofos + 2,4-DEE (0.3 + 0.42 and 0.4 + 0.53 kg/ha) controlled weeds effectively (weed control efficiency 84.8 to 90.0 per cent). The anilofos + 2,4-DEE at both the levels showed phytotoxicity on rice seedlings. The herbicide treatments which gave comparable yields with weed free check (3.37 t/ha) were anilofos at both the levels, anilofos + 2,4-DEE (0.3 + 0.42 kg/ha), butachlor and pendimethalin at both the levels. Two rounds of hand weeding also produced yield (3.29 t/ha) similar to that of weed free check.

Disease management

Studies on toxin produced by brown spot pathogen

Extraction of toxin from culture.: Several extraction procedures were tried for extracting the toxic metabolites produced by *Dreschlera oryzae* in culture. For assessing toxicity of different fractions and the use of appropriate concentrations of the toxin preparation, a rice seedling bioassay was perfected using cultivar Benibhog, most susceptible to brownspot. Batches of 500 ml aliquots of culture filtrates obtained from 21-day-old cultures grown in Czapek's solution were concentrated 10 per cent of their original volume, methanol was added and aged overnight at 5°C. Methanol was evaporated after the extract was paper filtered. The remaining water fraction was extracted with chloroform. The chloroform fraction was evaporated and was dissolved in small quantity of methanol, the volume was raised with water to such a volume so that ml of the crude toxin extract represents 20 ml of the original culture filtrate.

Bioassay of the toxin: The toxicity of crude toxic preparation was tested using the rice seedling bioassay. The extract was highly toxic as shown by the inhibition of both

coleoptile and radicle growth of the brown spot susceptible cultivar, Benibhog.

Sensitivity of different rice varieties : Toxicity of the crude extract was influenced by varieties and the concentration of the extract. A set of 10 rice varieties differing in their reaction to brown spot varied in their sensitivity to the toxin fraction. Brown spot susceptible rice varieties, Benibhog and Mahsuri were highly sensitive to the toxin preparation relative to that of Jaya, Dular and Karuna. However, the tolerant rice varieties, CH 13, RR 20-5, RR 35-4-1, RR 36-141 and RR 159-90 were conspicuously less sensitive to the toxic fraction. Among these tolerant rices, RR 20-5 and RR 36-141 were significantly less sensitive to the toxin preparation.

Host-specificity of the toxin : When tested on a set of non-host plants, the extract was toxic to wheat, barly, maize and tomato and was not toxic to cucumber, green gram, blackgram and groundnut. Thus, the toxin preparation is not strictly host-specific in nature, but may be toxic to a restricted group of plant species.

Pathogenic variation in bacterial leaf blight

Grouping of rice varieties and bacterial isolates on the basis of differential interaction : The differential interaction among the isolates, genotypes and their interaction was studied through analysis of variance. It revealed significant differences among isolates, genotypes and in their interaction. The mean lesion length of 41 genotypes averaged over their reaction against 52 bacterial isolates ranged between 3.3 and 15.9 cm. The genotypes could be grouped into live groups on the basis of significant differences among them.

Clustering pattern of the genotypes : The 41 genotypes of diverse origin could be grouped into five clusters through cluster analysis following numerical taxonomic approach. It is interesting to note that each group of genotypes joined together to construct independent cluster even at a similarity level of 0.98 (Fig. 2). Among these, cluster III and IV merged together into a single group at a phenomic level of 0.95 which in turn merged with cluster II and cluster I to form a single cluster at a similarity level of 0.93. Cluster V genotypes exhibited its identity as an independent group which ultimately merged upon the blended group of clusters of I, II, III and IV at a similarity level of 0.85.

Cluster mean : Among the five clusters, cluster V consisting of eight genotypes exhibited highest lesion length form 13.8 to 21.6 cm with a mean lesion length of 15.59 cm. All the varieties in this group were found to be highly susceptible to all the 52 bacterial isolates tested.

Cluster I genotypes showed the range of reaction between 3.6 and 12.2 cm with a mean lesion length of 5.35 cm. The range of lesion length was from 2.3 to 8.5 cm with a

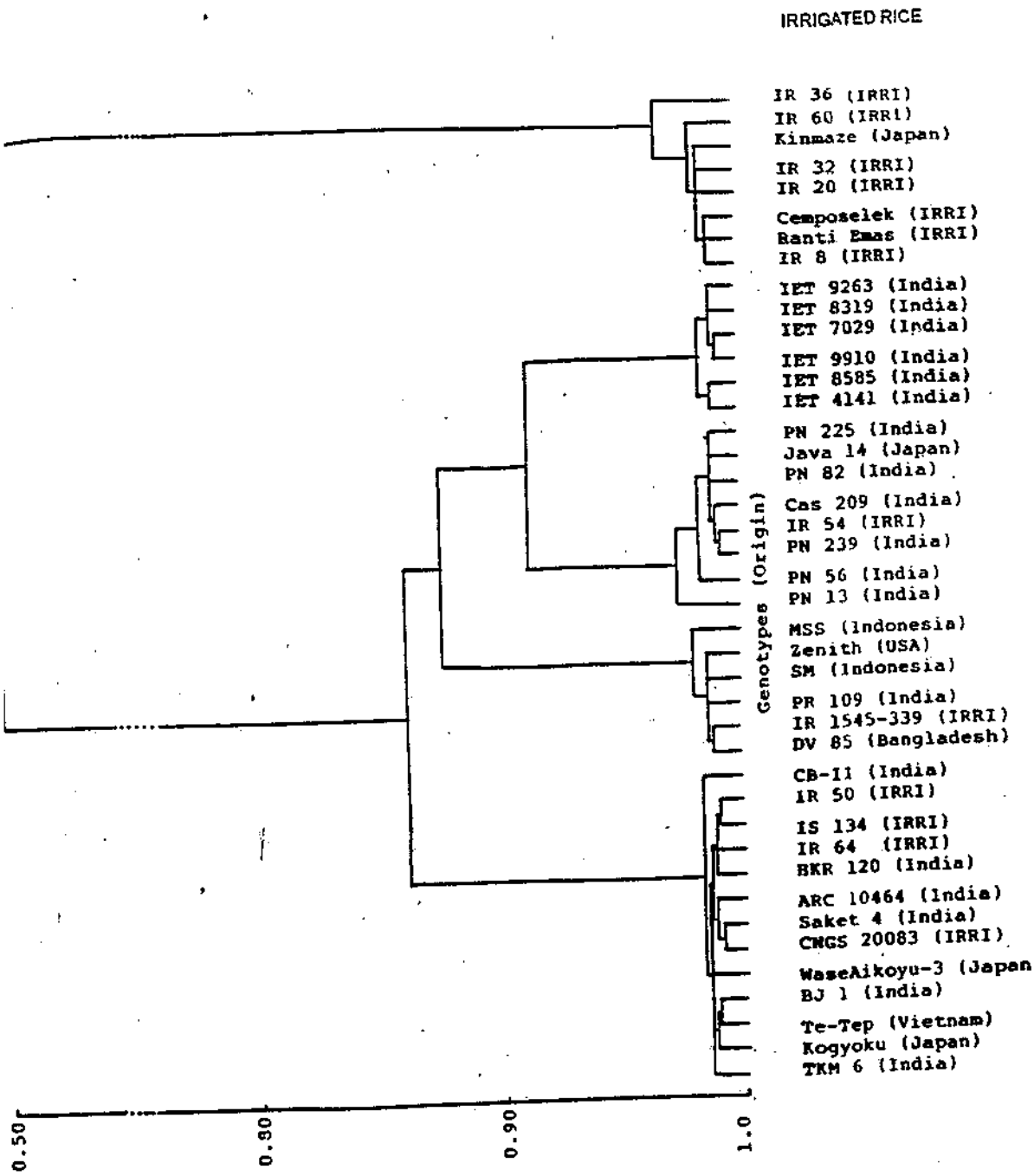

Fig.2 A dendrogram showing the similarity and successive clustering of 41 rice genotypes on the basis of their reactions against 52 isolates of *anthomonas campestris* pv. *oryzae*

mean of 3.50 cm for the genotypes of Cluster II, while the genotypes of cluster III showed lesion length ranging from 2.6 to 8.0 cm with a mean of 3.97 cm. Likewise, genotypes of cluster IV exhibited their reaction against 52 isolates ranging from 3.1 to 9.1 cm with a lesion length of 4.91 cm.

It is evident from the analysis of variance that there existed significant differential interation between host and pathogen involving 41 genotypes and 52 bacterial isolates. Such differential interactions led to the identification of five rice varieties viz., IR 8, TKM 6, DV 85, PN 13 and IET 8585 showing highly specific variety-isolate interaction. Among these IR 8 exhibited susceptible reaction against all the isolates while rest of the four genotypes could differentiate the isolates into specific groups.

Clustering pattern of bacterial isolates : Attempts were made to classify 52 pathogenic strains into specific groups/clusters on the basis of their virulence pattern on live differential host genotypes. Similarity and successive clustering of 52 isolates on the basis of their virulence pattern on 5 host genotypes has been depicted in the dendrogram (Fig. 3). The 52 isolates could be grouped into six clusters even at a similarity level of 0.99. Number of isolates in each cluster were varying belonging to diverse geographical origin.

Identification of pathotypes : It was felt essential to designate each group of isolates identified on the basis of their reaction pattern on five rice varieties in a standard system. The standard system is based on qualitative reaction pattern of five differential host genotypes as susceptible (S) or resistant (R). Through this, 32 possible pathotypes could be identified on the basis of different permutations and combinations. The six pathotypes identified among the 52 bacterial isolates could be numbered as 1, 4, 7, 14 and 16. New pathotypes would add to the list in future.

Multiplication pattern of *Xanthomonas campestris* pv. *oryzae* in differential rice varieties

Symptoms of bacterial blight disease were characterised by a visible lesion with tissue necrosis and a part of the leaf beyond the lesion showing bacterial streaming (invisible lesion) combined together is called virtual lesion.

Visible lesion : Typical symptoms of the visible lesion characterised by water soaking with longitudinal folding of the leaves which developed within four days after inoculation in the susceptible rice cultivar IR 8. Under compatible host pathogen combination, pale yellow lesions with slight water soaking developed within 5 days after inoculation in the varieties BJ 1, TKM 6, DV 85 and Sumera

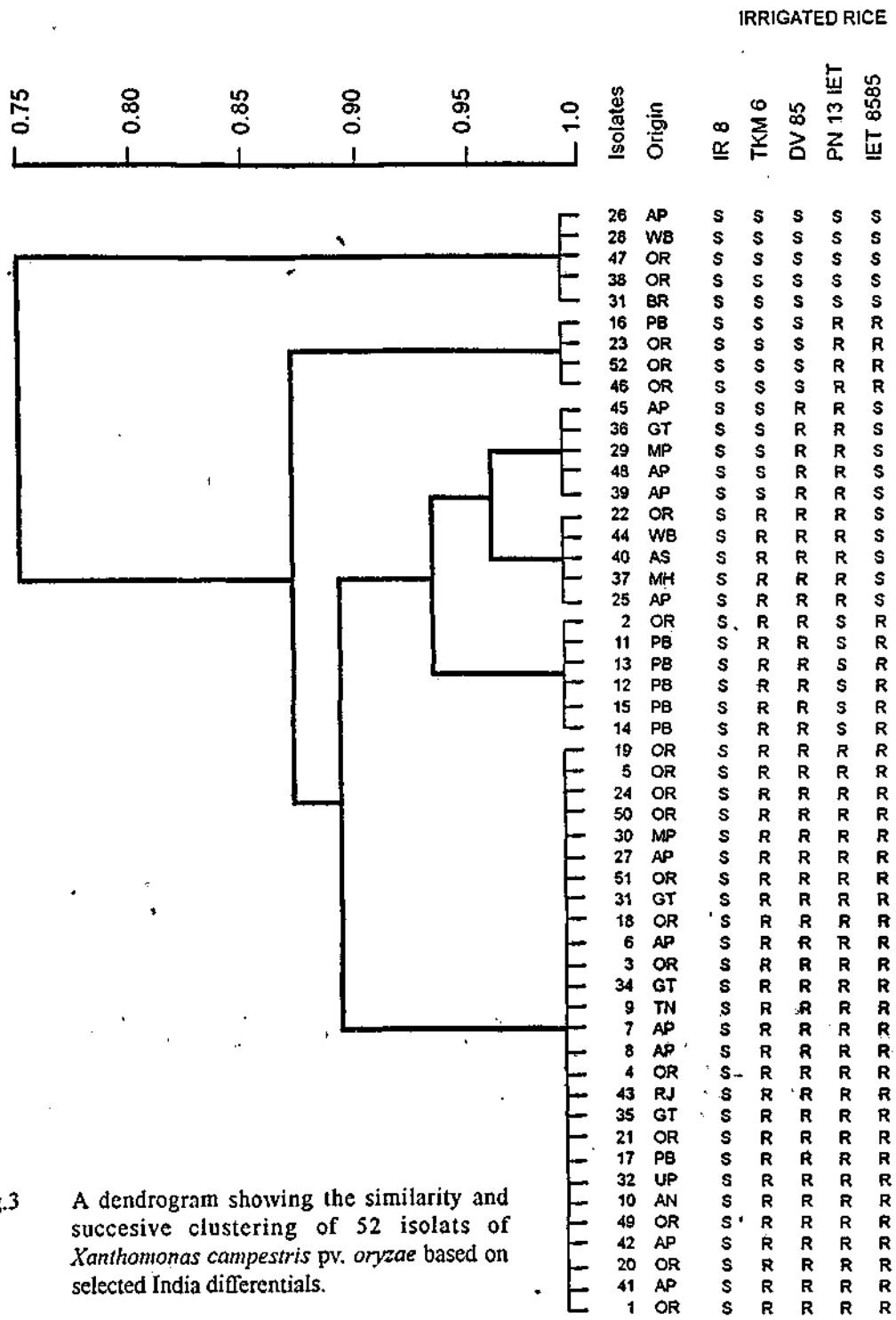

Fig.3 A dendrogram showing the similarity and succesive clustering of 52 isolats of *Xanthomonas campestris* pv. *oryzae* based on selected India differentials.

mangga. On the other hand, yellowish brown lesions or browning of cut ends appear without any water soaking as a result of incompatible host pathogen interaction within 7 to 8 days after inoculation in the varieties Malagkit sungsong, IET 8585 and PN 13. Thus, the criteria of lesion development and lesion length in both compatible and incompatible host pathogen combinations can be used to categorise the bacterial isolates into pathotypes (Fig. 4).

Invisible lesion : In general, it appeared that the length of the bacterial streaming was dependent upon the length of the visible lesion. In typical susceptible cultivar IR 8, the length of the leaf showing bacterial streaming was to an extent of 8.5 cm while it was in the range of 2.1 to 3.7 in other varieties of compatible pathosystem depending upon the length of the visible lesion. It was still limited in the range of 1.1 to 2.1 cm under incompatible host-pathogen combination. Thus, the length of visual and virtual lesions varied greatly in different rice varieties depending upon host pathogen compatibility.

Bacterial multiplication

Visible lesion : The susceptible cultivar IR 8 favoured rapid bacterial multiplication of the bacterium with a maximum of 4.8 x 10.6 cells/cm of leaf tissue by 12 days after inoculation and gradually declined over a period of time. On the other hand, differential rate of multiplication under compatible and incompatible host pathogen combination was observed in other varieties. Under resistant pathosystem, the varieties IET 8585, PN 13 and Malagkit sungsong showed low rate of multiplication with the population in the range of 5.0 x 10.3 to 7.0 x 10.3 cells/cm leaf tissue within first four days and increased to 10 times only by 12 days after inoculation.

Invisible lesion : Bacterial multiplication in the invisible part of the lesion gradually declined with an increase in the distance from the tip of factual lesion. The rate at which the bacteria move within the leaf tissue appears to depend upon the susceptibility of the host plant. Thus the differences in the bacterial multiplication in different rice varieties under compatible and incompatible pathosystems indicate the ability of certain varieties to differentiate the bacterial isolate into pathotypes.

Molecular characterization of blast and Bacterial blight pathogens of rice in India

Status of pathogen isolates

Several trips were undertaken in Cuttack (Orissa), Chinsurah (West Bengal), Pusa (Bihar), Faizabad (U.P.) and Raipur (M.P.) for collection of bacterial blight diseased leaves. From these samples, so far a total of 898 isolates of *Xanthomonas oryzae* pv. *oryzae* were isolated. DNA has been extracted from 200 isolates and are preserved

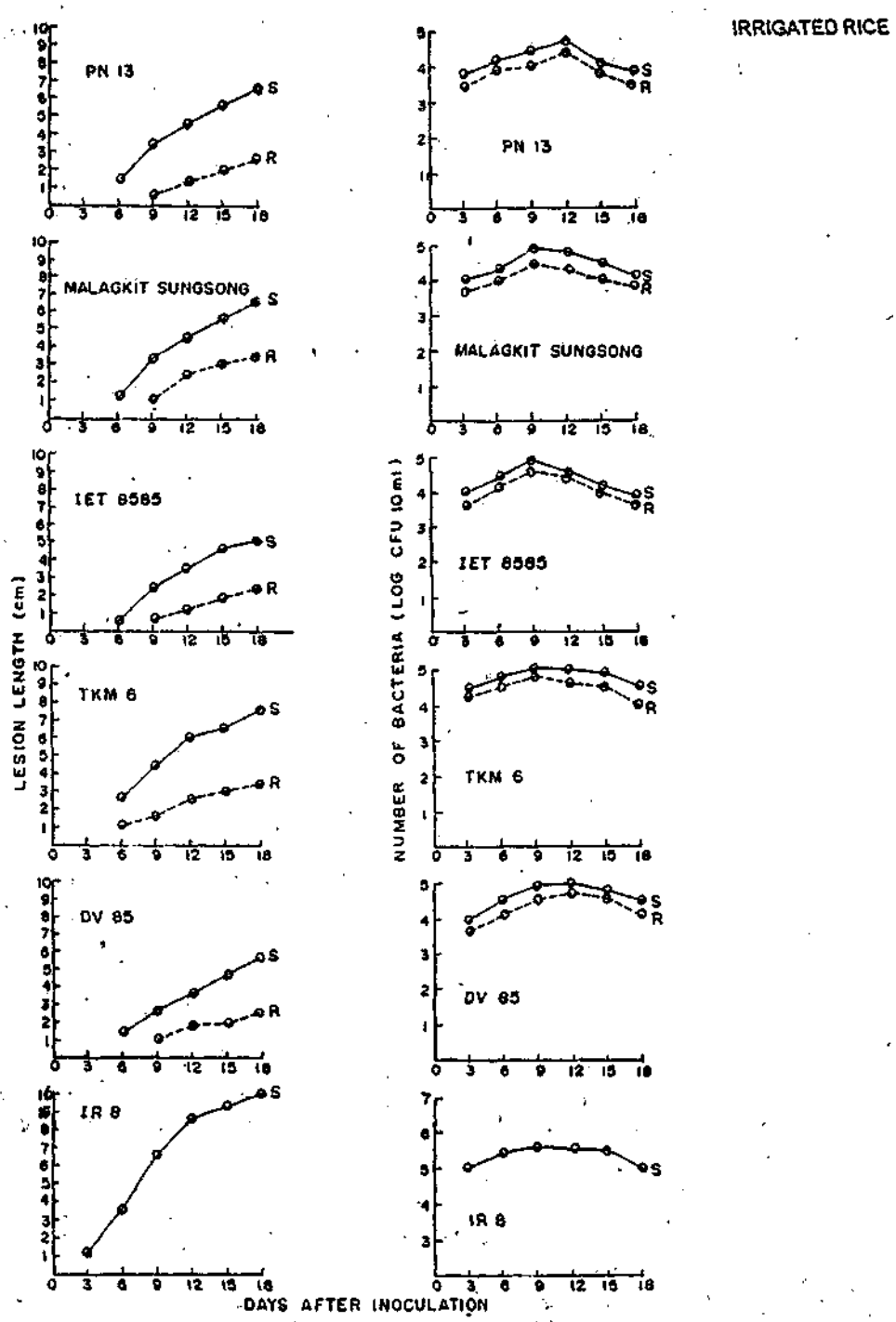

Fig. 4 : Lesion length and multiplication of *Xanthomonas compestris* pv. *oryzae* in differential differential rice varieties.

for analysis.

Blast: Collection trips undertaken in Cuttack and in Semiliguda and Jeypore (Orissa), Kalimpong (West Bengal), Jagadalpur (M.P.) and Gangtok (Sikkim) have yielded so far 300 isolates of *Magnaporthe grisea*.

Database on isolates : A database on all the isolates with complete details on the place of collection, variety from which isolated, ecosystem in which the crop was grown etc. is being maintained.

Bacterial blight : In order to arrive at a standard set of differential for pathotyping the lineages classified based on RFLP or PCR, RAPD data for drawing meaningful conclusions, a set of 34 varieties were used for pathotyping 10 isolate originating from different regions. These test varieties included the near isogenic lines, popular varieties and donors of resistance.

Three of the 34 varieties tested, *O. minuta* line, DV 85, M. Sung song were resistant to all the isolates used, while 14 varieties (Zenith, Tetep, Karuna, Ratna, Pankaj, Mahsuri, Madhukar, Swarna, Rajashree, Ajay, Tulasi, Pusa Basmati, Karnal Local and Heera) were susceptible to all the 10 isolates. The reaction of the rest of 17 varieties (IRBB 1, IRBB 3, IRBB 4, IRBB 5, IRBB 7, IRBB 8, IRBB 10, IRBB 11, IRBB 13, IRBB 14, IRBB 21, IR 20, IR 24, IR 54, IR 1545, PR 106 and Swarna) varied with the isolates used.

It is of interest to note that none of the near isogenic lines carrying single resistance gene was resistant to all the 10 isolates tested. Therefore, development of varieties resistant to bacterial blight carrying these known resistance genes should be based on precise knowledge of pathogenide strains of the bacterium prevailing in a particular location. Further, pyramiding resistance genes in the new varieties may be rewarding. A better understanding of the population structure of the pathogen and use of marker-aided selection would greatly enhance the success rate for achieving these aims.

Blast : Ten near isogenic lines and Moroberekan were evaluated in a uniform blast nursery at Hazaribag (Bihar). The lines C 101 LAC and C 101A 51 and Moroberekan were consistently resistant to blast.

Breeding : Resistant and susceptible parents for both the diseases have been selected and several crosses have been made (Table 16). Presently, F_1 seeds are available and the F_2 generations will be raised in the forthcoming wet season.

Simulation of the effect of bacterial blight disease on crop growth and yield of rice

Crop loss assessment has been undertaken through system analysis and simulation. System analysis can be used to integrate various growth processes including quantita-

Table-16 Parents selected and crosses made

Parents	Blast	Bacterial blight
Susceptible	Vandana	Tulasi
Kalinga III	Sabita	
Donor	Moroberekan	M.Sung Song (Xa 6)
	C 101 Lac (Pi - 1)	IRBB 21 (Xa 21)
	C 101A 51 (Pi-2)	O. minuta (WHD 18-78-1)
Crosses made		
Blast	Vandana x Moroberekan	
	Vandana x C 101 Lac	
	Vandana x C 101 A 51	
Bacterial blight	Tulasi z M. Sung Song	
	Tulasi x IRBB 21	
	Tulasi x O. minuta (WHD (18-78-1)	
	Sabita x M. Sung Song	
	Sabita x IRBB 21	
	Sabita x O. minuta (WHD 18-78-1)	
	Swarna x IRBB 21	
	Swarna x O. minuta (WHD 18-78-1)	

tive data on disease characteristics, such as the amount of diseased leaf area and severity. The BLIGHT simulation model was used to simulate crop growth using the observed data on green and diseased leaf area and severity in different crop canopy layers as input. For the purpose of validation, the data on dry weights of leaves, stems and storage organs were collected from the field experiments.

Different disease epidemics were created in the field at three developmental stages of crop growth viz., early tillering, late tillering and flag leaf appearance. Inoculations at early tillering stage resulted in disease spread throughout crop canopy. In late tillering inoculations, disease was present in middle and top leaf layers, and disease spread was restricted only to the top leaf layer in flag leaf

inoculations. Late tillering inoculations showed maximum grain yield reductions over healthy treatment followed by inoculations at early tillering and flag leaf appearance. Simulated results coincided with the observations indicating the disease progress as quantified by the fraction diseased leaf area from late tillering stage to maturity damages the crop comparatively more than the other treatments. Though the disease onset was earlier with faster progress on the crop in the early tillering inoculation, damage caused was slightly lower due to higher green leaf area during vegetative stage. In the flag leaf inoculations, crop was infected for a shorter duration with a moderate disease level. Leaf area observations have shown that amount of diseased leaf area and severity were higher in the inoculation made at late tillering stage than at another inoculation. This is because, the crop has compensated leaf area reduction during early tillering stage with the formation of new leaves. There was a steady increase in the leaf area diseased and severity in the treatment of late tillering inoculations while the duration of the disease on the crop was short in flag leaf inoculations.

Different degrees of BLB epidemics caused different reductions in total dry matter production. Simulation results have shown that it was lowest with 856 kg/ha in the plot inoculated at flag leaf appearance and highest with 1630 and 1814 kg/ha in the late tillering inoculated plots. The reduction was inthe range of 1095 kg/ha in the early tillering inoculation.

Similar trend was found for final grain yield reductions of different inoculated plots. The lowest was 659 kg/ha in the plot inoculated plots at flag leaf appearance. Late tillering inoculated plots showed reductions of 1360 and 1526 kg/ha. The reductions in the early tillering inoculated plots was in the range of 1035 to 1182 kg/ha.

In general, observed reductions were slightly higher than the simulated valued (Table 17).

Results discussed above show that the BLIGHT model simulated satisfactorily the reductions in grain yield and total dry matter production at different disease severity levels. Model application requires good model calibration. Application of the model to analyse the effect of different disease scenarios in combination with different levels of leaf nitrogen on crop growth and yield were taken up under exploratory studies. Two rice cultivars IR 64 and Annada were chosen for the study. The varieties differ in their susceptibility to the disease. Disease scenarios were created for the two cultivars separately under different levels of nitrogen suffer most due to early disease initiation and spread. Maximum yield losses were observed in case of disease onset at early and late tillering stages at higher levels of leaf nitrogen. Lower

Table - 17 : Observed and simulated reduction in total dry matter, grain yield and stem dry weights of different BLB inoculated plots over health treatment (kg/ha)

Treatment	Total dry matter		Grain Yield		Stem	
	Observed	Simulated	Observed	Simulated	Observed	Simulated
Early Tillering inoculation						
Plot-1	1496	1095	1665	1158	115	100
Plot-2	1968	1466	1487	1182	288	059
Plot-3	1522	1158	1310	1035	199	07
Late tillering inoculation						
Plot -1	1227	1639	1115	1360	155	233
Plot-2	2348	1814	1657	1526	448	287
Flag leaf inoculation						
Plot-1	1327	856	1177	659	--	064

nitrogen levels reduced disease severity on the crop and resulted in lower yield losses. Thus it would be more appropriate to grow the crop at moderate levels of leaf nitrogen to delay at disease onset and reduce severity which in turn increase production.

Durable resistance of tungro tolerant varieties

Thirty five tungro tolerant varieties (tolerance score 1-3) were tested under field conditions in 3 replications to see their durable resistance over a period of 5 years. Due to severe disease pressure, five varieties namely Pankaj, GEB-24, Ptb. 18, Daya and TKM-6 recorded higher levels of disease (40-48 per cent).

Screening of International Rice Tungro Nursery (IRTN) entries

Ninety one IRTN entries were screened for tungro resistance under field conditions. It was observed that 5 entries namely ARC 11554, ARC 12778, Naria Bachi, ARC 10312 and ARC 10342 recorded no disease.

Optimum concentration of Imidacloprid for control of tungro

Different concentrations of Imidacloprid viz. 0.1 g/l, 0.5 g/l, 1.0 g/l, 2 g/l, 3 g/l and 4 g/l were tested under green house conditions. Vector mortality and per cent disease were similar to the above experiment. It was

observed that a concentration of 0.5 g/l was optimum for effective control of tungro because vector mortality was 100 per cent and disease was 10 per cent.

Insect management

Survey of indigenous parasitoids of stem borer and study the extent of parasitism

Stem borer moths started appearing during 2nd week of January, 1994 and reached the peak during last week of February, 1994. Moths were available during March and April months and a small second peak reached during last week of April, 1994. The population dwindled by June. During wet season, moths appeared from 2nd week of September and reached the peak sometimes during 1st week of October, 1994 and thereafter moths population dwindled and became scarce by December.

The egg masses and larvae and pupae of stem borers were found in low numbers. Egg masses were not available in rice fields during certain number coinciding the scarcity of moths.

During dry season 1994, parasitism by *Trichogramma japonicum*, *Telenous dignoides* and *Tetrasitchus schoenobii* ranged from 20.1 to 100.0 per cent in different weeks, the peak is during 4th week of June, 1994. Egg masswise parasitism is 25.0 to 100.0 per cent. During wet season, eggmasswise parasitism ranged from 10.2 to 100.0 per cent and eggwise parasitism from 2.1 to 86.2 per cent. Complete parasitism of eggmasses did not occur any time during the year (Table 1). The amount of egg parasitism in dry season is less (75.6 per cent eggmasswise 38.3 per cent eggwise) than in wet season (93.1 per cent and 56.4 per cent respectively). Number of eggs per eggmass

Table - 18 : Important data on stem borer S. incertulas during 1994

Parasitism	Dry season	75.6 and 38.3 eggmass and eggwise
	Wet season	93.1 and 56.4 eggmass and eggwise
Parsitism range	Dry season	25.0 to 100.0 and 19.5 to 94.3 eggmass
	Wet season	10.2 to 100.0 and 2.1 to 86.2 eggmass
Total no. of eggs	Dry season	201 (11936) or 59.3/eggmass
	Wet season	188 (9258) or 49.2/eggmass
Emergence of Larvae	Dry season	1668 42.1%
	Wet season	2150 47.4%

is, however, more in dry season (59.3) than in wet season (49.2). Number of stem borer larvae emerged from eggmasses is almost the same in both the season (Table 18).

Very negligible amount of larval and pupal parasitism was observed from infested tillers collected from rice fields.

Eggmasses of *Schocnobius incertulas* parasitised by different egg parasitoid combinations : Eggmasses of *S.incertulas* were parasitoid by three egg parasites in seven combinations in nature (Table 19). Maximum number of egg masses collected during dry and wet seasons were parasitised by *Tryporyza dignoides* alone, very few eggmasses by *Tryporyza japonicum* (2.5 and 3.2 per cent). Among combinations, *T. dignoides* and *T. schoenobii* combine parasitised more eggmasses 10.2 per cent and 18.2 per cent) in both seasons. The other combinations also contributed to the parasitisation of stem borer eggmasses but to a lesser extent; again among them *T. dignoides* component is a major parasitising against among others.

Eggwise maximum number of eggs were parasitised by *T. dignoides* alone followed by *T. schoenobii, T. japonicum* parasitised least number of eggs in both seasons. More eggs were parasitised by *T. japonicum* (Table 20).

Mortality factors operating on stem borer eggs : Biotic and abiotic factors operate on stem borer eggs and account for mortality of individual eggs in both seasons (Table 21).

The total mortality of eggs due to biotic (parasitism, predation etc.) and abiotic (weather factors like temperature, rainfall, humidity) was 84.5 per cent (dry season) and 81.2 per cent (wet season).

Maintenance and multiplication of egg larval and pupal parasitoids of yellow stem borer : Cultures of the egg parasitoids viz. *T. japonicum, T. dignoides* and *T. schoenobii* are maintained on the host eggmasses in potted plants through the seasons. Potted plant containing 10 egg masses yielded 32.3, 50.7 and 20.6 nos. of *T. japonicum, T. dignoides* and *T. schoenobii* respectively per day.

Negligible number of larval and pupal parasitoids were isolated from affected rice tiller from fields. They could not survive in the laboratory and no cultures could be maintained.

T. japonicum, in addition is also being reared on the stored grain pest *Corcvra cyphalonica* eggs which in turn is being maintained on maize powder.

For *T. dignoides* and *T. schoenobii* large scale multiplication is possible only on the original host (pest) since no alternate labora-

Table - 19 : Eggmasses of *S. incertulas* parasitised by diffferent combinations of egg parasitoids during dry and wet seasons of the year 1994

Season	Eggmass collection	Eggmasses parasitised	Unparasitised egg-masses	Eggmasses parasitised by different combinations of egg parasitoids						
				T.japonicum	T.dignoides	T.Schenobii	T.jap. +T.dig. + T.sch.	T.dig + T.jap	T.dig. + T.sch.	T.jap. + T.sch.
Dry	201	152	49	5 (2.5)*	83 (41.3)*	24 (11.9)*	4 (2.0)	13 (6.4)*	20 (10.0)*	3 (1.5)*
Wet	188	175	13	6 (3.2)	61 (32.4)	38 (20.2)*	11 (5.8)*	19 (10.1)*	34 (18.2)*	6 (3.2)*

* Percentages of parasitised egg masses

Table - 20 : Eggs of *S. incertulas* parasitised by individual parasitoids during rabi and kharif seasons of the year, 1994

Season	Total no. of eggmasses/eggs collected	Parasitised eggmasses/ eggs	Unparasitised eggmasses/ eggs	Eggs parasitised by *T.japonicum*	*T.dignoides*	*T.schoenobii*
Dry	201 (11936)	152 (4594)	49 (7362)	277 (2.3)*	2567 (21.5)	1730 (14.5)*
Wet	138 (9258)	175 (5223)	13 (704)	263 (2.8)*	2146 (23.2)*	2814 (30.4)*

* *Percentages of eggs parasitised*

Table - 21 : Mortality factors operating the stem borer eggs in nature during the period 1994-95

Season	Mortality of eggs % due to		Total
	Biotic factors (parasitism)	Abiotic factors Temp. Humidty etc.	
Dry	38.3	46.2	84.5
Wet	56.4	24.8	81.2

tory hosts are available so far.

Efficacy of neem based chemicals on the rate of oviposition of rice yellow stem borer

Four neem chemicals, i.e. Rakshak, Nimbecidine, Nethrin and Neemazole were tested alongwith the previously tested five neem chemicals, namely Margoside DCK, Margoside OK, Neemox, Greenmark and Sukrina were tested for their efficacy on yellow stemborer. All the chemicals were tested at 1.0 per cent concentration (1 ml/100 ml of water) on 55 to 60 day old Jaya plants.

Maargocideok and Nethrin were found to reduce oviposition to 35 per cent and Margocideok, Nimbecidine and Neemazole to 40 per cent. Sukrina and Neemox showed about 50 and 55 per cent oviposition respec-

tively ;whereas it was 80 per cent with Rakshak. Green mark had maximum oviposition which was about 93 per cent in comparison to control.

Ovicidal action of insecticides as foliar spray against YSB eggmasses in field

Ovicidal action of insecticides was studied in two different methods. In one, moths were released to lay their eggs on rice plants after which insecticides were applied. In another method, insecticides were sprayed on plants after which moths were released for oviposition. Eggmasses in both the treatments were allowed to remain in field for 5 days after which they were clipped off and kept separately to observe larval hatching.

Carbosulfan reduced the rate of hatching to a minimum of 22 and 17 per cent hatching respectively in both the conditions Hatching was much less in the eggmassescides afterthe eggmasses laid did not help much in controlling the larval hatching.

Simulation of the effect of stem borer damage on crop growth and yield of rice

In order to confirm the effect of white ear head on yield, sampling was done in white ear head created plot with known number of white ear heads. It was observed that there was a gradual decrease in yield with increase inwhite ear head number.

Studies on rice bugs, mites and strong insects

Studies on the occurrence and incidence of rice bugs : During weekly ;surveys of rice fields during wet season 1994, eight species of rice bugs viz., *Leptocorisa acuta, Riptortus sp., Evsarcoris ventralis, Mendia histrio, Nezara viriduala, Andrallus spiridens, Scotinophora coarctata and Paremius exigens* have been infesting paddy seeds at CRRI farm as well as in the farmers paddy fields. *A. spinidens* has been found for the first time in India. Whereas, *S. coarctata* is first report from eastern India. These bugs are found to such the esap/milk of the developing/developed paddy seeds and deteriorated its quality.

Grain damage caused by the rice bugs : *L. acuta* caused a grain damage from 2.93 to 5.68 per cent when its population ranged from 5.20 to 12.00 bugs sq. meter in the rainfed lowland varieties. In the upland rainfed varieties this bug caused 3.12 to 6.26 per cent grain damage at the population level of 8.70 to 13.80 bugs/sq.meter. This bug caused highest grain damage of 5.06 to 7.62 per cent in the irrigated medium land ecosystem, when its population ranged from 12.80 to 14.00 bugs/sq. meter.

The individual population of the pentatomid *E. ventralis* and *M. histrio* was very low but when combined ranged from 0.4

to 1.0 bugs/sq. meter. These bugs damaged upto 0.58 per cent seeds in the rainfed upland varieties. In the rainfed lowland varieties both these bugs species caused 2.41 to 3.21 per cent grain damage at its population level of 3.60 to 5.20 bugs/m^2. Under irrigated ecosystem these bugs caused 2.90 to 4.00 per cent grain damage at population level of 4.60 to 8.10 bugs/m^2.

Natural enemies of rice earhead bug, *L. acuta*: A natural enemy, *Antilochus nigripes* Burn (Hemiptera Pyrrhocoridae) was found to predate on the nymphs and adults of gundhi bug *L. acuta*. *A. nigripes* required 22-25 days (22 + 2.36 days) to complete its life cycle on *L. acuta* and its adult longevity was found as 44.47 + 2.31 days. First instar of the natural enemy was instar 2.33 bugs/day, fourth instar 3.5 bugs/day and adult 5.66 bugs/day. Total time required to predate a single adult of host was 44-45 minutes. Extent of predation of *A. nigripes* has been studied for the first time.

Life tables of the rice earhead but, *L. acuta* and stink bug, *E. ventralis*: For the first time attempts have been made to study the life tables of these bugs under green house condition on the caged and potted rice plants of variety Ratna at temperature ranging from 25 to 32°C and 90-95 per cent R.H. during wet season, 1994.

Observations were made on the fecundity and survivity of the female. Results thus obtained, revealed that the intrisnsic rate of increase (rn) of *L. actuawas* 0.107, rate of its multiplication finite rate of increase was 1.266.

The intrinsic rate of increase (rn) for *E. ventralis* was 0.099, rate of multiplication (o) was 53.72 in the mean generation time of 400.24 and its finite rate of increase was 1.104.

***Efficacy of the plant products against rice* bugs:** Eleven commonly available plant aqueous extracts in crude forms were evaluated against *L. acuta* under green house conditions, on the potted and caged rice plants of variety Ratna. These plant products were leaves of begunia, neem, wild sage, king of bitters, scented coleus, holy basil, bael, marigold, karade, bhrangraj, lemon grass and the commercial formulations of neem based products like A chook and nibecidine. These extracts were sprayed 20 days after flowering and the adults were released one day after flowering and the adults were released one day after the spray @ 5 bugs/hill. Observations were made on the grains sucked by the bugs after 1st, 7th and 15th days of the bugs released. Per cent grain protection was counted. A protection upto 93.7 per cent and achook 1 per cent upto 89.36 per cent has observed followed by the other products lemon grass extract (72.16 per cent), neem leaf extract (69.75 per cent), karada leaf extract (61.16 per cent. In N carbaryl 5 per cent as

a check the grain protection was recorded as 94.36.

Population dynamics of the rice tarsonemid mite, *Steneotarasonemus spinki* Smiley : Population dynamics of this tissue feeder mite was studied under green house condition on the potted rice plants of variety, Ratna. Total number of the adults and larvae/tiller and also number or eggs/tiller were considered as two parameters to correlate with the weather factors. Mites were initially inoculated through infested cut pieces of rice ratoons having about 100 mites/g inoculation.

There were two peaks in total population of adult and larvae of the mite, one in June and other in November. Its total population was recorded to be as high as 626.7/mites/tiller. Number of eggs also showed two peaks, one in March and other in September but highest number of eggs was recorded as 344.77 eggs/tiller in March. There was a significant positive correlation between R.H. and number of the eggs, whereas, significant negative correlations were found between total number of adults and larval population andRH and also with rainfall.

Total population of adult and larvae and also number of eggs showed insignificant correlations with the maximum and minimum temperatures.

Life table of rice tarsonemid mite, *Tarsonemus Cuttacki Iswari* under controlled conditions : Life table of this mite has been studied on the pure culture of rice pathogenic fungus, *Fusarium moniliforme* grown on the 2 per cent cat meal agar medium under aseptic laboratory conditions at a temperature range of 20-30°C. Observations were made on the fecundity and survival of the female mite using stereoscopic binocular microscope. Results thus obtained revealed that the intrinsic rate of natural increase (rm) was 0.236. The rate of multiplication (RO) was 13.05 times in the mean generation time of 10.88 days. The finite rate of increase was 1.266. Male and female mites survived upto 10 and 15 days respectively. :

Studies on the quantitative and qualitative losses of paddy seeds due to storage insects : Losses due to storage insects were assessed in newly fabricated Pusa bin and also in the gunny bags in the farmer's house at the village Kulakijangs (Biridi, Cuttack) by collecting periodical samples. Per cent grain damage were recorded to be 2.09 per cent at 45th day and 6.15 per cent at 120th day of storage in the Pusa bin as compared to 3.23 per cent and 8.56 per cent in the gunny bags. *Sitotroga cerealella* and *Rhyzopertha dominica* were two major insect pests to damage the stored seeds of rice variety Kalashree. Similarly, per cent seed germination was recorded to be 91 per cent at 45th day and 79 per cent at 120th day in the bin and 88 per cent and 74 per cent in the gunny bags.

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Pusa bin as well as the seeds stored were not properly dried before storage, therefore, grain damage observed to be higher than its earlier performance in northern India.

Studies on evaluation of botanicals and other safer grain protectants against storage insects : (a) Seven botanical products viz., leaf powder of *Ocimum canum, oumiphora mukul, Cinnamomum camphora, aveta indica, Strychnos potaorum, Terminalia arjuna and Betula bhojpatra* and four inert materials like lime powder, water soaked carbide powder, air dried carbide powder each one @ 1 per cent w/w and insect 0.5 per cent w/w were tested under controlled laboratory conditions against multiplication and ultimately grain damage caused by lesser grain borer, *5Rhyzopertha dominica* in the stored paddy grains of varietyRatna. Grains sterilised and admixed with the test products were stored in plastic jars each contaiing 250 g grains of and 5 pairs of insect population. Results on per cent grain damage after 4 months of storage revealed that leaf extracts of *O. canum, S. ptatorum, P. indica and C mukul* showed promising grain protection recording only 8.27, 9.02, 10.23 and 11.66 per cent grain damage as compared to 39.58 per cent grain damage in control. Insects showed 100 per cent grain protection but all other products failed to protect grains above 50 per cent no doubt showed significant differences in grain damage as compared with control. All these botanical/medicinal products have been tested for the first time.

(b) Studies were made on fabric treatment with deltamethrin (2.5 per cent WP) to find a suitable storage container disinfectant. Treatment of cloth bags using 2 g/30 ml of water/sq. meter reduced grain damage due to storage insects upto 1.96 per cent as compared to 32.43 per cent in control. In jute bag treatment grain damage was recorded to 10.48 per cent as compared to 39.0 per cent in control after 9 months of storage of rice variety Ratna in farm godown under natural conditions of insect infestation.

Evaluation of pheromones for monitoring and mass trapping of yellow rice borer

Pheromone trapping system was evaluated for monitoring the population of yellow stem borer. Three dry funnel sleeve traps baited with rubber septa impregnated with pheromone mixture of Z, 9-hexadecenol and Z, 11-hexadecen (in 1:3 ratio) were placed at 60 mt. and 1.0 mt from the ground at vegetative and reproductive stges of the crop during dry season, 1994. The yellow stem born moths started appearing in the traps from 3rd week of February reaching a peak of 10 moths per trap. Their incidence in the trap continued and reached the next peak during 3rd week of March with a average catch of 30 moths per trap. The third peak was observed during 1st week of April with 88 moths per

trap and the traps continued to attract moths till the end of April.

There was very negligible catch during the reproductive stage of the crop.

During wet season 1994, the moth started appearing from the first week of October, reached its peak during second week of November with a catch of 41 moths per trap and gradually declined towards the last week of November.

Effect of pesticides on egg parasitoid populations and parasitism of stem borer in rice fields

An experiment was laid out with Jaya and IET 9688 in a plot of 800 m^2. The treatments are (1) Seedling root dip plus spraying with Dursban, (2) Spraying with Dursban (0.05 per cent), (3) Application of carbofuran granules at 1.0 kg a.i./ha, (4) Control. Eggmass of YSB were collected from all the sub-plots (treatment) before and after treatments including control. Egg parasitism was recorded and egg parasite populations were estimated as number emerged from 100 eggmasses.

No significant differences were found between pre and post application of Dursban and Carbofuran when these are applied twice at an interval of 25 days. Need based application of pesticides like Dursban and carbofuran had no adverse effect on the parasite populations and parasitism.

Assessment of factors affecting multiplication of gallmidge and biotype maintenance

Gall midge population belonging to GMB 4 from Srikakulam was brought in the months of October. The period during the months of December-January affected the multiplication with poor adult emergence (2 to 3 adult per day) the level increased to 20 adults per day by the end of March. The emerging sex ratio was 32 male to one female normal but at times it went to 5 male to one female. On the other hand, the population of GMB 2 (Cuttack) was maintained throughout the year with an average of 20 adults from June to November and 5 adults in winter month and rose to 50 adults per day in March. The emerging sex ratio was one male to 3 female in normal months and one male to one female in winter months. The gall midge population from Hyderabad (GMB 1) did not come up well. Only less than 2 adults/day, the sex ratio was unusually higher in favour of females (1 male to 5 females).

Owing to higher parasitism observed in the field at Ranchi (GMB-3), a few adults only could be brought and it did not establish at Cuttack.

The life cycle constitutes normally in all the biotype in 20-22 days, however, it takes

30-35 days during winter months.

It was observed that the egg development and hatching was seriously affected beyond 32°C temp.

Coordinated trials

Gall midge

Gallmidge biotype trial (GMBT) (Coordinated trial of DRR): Ten entries viz. W 1263, ARC 6605, Phalguna, ARC 5984, MR 1528, Velluthichera, Aganni, Ptb.10, T 1477 and TN 1, were planted in last week of July and their reaction against rice gall midge was studied. Heavy gall midge infestation was created in field. The experiment was done in two replications (Table 22). The varieties -phalguna, ARC 5984, MR 1523, velluthichera Agani, Pt_0. b10, and T 1477 were found resistant.

Multiple resistant screening trial (MRST) : Sixty entries received had been planted in last week of July, 1994. Observations of percentage silver shoot and percentage dead hearts and white ear head had been taken. Cultures like KAU 8754, R646-89-19, R650-18-17, RP 2542, 26783, RP 3191-13297, RP 3750-

Table - 22 : Extent of gall midge infestation on different rice varieties

Name of varieties	Mean % hills infested	Score
W 1263	97.9	S
ARC 6605	100.0	S
Phalguna	0	R
ARC 5984	0	R
MR 1523	19.0	R
Velluthichera	7.5	R
Aganni	2.1	R
Ptb-10	12.0	R
T 1477	3.8	R
TN 1	97.9	S
Jaya	85.5	S

S : Susceptibel R : Resistant

26774, TTB-148-174-3-2-1, SKL 5-11-230-49 and SKL-1-39-138-69 received zero infestation of gall midge. The cultures like BPT 6866, BPT 7325, BPT 8799, KAU 10-4-1, RP 2541-26729, RP 2542-1520, RP 2941-1612, RP 37-3739, IR 72, KAU 8754, RP 646-89-14, R 650-1817 remained free from stem borer infestation both at vegetative and heading stages.

Out of the sixty cultures KAU 8754, R 646-89-14 and R 650-1817 were found to be resistant to both stem borer and gall midge.

Gall midge screening : Sixtyone cultures crosses involved with different gall midge resistant donors (Banglei Phalguna Ptb 21 Eswarakora ARC 6232) along with six resistant donors (Velluthecheera, NHTA 8, Orumundakan RGL 3273, Phalguna and W 1263) and a susceptible check TN 1 were tested against gall midge (biotype 2). The check variety TN 1 recorded 100 per cent plant damage with 32 per cent silver shoot. cultures The RGL, 3249, 3250, 3260, 3265, 3269, RP 2932, TTB 148, 169, WGL 3306, 3862, 3955 were found promising and all the donors except W 1263 cotinued to exhibit resistant reaction.

One hundred primary donors and 10 released gall midge resistant varieties were evaluated in the field to know their reaction to gall midge (biotype-2) so as to identify new donors. Forty donors were absolutely free from gall midge attack while 16 donors recorded less than 5 per cent silver shoots. The donors Ptb 21, Ptb 18 and the varieties crossed with the said donors recorded increased incidence more than 10 per cent silver shoots.

Insecticidal control of BPH & YSB

Insecticidal control of BPH : The insecticidal action of plant *Polygonum hydropiper* against brown plant hopper *Nilaparvata lugens* (Stal.) was evaluated in the laboratory.

Several solvents viz. as water, acetone, benzene, methanol, hexane, ethyl ether, chloroform and alcohol were tested for the extraction of leaf samples of *Polygomum hydropiper*. Benzene extract was the least. Absolute mortality of BPH (5th inst. and adults) was observed at 10 per cent concentration i.e. 10 g leaf extraction with 100ml water and 0.5_0, teepol.

Effectiveness of Imidacloprid, a new insecticide, against BPH and YSB : Imidacloprid, obtained from Bayers (India) Limited was found very effective against BPH for its persistant toxicity. It killed 100 per cent of the 5th instar nymphs upto 7 days and 10 days at 0.02 and 0.04 per cent concentrations respectively. Once the efficacy was decreased, no mortality was observed after another 7 days.

The insecticide did not reduce the rate of oviposition significantly in YSB (88-89 per

cent). The larval hatching was also higher (79.2 per cent) from the egg masses which were treated after they were laid. But when the insecticide was applied to the plants before oviposition, it could reduce the larval hatching to 25.5 per cent.

The rate of oviposition of female BPH in insecticide treated plants

Ten insecticide were applied as foliar spray at 0.04 per cent concentration to test their efficacy for inhibiting or reducing the rate of oviposition.

Carbosulfan, BPMC ad ethofenprox killed the females immediately after release so that they could not lay any eggs. Chlorpyrifos, quinalphos, and hostathion killed 100 per cent of the insect within 24 hours but before their death they could lay 52.6, 26.3 and 63.2 per cent eggs respectively. Carbaryl, monocrotophos, metasystox and phosphamidon could not bring about 100 per cent mortality of the females and the rate of oviposition was also above 60 per cent.

Screening of rice germplasm to white tip and root-knot nematodes

Screening for the white tip nematode *(Aphelechoides besseyl)* : One hundred seeds of each of the 509 rice accessions were examined for the seed-borne nematodes. The populations of this nematodes ranged from nil to 365 neams/100 seeds. Based on the population in seeds, 75 rice accessions were grouped as resistant (less than 10 neams), 223 moderately susceptible (less than 50 neams) and 111 susceptible (50 and above).

Screening for the root-knot nematode *(Meloidogyne graminicola)* : Fifty-six rice accessions of the 509 collected from the Genetic Resources Division were screened against the root-knot nematode under artificial nematode inoculation in the green house. Among these 23 rice accessions was susceptible based on the gall index on the roots.

Chemical control of insect pests

Evaluation of insecticides for their efficacy : Two granular insecticides such as isazophos 3G and carbofuran 3G, five spray formulations such as ethofenprox 10EC, Carbaryl 42F, trizophos 40EC, quinalphos 20AF, and chlorpyriphos 20EC, and seedling root dip with chlorpyriphos at 0.2 per cent concentration for 12 hrs were evaluated during wet season against yellow stem borer, the most prevalent insect of the season. Dead hearts incidence at 30 days after transplanting was to the maximum of 19.3 per cent under untreated control where as it was lower in all other treatments, showing only 2.06 per cent under seedling root dip treatment. The incidence of stem borer reduced in subsequent weeks and thus the dead heart incidence at harvest was very low.

Granular insecticides isazophos 3G, Lindane 6G ad carbofuran 3G, spray formulation insecticides such as ethofenprox 10EC, carbaryl 42F, BPMC 50EC, triazophos 40EC, quinalphos and other formulations viz. Delfin 85 per cent and Dipel 3.5 per cent were evaluated for their effectiveness at different doses against gall midge and yellow stem borer during wet season, 1994. The incidence of silvershoot was low at 30 days after transplanting but they started increasing and reached upto 47.7 per cent at 50 days after transplanting under untreated control. There was not much reduction in the incidece of silver shoot under different insecticidal treatments as spray formulations did not prove effective against gall midge and granular application of insecticide at 25 days after transplanting was perhaps late and thus the tillers were already damaged whose manifestation occured after 30 days after transplanting.

The application of Bt. formulations for the control of stem borer did not influence the white ear head incidence as compared to untreated control. However, white ear head incidence was low (6.0 per cent under untreated control).

Efficacy of imidacloprid in comparison to standard insecticides : Standard insecticides known for control of tungro like cypermethrin, Decamathrin, carbofuran and monocrotophos were included in the trial besides non-resurgence synthetic pyrethorid. Trobon, to see the efficacy of Imidacloprid for control of tungro under green house conditions. Insecticides were sprayed on 15 day old T(N) 1 seedlings and 3 viruliferous leaf hoppers were released on the seedlings 1 day after treatment (1 DAT) and 10 days after treatment (10 DAT). Vector mortality was recorded 24 hrs after release and disease incidence was recorded 15 days after inoculation. It was observed that vector mortality was 100 per cent in all the treatments in 1 DAT. But vector mortality was decreased in 10 DAT in all the treatments except imidacloprid treatment. Per cent disease in 1 DAT was very less in treatments cypermethrin, Trobon, Decamathrin, Carbofuran and Imidacloprid treatments. But per cent disease in 10 DAT increased to 70 to 90 per cent in all other treatments except Imidacloprid treatment.

Optimum insect pest control (Coordinated trial) : Six pre-release cultures viz. IET 10402, IET 9691, IET 9976, IET 9978, IET 9219 and IET 9688 along with susceptible check RP 4.4 and their were field evaluated for its reaction to stem borer under unprotected and protected conditions (Carbofuran @ 1.0 kg a.i./ha), IET 9978 recorded less incidence of 8.7 per cent dead heart as against 20.3 per cent dead heart under unprotected condition. However, the culture IET 9691 (IR 50/Phalguna) although with 18.4 per cent dead heart incidence recorded the highest

grain yield of 4.4 t/ha under unprotected condition and 5.4 t/ha under protected condition. This culture also proved to be better in the other locations.

Effective persistence of insecticides against freshly hatched larvae : No dead heart formation was observed in treatments like ethofenprox, carbosulfan, imidacloprid, monocrotophos, BPMC, methyl parathion and chlorpyrifos upto 10 days. Only quinalphos and dimecron showed dead hearts upto 15 and 30 per cent respectively in comparison to control. But plant growth was suppressed in monocrotophos, chloropyrifos, methyl parathion and BMPC. Dead hearts were observed after 15 days of treatment in monocrotophos, BPMC, chlorpyrifos and imidacloprid. Ethofenox and carbosulfan did not allow the formation of dead heart upto 25 days. Among all the treatments, growth of unaffected plants was best on Ekalux.

Studies on reservoir hosts of rice pest parasitoids

The species of parasitoids viz., *Isotima* sp., *Goryphus* sp., *Ceraphron* sp. were reared from the pupae of *Lema* sp., a beetle pest on *Conmelina* sp. Cumulative parasitism due to these parasitoids ranged from 2.5 per cent to 6.5 per cent in July, 3.0 to 5.8 per cent in August and 11.2 to 18.5 per cent in September. Besides, *Lema* sp. *Nanophyes* sp. a beetle pest on Ludhigia also supported three species of parasitoids viz., *Eupteromalus* sp., *Eupelmus* sp. and *Pediobius* sp. cumulative parasitsm due to those parasitoids ranged from 2.2 per cent to 5.5 per cent in October, 14.5 to 20.5 per cent in November and 3.5 to 7.0 per cent in December.

Eupteromalus parnarae, Paraphylax sp. and *Bentvra* sp. were reared from unidentified egg sacs of spiders, cumulative per cent parasitism due to these parasitoids was 15.3 per cent in September, 12.5 in October and 26.5 in December.

Among these parasitoids, *Eupteromalus parrama, Eupelmus* sp., *Paraphylax* sp., *Ceraphron* sp. were also recorded as parasitoids of rice pests.

Semi-artificial diet with Rajmah seed and and *Echinochloa* leaves as major ingredients was tested for rearing the leaf folder *Brachmia arotraea*. It could successfully complete its life cycle on this diet.

Scent and cooking quality with progress of storage of scented rice and cooking quality of scented and non-scented rice varieties

Initial Variety Trial (IVT-BT): Twenty five cultures grown at CRRI and DRR were analysed for quality features. Among them,

IET 13855, IET 14128, IET 14127, IET 14132,IET 14133 were recommended for advance trial of Basmati derivatives.

Advance Variety Trial (AVT-BT): Twenty one cultures from Advance Variety Trial of Basmati derivatives were analysed for quality features. Among them IET 13857, IET 13553 were comparable to Tarai Basmati. But yield was not of advantage in comparison with Pusha Basmati. Hence no cultures could be recommended for minikits.

Non-scented long slender grain for export purpose: Eighty four released rice varieties were analysed for quality ;characters. Among them 21 varieties were promising and could be recommended for export purpose.

SHALLOW WATER ECOSYSTEM

SHALLOW WATER ECOSYSTEM

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- Evaluation of advanced fixed cultures for yield and quality under raifed shallow lowland situation
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Weed Management

- Chemical weed control in direct seeded rice

Disease Management

- Epidemiology of sheath blight
- Cellular selection for tolerance to sheath blight fungus
- Studies on false smut disease of rice
- Varietal resistance to tungro
- Epidemiology and control of tungro

CROP IMPROVEMENT

Evaluation of donors and generation of breeding materials

One hundred donors collected from different agencies were screened under shallow water ecosystem. Swarna, Sabita and Krishnaveni were found to perform well under shallow ecosystem. These have been used in breeding programmes and 26 new crosses were made.

F_2 populations from Boitha/CR 662-221, Sagari/CR 660-947, Mayurkantha/CR 661-236, were grown and selections were made.

Assessment of breeding materials received from other sources

In IVT-SHW, 11 entries recorded more yield than the checks. Of these, IET 14381 recorded an yield of 5.5 t/ha followed by IET 14390 (4.2 t/ha) and IET 14399 (4.2 t/ha). Thirteen entries were affected by RTV and BPH incidence were recorded in 4 entries.

In AVT-SHW, only IET 13524 was better than the high yielding checks viz. Salivahana and Pranava. However, rest of the entries were better than Kabirajsail.

Evaluation of advanced fixed cultures for yield and quality under rainfed shallow lowland situation

Twenty one varieties viz. Biraj, Manasarovar, SM 50, Jagannath, SM 3, IET 2254, CR 1016, SM 149, IET 7251, SH 59, Utkalprabha, C 8, Pankaj, SM 55, SM x CR 1009, Padmini, C 6, SM 147, S 57, C 10 and CR 1009 were tested under (0-30 cm) shallow lowland conditions at N 60, P 40 and K 20 levels. Among the cultures tested, C 8, SM 55, Padmini, Biraj, Mansarovar produced an yield potential of 5 t/ha, although planting was late i.e. on 11.8.1994.

Yield performance of elite line under late planting condition (Observational Trial) :

An observational trial was conducted to assess the performance of elite lines under normal and late planted conditions. CR 580-5, CR 580-17-1 and CR 581-9 planted with 70 day old seedlings have recorded comparable yields in both the situations (4.0 t/ha under normal planting and 3.0 t/ha under late planted condition). The reduction in plant height under late planted condition was very less in these lines.

Evaluation of breeding materials for yield:

In a trial thirtysix photosensitive lines were evaluated for yield.. CR 758-137-13 (Jagannath/Padmini), CR 689-4-9 (CR 260-0-77/Pusa 33) recorded highest yield of 5.0 t/ha. These lines flowered during 3rd week of October to 2nd week of November.

In another replicated trial, fifteen fixed lines along with six check varieties viz.

Pratibha, Mahsuri, Chaitanya, Krishnaveni, Jagannath and Savitri were evaluated for their yield potential. CR 780-79-982 recorded the highest yield of 5.3 t/ha, CR 772-147, CR 661-291, CR 665-507, CR 664-259 and CR 661-52-337 recorded yields between 4.0-4.7 t/ha. Among the che;ck varieties, Savitri recorded the highest yield (3.8 t/ha) and Jagannath recorded lowest yield (2.4 t/ha).

Evaluation of breeding materials for photosensitivity range and late planted conditions :

A replicated trial was conducted with 16 elite lines and three check varieties viz. Savitri, Mahsuri and Swarna under two sowing dates (6.6.1994 and 12.7.1994) and three planting dates : with 30 day old seedlings (normal planting D.P. 6.7.94), 65 day old seedlings (late planting, D.P. 10.8.94) and Mid season planting with 30 day seedlings (D.P. 12.8.94).

The performance of the cultures under two planting dates revealed that four elite lines viz. CR 668-112-1038, CR 664-70-600, CR 665-178 and CR 665-811-342 were photosensitive. One culture CR 668-102-1038 as performed well in both the conditions (Table 1).

Under normal planting CR 780-1937 recorded the highest yield whereas CR 660-41-7061 recorded highest yield under late planted codition.

The entries under the late planting with 30 day old seedlings were affected by pests and diseases and all the entries flowered very late excepting CR 668-112-1038, CR 664-70-600, CR 665-178 and CR 668-811-342. Only those lines flowered and completed their life cycle and recorded yields ranging between 1.0-1.5 t/ha.

In another trial, 15 photosensitive lines were evaluated for their suitability for late planted condition (normal planting - 2nd week of July, late planting - 2nd week of September). CR 683-123, CR 683-162 and CR 833-101 recorded higher yields than checks under both the plantings. CR 629-256 recorded highest yield under normal condition.

Varietal improvement with built-in-tolerance to pests and diseases

Single plant selections were made in F_3 progenies from the crosses Savitri/OS 4, Gayatri/OS 4 and Heera/Padmini based on plant height (semi/dwarf), stiff straw, long and dense panicle and tolerance to pests and diseases.

Two hundred progenies (F_7 and F_8) from four crosses involving Jagannath, Mahsuri,

Table - 1 : Performance of elite lines under two date of planting under shallow water ecosystem

Entry	Normal Planting		Late Planting	
	Yield (t/ha)	Flowering date	Yield (t/ha)	Flowering date
CR 662-1133	3.8	26.10.94	2.8	11.11.94
CR 665-791-182	4.5	26.10.94	3.1	14.11.94
CR 780-2-2318	4.0	20.10.94	3.4	3.11.94
CR 660-41-7061	4.1	26.10.94	3.8	15.11.94
Mahsuri	4.0	12.10.94	1.4	2.11.94
CR 668-119-95	4.3	20.10.94	3.5	3.11.94
Savitri	3.4	28.10.94	3.7	14.11.94
CR 668-956	5.1	13.10.94	3.8	4.11.94
CR 668-112-1038	4.4	13.11.94	3.7	16.11.94
CR 661-179	4.1	10.10.94	2.1	6.11.94
CR 665--787-178	3.8	26.10.94	2.2	30.10.94
Swarna	4.7	6.10.94	2.7	6.11.94
CR 780-1937	6.2	18.10.94	2.9	2.11.94
CR 664-132-600	4.3	10.11.94	2.7	13.11.94
CR 661-235	3.7	2.10.94	2.5	24.10.94
CR 661-240	4.4	16.10.94	2.7	3.11.94
CR 665-811-342	2.8	8.11.94	2.1	8.11.94
CR 662-2211	5.2	18.10.94	2.6	4.11.94
CR 663-631	4.5	22.10.94	2.3	6.11.94

Padmini, Mahipal, CR 260-77 and M_6 generation of CR 256 mutants were grown and selections were made based on duration, photosensitivity range, plant type and yield potential. Uniform lines were bulked for further evaluation.

HYBRID RICE

Source Nursery

Thirty CMS lines including 13 developed at CRRI, Cuttack, 250 maintainers, 325 re-

storers, 394 lowland varieties and 35 wild rices were grown in the Source Nursery for purification, seed multiplication and utilization in test and back crosses for identification/development of CMS maintainer and restorer lines. Agronomic characters and flowering behaviour of all these lines were recorded.

Test crosses

A total of 335 test crosses were attempted utilising 10 CMS lines (PMS 3A, PMS 10A, IR 58-025 A, Sarasa A, Pusa 33 A, Pragati A, Annada A, Deepa A, Moti A of WA Source, Krishna A of Kalinga-I source and 70 tester parents to identify effective maintainers and restorers for development of new CMS lines and high heterotic hybrids suitable for shallow lowland ecosystem.

Backcrosses

Thirtyone crosses in the conversion programme of different CMS lines were backcrossed with their respective *indica* pollen parents to develop new CMS lines which are in BC_1 to BC_4 generations.

A number of inter-varietal crosses between *indica* (primitive land races) and *indica* (cultivars) were made to identify new male sterile cytoplasm. Only 10 crosses between *indica/indica* were found to be completely sterile (both pollen and spikelet), out of which five backcross lines (BC_2-BC_4) involving Krishna, Moti, Kalashree, PN 56-65, Padmini against two cytoplasm sources, viz. Miz. 4 and Miz. 21 (primitive *indicas)* were found to be stable. These were backcrossed with their respective pollen parents for advanced backcross generation.

Identification of maintainers and restorers

Test cross data involving 11 CMS lines and 66 tester parents which resulted in identifying a number of effective maintainer and restorer lines (Table 2).

Identification of promising heterotic combination

One hundred and thirty hybrids along with their respective parents and 4 checks were assessed for their yield performance (single row with 20 plant/row). Twenty six hybrids yielded more than the checks (Table 3).

Thirty five hybrids along with their respective parents and 9 checks for lowland situation were assessed for their yield performance (4 rows with 2 replications and 20 plants/row). Five hybrids PMS 10 A, BR 1870-88-11, Sarasa A/C 2757-22-1-1-1, Kiran A/C 2767-10-2, PMS 3A/Vajram and PMS 10A/Vajram gave 45 per cent more yield than the check.

Table - 2 : Identification of Maintainers and Restorers

CMS Lines	R	M	PR/WM	Total Crosses
IR 58025 A	20	12	5	37
PMS 3A	22	4	2	28
PMS 5A	1	4	1	6
PMS 10 A	14	3	--	17
CRMS 6A	32	7	12	51
CRMS 8A	11	6	3	20
CRMS 10A	13	9	10	32
CRMS 13A	4	--	2	6
CRMS 16A	4	1	7	12
CRMS 17A	6	12	--	18
CRMS 21 A	19	8	12	39
Grand Total	146	66	54	266

Evaluation of National Hybrid Rice Trials

Five replicated trials (1 during dry season and 4 during wet season, 1994) involving 88 hybrid and 4 checks were conducted. Promising hybrid combinations are listed below :

IHRT.1 (17 hybrids + 3 checks) dry season, 1994

Five hybrids IHRTR-IR-14 (6.17 t/ha), IHRT-1-R-1 (5.72 t/ha), IHRT-1-R-11 (5.61 t/ha), IHRT 1-R-8 (5.31 t/ha) and IHRT-1-R-16 (5.10 t/ha) performed better than the check, IR 36 (5.47 t/ha) and Sarasa (4.92 t/ha).

IHRT.2 (22 hybrids + 3 checks) Wet season, 1994

Four hybrids IHRT 20-07 (5.61 t/ha), IHRT 2-21 (4.69 t/ha), IHRT 2-14 (4.62 t/ha) and IHRT 2-13 (4.57 t/ha) yielded better than the check, Rasi (2.92 t/ha).

NHRT.1 (17 hybrids + 4 checks) Wet season, 1994.

One hybrid UPHR 31 outyielded the check Rasi (2.65 t/ha) by 0.75 t/ha.

NHRT.2 (21 hybrids + 3 checks) Wet season, 1994.

Table - 3 : Promising hybrid combinations identified from test crosses during wet season of 1994 atCRRI

Combinations	50% flowering duration (days)	Yield (g)
PMS 3 A/NDR 30039	112	761
IR 58025 A/CR 580-5	120	427
PMS 10 A/TCA 88-69	99	555
PMS 10 A/NDR 30076	106	1000
PMS 10 A/NDR 30076	111	747
PMS 3A/Johinga	109	740
CRMS 21 A/BKS 246	99	589
CRMS 6 A/TCA 88-69	102	707
IR 58025 A/TCA 88-69	104	749
PMS 10 A/NDR 40032	111	673
IR 58025 A/PSR 1326-40-22-3	111	673
CRMS 6 A/PSR 1326-40-22-3	99	410
PMS 10 A/NDR 40013	121	992
PMS 4 A/NDR 40076	111	765
CRMS 13 A/NDR 30030	95	600
CRMS 13 A/IET 10002	102	720
PMS 3 A/MDR 30037	106	750
CRMS 6 A/CN 1035-59	106	620
CRMS 6A/CN 1035-42	98	410
FMS 3 A/TCA 48	105	468
CRMS 13 A/CN 917-6-30 B	108	410
CRMS 21 A/CN 845-80-7-1	101	421
CRMS 8 A/NDR 30077	109	463
PMS 3 A/TTS 101-14	107	420
PMS 3 A/IR 57540-10-62-1-16	127	513
PMS 3 A/CN 1035-42	129	722
Checks : Mahsuri	114	230
Swarna	115	358
Savitri	129	252
Sabita	120	370

Three hybrids, 2 R.1075 (POC) (5.26 t/ha), PKHR 5 (4.79 t/ha) and PKHR 4 (473 t/ha) performed better than the checks Jaya (4.15 t/ha) and Swarna (4.09 t/ha).

IRRI Hybrid Rice Trial for shallow water ecosystem

Five hybrids PMS 8 A/IR 46 R (5.71 t/ha), IR 58025 A/IR 54742 (5.12 t/ha), IR 58025 A/RP 1057 (5.07 t/ha), IR 58025 A/BR 1356 (4.89 t/ha) and PMS 10 A/BKN 6486 (4.77 t/ha) yielded better than the checks IR 46 (3.91 t/ha), IR 68 (3.78 t/ha) and Swarna (4.42 t/ha).

Seed Multiplication

Bulk multiplication and maintenance of CMS lines-V.20 A, IR 46829, IR 46830 A, IR 58025 A, IR 62829 A, Annada A, pragati A, Krishna A (WA), Deepa A and Krishna A (Kalinga-I) were carried out both manually and small scale field operations.

Seed supply

Seeds/stubbles of various CMS, maintainer and restorer lines were supplied to CRRI/DRR and other experimental stations.

CROP MANAGEMENT

Crop stand establishment for optimum production under rainfed lowland conditions

Four methods of crop stand establishment i.e., direct seeded broadcast, direct seeded drilled, staggered transplanting and transplanting in rows were compared for eight rice varieties viz., Gayatri, Tulasi, Padmini, Manasarovar, Utkalprabha, Biraj, Pankaj and Kabirajsal. Direct sowing in puddled condition was found significantly better than transplanting. Direct seeded broadcast and drilled were at par. Similarly staggered planting as well as planting in row were significantly at par. Irrespective of methods of stand establishment, Gayatri and Mansarovar gave the highest yield of 2294 and 2257 kg/ha respectively, which was followed by Tulasi, Utkalprabha, Kabirajsal, Biraj and Pankaj.

Improvement on the existing practice of beaushening

Eight treatment combinations (broadcast seeding, broadcast seeding + *beaushening* without gap filling, broadcast seeding + *beaushening* with gap filling, broadcast seeding + *beaushening* with gap filling + green manure, line seeding, line seeding + interculture with Cono Weeder + 30 kg N/ha at interculture and transplanting with 45 days old seedlings) were compared to find out the ways of improving the traditional practice of *beaushening* and also to develop an alternative system to this age old practice. Results revealed that improved *beaushening* operation (sowing of 1/20 area of a field separately with 3 times of normal seed rate and use of excess seedlings for gap filling during

beaushening) increased the grain yield by about 20 per cent over unbeaushened crop and by about 15 per cent over traditional beashened crop (*beaushening* without proper gap filling). Supply of nitrogen (30 kg/ha) to this crop either through prilled urea or organic source (green manure) further increased the grain yield by about 9 and 12 per cent respectively over improved beaushened crop. The results further revealed that row seeded crop coupled with interculture operation with cono weeder + 30 kg N/ha as prilled urea at interculture gave 5.1 t/ha which was comparable to that of improved beaushened crop combined with green manure/30 kg N/ha at beaushening (4.9 to 5.1 t/ha). The transplanted crop gave the lowest grain yield (2.8 t/ha) because of restricted tillering under waterlogged condition.

Effect of skip row planting and different populations on the performance of rice

To ascertain the advantage of skip row planting with different plant population levels in rice (*cv.* Gayatri), an experiment was carried out in wet season. Three methods of planting - normal planting, skipping one row after every 2 rows and skipping one row after every 3 rows were tried in main plots and five spacings 20 cm x 10 cm, 20 cm x 20 cm, 20 cm x 15 cm, 15 cm x 10 cm and 15 cm x 15 cm in sub-plots in a split plot design with 3 replications. Crop was planted on 2 August. Results revealed that skipping one row after every three rows produced grain yield (3.84 t/ha) comparable to that of normal planting (3.87 t/ha). However, the yield was significantly reduced (3.59 t/ha) in the crop planted by skipping a row after every two rows. Different plant populations produced comparable yields (3.70 to 3.82 t/ha).

Rice varieties for late planted situation

Five rice varieties, IET 6080, IET 9760, IET 5914, Gayatri and Pankaj were tested under three dates of planting at 10 days intervals starting from 16th August until September 5 at Kharagpur. IET 6080 and IET 5914 recorded the best performance at August 16 planting with mean grain yield of 5.10 and 5.00 t/ha respectively. Subsequent delay in planting registered drastic reduction in mean grain yield of these varieties (3.62 and 3.19 t/ha respectively). However, Gayatri and Pankaj produced consistently reasonable grain yields i.e., 3.50 and 3.23 t/ha respectively even at 5 September planting.

Optimum date of planting for traditional scented rice varieties

Five traditional scented rice varieties, Basmati 370, Ranbir basmati, Taraori basmati, Dehradun basmati and Pakistan basmati were tested under three dates of planting at 10 days intervals starting from 16th August until 5 September. August 16 planting date produced maximum grain yield

(2.33 t/ha) followed by August 25 (2.21 t/ha) planting date and both these dates of planting were significantly superior over 5th September planting date (1.31 t/ha). However, yield differences between 16th August and 25th August planting dates were insignificant. The corresponding yield reduction was 44 and 41 per cent respectively. Averaged over dates of plantings, variety Dehradun basmati recorded maximum mean grain yield (2.11 t/ha) followed by Ranbir basmati (2.08 t/ha) and both these varieties were significantly superior to basmati 370 (1.99 t/ha), Taraori basmati (1.82 t/ha) and Pakistan basmati (1.74 t/ha). The interaction between dates of planting x varieties indicated that variety Dehradun basmati produced maximum grain yield (2.59 t/ha) by 16th August planting. The mean maximum panicles number (307/m^2) was recorded by Ranbir basmati while mean maximum panicle weight (1.35 g) was recorded by basmati 370. From this result it could be concluded that variety Taraori Basmati recorded the best results. Planting the crop by August 16 recorded optimum grain yield.

The incidence of case worm was recorded in the above varieties on different dates of planting. All varieties planted on September 5 recorded more case worm damage as compared to other date of planting i.e. August 25 and August 16. Among the varieties, Dehradun basmati recorded highest damage whereas Basmati 370 recorded lowest damage.

Performance of different rice varieties with different organic sources under late planted conditions

The performance of four rice varieties, Gayatri, Dharitri, Seema and Katarni were tested under three different sources of organics, viz., poultry droppings (2 per cent N) @ 2.5 t/ha, farm yard manure (1 per cent N) @ 5 t/ha and green manuring with dhaincha (1.85 per cent N) to supply 50 kg N/ha. Crop was planted during mid-August.

The highest yield of 4.6 t/ha was obtained with Dharitri when poultry dropping was used as organic manure. Gayatri and Katarni showed the next best performance with yields of 4.2 t/ha.

Farm yard manure showed the second best performance producing an yield of 4.2 t/ha with Dharitri followed by Katarni (3.8 t/ha).

With green manuring, the highest yield was achieved in case of Dharitri (4.0 t/ha) followed by Katarni (3.7 t/ha). These results showed the possibility of using organics specially poultry droppings for increasing rice yield even under late planted conditions.

Rice varieties for post-flood situation

In order to evolve a suitable production technology for rice planted very late during

the post-flood period in lowlands, six selected promising rice cultures/varieties viz., IET 5914, IET 6080, IET 9760, Padmini, Gayatri and CR 673-475 were evaluated under 3 spacings (10 cm x 15 cm, 15 cm x 15 cm and 20 cm x 15 cm). The crop was planted on 20 September with 60 days old seedlings. The variety CR 673-475 recorded a maximum grain yield of 4.13 t/ha followed by Gayatri (4.01 t/ha). These two varieties gave significantly higher grain yield over the other varieties. Out of the three spacings tested, a closer spacing of 10 cm x 18 cm gave the highest grain yield (3.4 t/ha) (Table 4).

Response of selected minikit rice cultures to N application

Long duration group: The growth, grain yield performance and the N-use efficiency of six selected minikit long duration rice varieties (150-165 days) identified under national rice testing programme, IET 12199, 10664, 8655, 12777, 5914 and Gayatri (local check) were assessed at graded levels of N ranging from 0 to 120 kg/ha during wet season. The local check Gayatri with a mean grain yield of 5.14 t/ha was superin to all the other test cultures. Among the other minikit cultures

Table - 4 : Grain yield (t/ha) of rice varieties/cultures under late planted condition, wet season 1994

Variety	Spacings			Mean
	10 cm x 15 cm	15 cm x 15 cm	20 cm x 15 cm	
CR 673-475	4.35	4.05	4.00	4.13
IET 5914	2.17	1.90	1.75	1.94
IET 6080	3.45	3.05	2.85	3.11
IET 9760	3.05	2.86	2.68	2.86
Gayatri	4.25	3.90	3.90	4.01
Padmini	3.15	2.90	2.50	2.85
Mean	3.0	3.11	2.94	

C.D. (P=0.05)
for varieties (V) 0.39
for spacings (S) 0.23
for V at same S 0.27
for S at same V 0.25

IET 10664 was the highest yielder (4.6 t/ha). There was a significant increase in yield with the application of nitrogen upto 80 kg/ha (4.68 t/ha). An average response of 21.3, 17.8 and 13.4 kg grain/kg N were recorded at 40, 80 and 120 kg N/ha levels, respectively. Highest panicle number (255/m^2) and panicle and weight (2.80 g) were also recorded in this variety.

Medium duration group : Among the six varieties of medium duration (125-135 days), IET 12555, 11768, 11771, 9925, Jaya (standard check) and IR 36 (local check) tested, the most promising varieties were IR 36 and Jaya with yields of 3.84 and 3.53 t/ha respectively. Grain yield differences among IET 12355 (2.8 t/ha), IET 11768 (2.68 t/ha), IET 11771 (2.72 t/ha) and IET 9925 (2.87 t/ha) were not statistically significant. Applied nitrogen increased the grain yield significantly up to 80 kg/ha (3.45 t/ha). The response at 40, 80 and 120 kg N/ha averaged to 11.3, 11.6 and 7.0 kg grain/kg N, respectively. The corresponding per cent increase in grain yield was of the order of 17.9, 36.9 and 33.3 at respective N levels over the grain yield of control. The maximum response of 16.8 kg grain/kg N with Jaya at the same level of 40 kg N/ha. Maximum panicle production (362/m^2) was observed in IR 36 while the highest panicle weight (1.57 g) by IET 9925.

Response of long slender grain quality rice varieties to different levels of nitrogen

The yield performance of five long slender grain non-scented export quality rice varieties - Hathipanjari, CRM 30,CR 662-2318, Sabita and Amulya was tested under four levels of nitrogen - 0, 30, 60 and 90 kg/ha during wet season. The varieties - CRM 30 and Hathipanjari were promising with yields of 2.61 and 2.54 t/ha respectively. The varieties responded upto 90 kg N/ha though the yield increase from 60-90 kg N/ha was the lowest. Irrespective of the varieties, N use efficiency (kg grain/kg N applied) was the highest (12.3) at 30 kg N level and it was decreased at 60 kg N (9.3) and 90 kg N (7.9) levels.

Nitrogen response in promising rice varieties of long duration under transplanted condition

Six rice varieties viz., IET 12199, IET 10664, IET 8655, IET 12777, IET 5914 and Gayatri were tested under 40 and 80 kg N/ha. Gayatri produced maximum grain yield of 3.44 t/ha although it did not differ significantly from IET 5914,IET 12199 and IET 10664. Graded levels of nitrogen increased the grain yield upto 80 kg N/ha. The response at graded levels of 40 and 80 kg N/ha averaged to 24.0 and 15.1 kg grain/kg N.

Response of new rice varieties to nitrogen

To find out response of five new varieties of rice of medium to long duration (145 to 175 days) to levels of nitrogen in wet season, a trial was conducted. The varieties, CR 260-77, Mahalaxmi, Swarnadhan, CR 1006 and Jagannath were grown under 4 levels of nitrogen 0, 30, 60 and 90 kg/ha. Irrespective of N levels, the variety CR 1006 was the highest yielder (3.28 t/ha) and Swarnadhan and CR 260-77 were the next best with yield of 3.25 and 3.21 t/ha respectively. There was a progressive yield increase up to 90 kg N/ha. However, response (kg grain/kg N applied) was highest (30.6) at 30-60 kg N/ha level while it was lowest at 60-90 kg level (14.0). The varieties also responded to nitrogen levels differently. The yield increased progressively upto 90 kg N/ha in case of varieties CR 260-77 and Swarnadhan while in the others, the yield increase was significant upto 60 kg N/ha only.

Effect of planting density and N levels on the crop performance of rice

The performance of long duration rice variety CR 260-77 was tested under four densities of planting (2, 4, 6 and 8 seedlings/hill) and four levels of nitrogen (0, 30, 60 and 90 kg/ha) during the wet season. Grain yield increased with the increasing N level from 0-90 kg N/ha (1.83 to 4.06 t/ha). No significant difference in yield was observed with planting densities 2 and 4/hill irrespective of N levels. But with the increasing in seedling number 6 and 8/hill, there was a significant improvement in yield. Interaction effects also revealed that yield increased significantly upto 8 seedlings/hill under 0, 30 and 90 kg N/ha while such yield increase was upto 6 seedlings/hill under 60 kg N/ha level. The reasons for better crop performance under higher number of seedlings could be adduced to continuous waterlogged condition in the field.

Evaluation of coated urea materials for higher grain yield and N-use efficiency

The efficiency of gypsum coated urea (GCU), nimin coated urea (NCU) and large granulated urea (LGU) was compared with that of prilled urea (PU), when they were applied at 60 kg N/ha in a single dose of planting or in two splits-two third at planting and the rest at panicle initiation (PI). Another treatment of green manuring 10 t/ha supplying 10 kg N/ha supplemented with prilled urea (30 kg N/ha) in two splits, 2/3rd at planting and the rest at PI stage was also kept as check. The test variety was Gayatri and was planted on 11 July. The highest yields (5.92 t/ha) was recorded in the treatment of green manuring *in situ* supplemented with urea in two split doses with a mean N-response of 31 kg grain/kg N. It was closely followed by GCU in two splits (5.71 t/ha) or NCU in two splits/basal (5.65 t/ha) and LGU in two splits (5.56 t/ha) (Table 5).

Table - 5 : Yield and yield attributes of rice (cv. Gayatri) as affected by different coated urea materials, wet season 1994.

Treatment	Grain Yield (t/ha)	Panicles (No./m2)	Panicle weight (g)	N response (kg grain/kgN)
Control (no N)	4.06	258	2.33	--
PU, all basal	4.93	275	2.59	14.5
GCU, all basal	5.56	288	2.79	25.0
LGU, all basal	5.32	281	2.65	21.0
NCU, all basal	5.65	296	2.79	26.5
PU, two splits	5.35	273	2.98	21.5
GCU, two splits	5.71	278	2.78	27.5
LGU, two splits	5.56	265	2.96	25.0
NCU, two splits	5.65	285	2.88	26.5
GM+PU, two splits	5.92	288	2.95	31.0
C.D. (P = 0.05)	0.39	NS	0.35	

PU - Prilled urea, LGU - Large granulated urea, NCU - Nimin coated urea, GCU - Gypsum coated urea, GM - Green manuring.

(N level in all the treatments except control : 60 kg/ha)

Evaluation of different organic N sources under rice-fish seed system

Performance of poultry droppings, FYM and water hyacinth compost was evaluated at 30 kg N/ha under fish (mrigal) fingerlings rearing @ 10,000 fry/ha with dry seeded rice var. Gayatri. Among the organics, poultry droppings were superior in terms of fish seed productivity (67.1 kg/ha/70 days), followed by FYM (57.2 kg/ha), water hyacinth compost also performed better (50.1 kg/ha) control (rice+ fish without organics 40.1 kg/ha) only. Use of these organics in five equal fortnightly splits during late vegetative and flowering stage of the crop had no impact on grain yield which ranged from 2.37 to 2.53 t/ha.

Poultry droppings increased the protein content in fish seed/flesh by 6.5 per cent followed by FYM (4.0 per cent), while water hyacinth compost had no effect over that of control (78.5 percent protein on dry weight basis).

Prawn seed raising

Fresh water giant prawn *(Macrobrachium rosenbergii)* seed(post-harvest to juveniles) were reared along with lowland rice (cv. Gayatri) at four levels of stocking density (number/m^2) like 1, 2, 3 and 5 area. Prawn seed population upto 5/m^2 (50,000 nos/ha) was found feasible as the productivity at this level was highest (83.1 kg/ha/100 days) realised from a retrieval rate of 48.7 per cent. The respective yields at other levels of population were 46.6 kg at 3 nos/m^2, 33.5 kg at 2 nos/m^2 and 22.1 kg/ha at 1 no/m^2. The grain yield of rice was within the range of 2.6 to 3.1 t/ha.

Phosphorus management

Six nursery treatments viz., no fertilizer (control), diammonium phosphate (DAP) at the rate of 2 kg/40 m^2, single superphosphate (SSP), Farmyard manure (FYM) and *Glyricidia* leaves to supply P_2O_5 equivalent to that supplied by ;2 kg DAP and root dipping of seedlings in superphosphate slurry at the rate of 20 kg P_2O/ha and three levels of phosphorus application to the main field viz., no phosphorus (control), 20 and 40 kg P_2O_5/ha were tested on variety Mansarovar.

Application of DAP, SSP and root dippling of seedlings with phosphate slurry greatly influenced seedling characters and recorded higher grain yield in the main field and were at par. Main field phosphorus fertilization had no significant influence in increasing the grain field.

Studies on K-response of rice

At Kharagpur, Gayatri was tested under different doses of K_2O like 0, 20, 30, 40 and 60 applied basally. Besides these, K40 and K60 were also given in two equal splits each 20 kg/ha and 30 kg/ha respectively applied as basal and top dressed after one month of planting. MOP (muriate of potash was selected as the source of potassium. There was no potassium response in any of the treatments.

The incidence of different insect pests was also studied in different treatments of potash. It was found that case worm damage was more at K_{40} and less at no added potash while gundhibug damage was more at no added potash and less at K_{40}. The incidence of deadheart was more at K_{60} in split doses and less at no potash whereas white earhead incidence was more in K_{40} at split doses and less at K_{20}.

Studies on sulphur nutrition of rice

Seven treatments viz., T_1 NPK as urea + DAP + MOP (no sulphur containing fertilizer)), T_1 + sulphur at 20 kg/ha as SSP, T_1 + pyrites to supply sulphur at 20 kg/ha, T_1 + gypsum to supply sulphur at 20 kg/ha, T_1 +

elemental sulphur at 20 kg/ha, T_1 + Ammonium sulphate to supply sulphur at 20 kg/ha and control (no fertilizer) were tested using the variety Salivahana of Kharagpur. The soil content of sulphur was below critical level (10 ppm). NPK + pyrites recorded a higher grain yield of 3.05 t/ha, as compared to of NPK alone (2.16 t/ha). The response to sulphur in this case was around 0-9 t/ha. Pyrites, gypsum and ammonium sulphate were equally effective in these soils.

The incidence of different insects was also recorded in the above mentioned treatments. Gundhibug damage was found to be highest in NPK + SSP source and lowest in NPK + elemental sulphur, whereas case worm damage was highest in NPK + Pyrite source and lowest in no fertilizer control.

Physiological parameterisation of photosensitive rice varieties under shallow submergence

Five rice varieties viz.Gayatri, Savitri, Swarna, Padmini and Moti were grown in field following the recommended cultural practices. Parameters like leaf area index, specific leaf weight and total dry matter were recorded at weekly intervals along with yield and yield attributes at harvest. Pre- and post-flowering dry matter contribution for grain filling was estimated.

During early vegetative phase, Moti (1.2 t/ha), at lag vegetative phase Swarna (5.8 t/ha) and at ripening phase Savitri and Gayatri (14 t/ha) produced highest drymatter. Grain yield was highest in Savitri (6.6 t/ha) and almost at par with Swarna (6.5 t/ha) followed by Gayatri, Padmini and Moti. Besides,it was observed that pre-flowering contribution of dry matter was more during the milky white state (43 per cent), while it was reduced to 35 per cent towards ripening stage. However, throughout the whole ripening period (from flowering to harvest) irrespective of variety, pre- and post-flowering dry matter contributions maintained a consistent ratio of 39 per cent and 61 per cent respectively. Variety Padmini showed less dry matter contribution of 26 per cent, while Moti recorded highest contribution of 54 per cent.

Evaluation of photosnsitivity in late duration cultivars (Coordinated trial)

A field trial was conducted in the field to evaluate photosensitivity of 22 late duration cultivars. Delay in transplanting by 15 and 30 days were introduced in addition to normal planting date (July 7) to evaluate relative magnitude of photosensitivity in terms of flexibility in duration to 50 per cent flowering. Irrespective of varied transplanting dates, 6 cultivars IET 13490, IET 13496.IET 13501,IET 13340,IET 13404 and IET 13406

were highly photosensitive and showed an earliness in flowering by 25-30 days exhibiting flowering duration confined to the 3rd week of October, whereas 8 cultivars ranged between 11-15 days earliness were moderately photosensitive and 8 cultivars of 5-9 days were weakly photosensitive. Three cultivars IET 13499, IET 13488 and IET 13402 were promising in yield (more than 8 t/ha) even under late planting conditions. At the same spot, a slight increase in dissolved oxygen which was more than 4 ppm while light penetration was about 1 per cent even though the water level decreased from 80 cm to 40 cm depth. This reveals how more turbid was the flood water was the less oxygen in contains. Studies will be initiated to estimate the turbidity of the flood water.

Observations made during 2nd flooding showed that oxygen concentration increased from morning to evening by about 30 per cent. Studies are neededto verify the causes of such increase in oxygen level.

Effect of N application on quality traits of long slender grain non-scented varieties

Long slender grain non-sented varieties - Sabita, Amulya, Hatipanjari, CRM-30 and CR.662-2318 were grown under four level of nitrogenous fertiliser (O, 30, 60, 90kg/ha) and the grain sample were analysed for quality characters. Application of nitrogen up to 90 kg/ha had no adverse effect on the quality of these cultivars.

Use of cheap lining material

Plastic was used as lining material in field channel. In CRRI farm, in B block a 40 meter length channel was lined with plastic. During the year it was observes that the plastic lining was not damaged due to weed infestation. The plastic lining is cheaper than brick lining. Also 55 meter channel lining was made in the farmer's field of Niranjan Sahoo of Bhairpur. It was observed that 10 per cent more area was irrigated with plastic lined channel. It is thus confirmed that plastic can be used as a cheap lining material for field channel system.

Development of green manure incorporator in dry seeded rice.

The two row bullock-drawn green manure incorporator was modified. The ground wheel edge blades were changed as no cutting of plants was possible. Two concrete rollers of 25 cm diameter and 25 cm length were attached behind the ground wheel to press the plants inside the soil. Two front guards made of M.S. flats were fabricated and fitted in front of the ground wheels to allow the plants to fall straight in the front without covering the rice plants. The preliminary testing of the implement was carried out in the field. There was problem in straight movement of bullocks in the cropped plot. The rollers pressed the plant but these were not pushed inside mud and floated when water depth was more

than 15 cm. Therefore, further modification of rollers is needed.

Design, fabrication and testing of notch type two-gang disc harrow

Secondary tillage equipment reduce cost of cultivation. This equipment is designed with the provision for pulling the sand inside the drum which will give the positive drive with penetration movement for different type of soil high, medium and heavy.

The two gang notch type disc harrow was fabricated. The drum diameter was 30 cm and the notch disc had 60 cm diameter. Both the gang could be set into an angle for its better performance of puddling as well as cutting the weeds. Drum rotates over the bush bearing provided at both ends. The drum got the opening with a closed cover for putting required amount of sand which would be in action gives a positive drive motion.

Testing of the equipment is in progress.

Energy requirements for the cultivation of transplanted rice

Study on energy requirements for the cultivation of rainfed transplanted rice using different level of tillage by powertiller rototiller and harvesting machine was carried out. Different levels of tillage used were two, three and four passes of rototiller. Harvesting was done with small engine operated self-propelled harvester and tractor operated harvester. The findings are summarised as follows:

1. Significant difference was found in the energy required for field preparation under different level of tillage treatment using power tiller. The energy required for field preparation (puddling) with two, three and four passes of rototiller was found to be 1333 MJ/ha, 2098 MJ/ha and 2841 MJ/ha respectively.

2. No significant difference in yield of rice was found due to different levels of tillage with powertiller operated rototiller. The yield obtained in tillage treatments two, three and four passes of rototiller was found to be 40.5, 40.2 and 40.0 O/ha respectively.

3. Energy required for harvesting rice by engine operated self propelled harvester and by tractor operated harvester was found to be 193 MJ/ha and 246 MJ/ha respectively. Higher energy requirements in tractor operated harvester was mainly because of idle reverse run during each forward cutting run due to small plot.

4. Energy contributed by different components in rice cultivation was found to be highest for fertilizer (51.03 per cent) followed by diesel (32.35 per cent), human (4.2 per cent) seed (4.38 per cent),

machinery (2.93 per cent) and electricity (0.58 per cent) respectively.

5. Soil compactness in different level of till age i.e. two and three passes of rototiller by powertiller was found to be almost identical. Highest soil compactness was found at about 30 cm to 32.5 cm depth, 30 cm to 32.5 cm below ground level for two, three and four passes of powertiller was found to be 5.6, 5.83 and 6.1 kg/cm^2 respectively.

6. Benefit cost ratio (ratio of gross income to cost) under different tillage treatments was found to be 1.80 to 1.85

CROP PROTECTION

Weed Management

Chemical weed control in direct seeded rice

To find out an effective weed control schedule for direct seeded rice (cv. Gayatri) in wet season, an experiment was conducted using 3 pre-emergence herbicides. The butachlor and thiobencarb were tested at 2 kg/ha and anilophos at 0.6 kg/ha. Reduced rates of application of the herbicides (1.0 kg/ha in case of butachlor and thiobencarb and 0.4 kg/ha in case of anilophos) combined with 1 hand weeding at 40 days after seeding were also included. The treatments - mechanical weeding, weed free and unweeded controls were kept for comparison. Crop was sown in dry condition on May 31. The field was predominantly infested with *Cyperus rotundus L.*, *Echinochloa colona* (L.) Link during initial stages and *Ipomoea aquatica* Forssk after water accumulation. It was observed that all the three test herbicides applied alone or in combination with hand weeding around 40 days after sowing provided effective weed control (weed control efficiency ranging from 71.8 to 87.4 per cent) comparable to that (86.0 per cent) of weed free check given 3 hand weedings. Grain yields under these treatments (3.6 to 3.92 t/ha) were also comparable.

Disease management

Epidemiology of sheath blight

Infectivity of different isolates of *Rhizoctonia solani* on certain known tolerant rice cultivars : Five known tolerant rice cultivars viz., Bharati, CR 1014, Nalini, OS 4, and FR 26-B to sheath blight were inoculated with 8 isolates of *R. solani* collected from different parts of India viz., Kerala, Nagaland, Orissa, Punjab and Tamil Nadu. Ptb. 10 and Bhagya were included as highly susceptible checks. Plants were inoculated at flowering stage and the lesion length was measured on 9th day after inoculation.

Among the 8 isolates, one from Nagaland was found to be highly aggressive and one from Orissa exhibited least aggressiveness producing tolerant reaction even on the highly susceptible check cultivars.

Among the tolerant cultivars, with 8 isolates produced less lesion length on CR 1014. The percentage of infection which was recorded on 15th day after inoculation showed less disease build-up in CR 1014 and Nalini.

The data clearly indicates the superiority of CR.1014 in the degree of tolerance to sheath blight even against highly aggressive isolates of the pathogen.

Cellular selection for tolerance to sheath blight fungus

Calli of Kalanamak were treated with 60 Co at (5-10 Kr) and EMS (0.01 per cent, 0.05 per cent and 0.1 per cent) and allowed to regenerate. The regenerants from the surviving calli were rest in the green house for their resistance to sheath blight. All the regenerants were found to be susceptible to sheath blight.

Studies on false smut disease of rice

Cross protection against rice tungro by false smut treatment: The effect of false smut treatment on germination of rice variety Jaya was studied. The results revealed that the treatment with toxin obtained from false smut balls adversely affected the germination percentage and growth of radicle. When treated seeds were transferred to soil, they affected the normal growth (Table 6) . These seedlings had least damage by tungro disease of rice (Table 7).

Integrated management of false smut and stem borer in shallow water ecosystem : Pesticides were applied (Table 8) before flowering and disease incidence was recorded in all the treatments. Phoret was effective in increasing the yield significantly. Monocrotophos, Blue copper, Sulphax and Thiram could reduce the number of false smut balls.

Studies on mode of infection of false smut disease : This study was conducted under green house condition using rice variety, Utkal prabha. The plants were exposed to false smut inoculum at early seedling and at active tillering stages which were compared

Table - 6 : Effect of false smut treatment on germination of rice variety "Jaya"

Treatment	Germination %	Av. Length of radicle (mm)	Av. length (mm) of plumule
Control	88	36.65	42.73
False smut Treatment	84.6	20.2	1.11

Table - 7 : Effect of various inoculations on plant characters of rice var. Jaya

Treatment	Tillers per plant	Plant height (cm)	Max. leaf width (cm)	Total leaves per plant	Tungro infection		EBT
					No. of infected leaves per plant	% Plants infected	
Uninoculated	1.33	35.7	5.8	5.35	--	--	6
False smut	1.88	30.62	6.7	7.3	1.2	60	5
Tungro	1.09	25.0	5.0	4.9	2.81	91.	9

Table - 8 : The effect of various fungicides/insecticidel treatment on yield, false smut balls and stem borer infected tillers in rice (cv.) Utkalprabha

Treatment	Yield kg/100m²	Total false smut balls	Stem boarer infested tillers
Phoret	33**	136	10
Monocrotophos	27	139	93
Bavistin	21	572	68
Blue copper	20	148	82.5
Mancozeb	19.4	411	91
Sulphax	18.5	268	61
Thiram	18.5	377	74
Control	23.6	497	75
L.S.D. at 1%	7.2	86	

with control where the plants were not inoculated. The results revealed that airborne ascospores might be the main source of primary inoculum.

Relation between sowing date and damage cause by false smut disease : Sowing of rice variety HR 12 was carried out under field condition in the months of June, July and August. Incidence of false smut, ear bearing tillers and yields were recorded. The incidence of false smut EBT and yields were higher in June sowing when compared to August sowings.

False smut infection in rice-cum-fish culture: The false smut infection was lower in paddy-cum-fish culture ecosystem (5 per cent) when compared to shallow water ecosystem (50 per cent).

Varietal resistant to tungro

Fifteen rice cultures popularly grown in West Bengal were evaluated for their reaction to tungro both in net house and field conditions. The cultivars Badsabhog, Bombai Mugi, Hathipanjara and Karnasal were resistant both in net house and field conditions. The cultivar Swarnadhan exhibited resistance in the field but could not withstand artificial inoculation and became susceptible. All the remaining cultivars were susceptible both in field and green house conditions.

Epidemiology and control of tungro

Observations with five rice cultivars under different land situations during wet season, 1994 indicated that rainfed shallow and rainfed intermediate lowland situations favoured faster multiplication of tungro associated viruses and its vector *Nephotettix* spp, than rainfed upland.

Tungro control experiment in intermediate deep water ecosystem under late transplanted condition indicated that sixty days old seedlings of cultures like CR 673-431, CR 673-475 and CR 674-470 could safely be planted as late as September 15 with minimal plant protection measure which consists of application of Carbofuran 3G @ 2 kg a.i./ha in two split doses as a precautionary measure.

Under the shallow water ecosystem, 45 days old seedlings of cultures like CR 682-162, CR 683-115 and CR 683-123 could be grown by transplanting them onSeptember 10 with yield more than 4.5 t/ha. Need based application of Carbofuran 3G @ 1.5-2.0 kg a.i./ha in three split doses was utilised.

INTERMEDIATE ECOSYSTEM

INTERMEDIATE ECOSYSTEM

CROP IMPROVEMENT 140

- Evaluation of germplasm for submergence tolerance
- Generation, Selection and evaluation of breeding material from Segregating Programmes
- Evaluation of promising cultures for nitrogen use efficiency
- Evaluation of fixed cultures under intermediate water depth.
- Eastern India rainfed lowland shuttle breeding programme (intermediate lowlands)
- Evaluation of germplasm for submergence tolerance.

CROP MANAGEMENT 143

- Effect of different agronomic management practices on submergence tolerance and productivity of Rice
- Effect of tillage, weed control method and N fertilizer on growth and yield of rice
- Effect of seed size and seed rate on performance of rice
- Performance of mixed-crop system of early and late maturing rice varieties
- Effect of green manuring with dhaincha (Sesbania aculeata) on the performance of direct-sown and transplanted rice
- Varietal tolerance to flooding at different growth stages
- Effect of organic manures on soil fertility and productivity of rice
- Rice-fish integrated system.

CROP IMPROVEMENT

Evaluation of germplasm for submergence tolerance

Two accessions from germplasm, AC 19 and AC 1631 were identified suitable for anaerobic seeding in addition to FR 13 A (59 per cent germination). These two accessions have shown high germinability (upto 65 per cent) when sown at 3 cm soil depth and 30 days continuous submergence of 80 cm high water column in the initial 10 days and 20 cm water column for later 20 days.

Generation, selection and evaluation of breeding material from segregating progenies

Under intermediate lowland, the breeding materials of different generations and crossed were grown (Table-1)

Evaluation of promising cultures for nitrogen use efficiency

A trial was conducted with 12 elite lines under direct seeded condition at 4 levels of N viz. 0,30, 60 and 90 kg/ha to identify donors which respond to native soil and applied nitrogen. CR 626-7-3(2.74 t/ha) and CR 683-123(2.71 t/ha) were identified as better responsive to native soil nitrogen (No) while PN 56-2 recorded only 1.16 t/ha. Only six entries showed response to applied nitrogen to 30-60 kg/ha level. Among them CR 673-431 recoreeed the highest yield of 3.7 t/ha at N60 level while MJ 27-9 recorded 1.28 t/ha. There was non-significant interaction between variety and nitrogen for different yield attributes except for plant height before flowering and at maturity.

Table - 1 : Number and generation of crosses grown in wet season, 1994

Generation	Number of cross combination	No. of progenies plants grown
Semi-fixed lines	10	30
F_4	4	60
F_3	280	3
F_2	9	--
F_1	40	--
New crosses made	25	--

The above crosses involved established submergence tolerant parents like FR 13 A, Sarubhujini, IR 38784-15-19, IR 57539-5-27, Boithalpakhia, CN 579-363-3-1, CR 383-10 etc.

Evaluation of fixed cultures under intermediate water depth

From a trial with 25 elite lines derived from 10 cross combinations and 11 check varieties under direct seeded condition, CR 673-368 recorded the highest yield of 3.3 t/ha followed by CR 674-470 (2.7 t/ha) and CR 673-420 (2.7 t/ha) compared to the best yielding check Panidhan (2.5 t/ha). Most of the entries flowered during 1st and 2nd week of November.

Eastern India Rainfed Lowland Shuttle Breeding Programme (intermediate lowlands)

The ICAR-IRRI Eastern India Rainfed Lowland Shuttle Breeding Programme, operating in 8 locations of the 6 eastern states, is coordinated by CRRI, Cuttack. The significant results obtained from the programme are given as follows :

(i) *Late planting experiment* :A set of 29 elite fixed lines developed in different locations in eastern India was tried under one and two dates of planting. It was observed that the optimum flowering for different centres ranged from 1st week of October (Raipur and Titabar) to 1st week of November (Ranital, Orissa, Chinsurah, West Bengal). The yield performance of the best entries are given in the Table 2.

(ii) *Screening for submergence tolerance:* Sixty entries were submerged under a

Table - 2 : Yield performance of promising entries under normal and late planted conditions

Culture	Yield (kg/ha) (Pooled data)			Flowering duration (days)
	Normal planting (30 days old seedlings	Delayed planting (60 days old seedings)	Mean	
PSR 1119-13-3	4253 (2)	2631 (3)	3442 (1)	120
RAU 73-16-1-60	4198 (3)	2593 (5)	3396 (2)	112
SBR 3025-2-1-8-2-1	3859 (10)	2735 (2)	3297 (3)	122
NDR 30039	4050 (6)	2487 (6)	3269 (4)	119
Rajashree (Check)	3550	2804 (1)	3177 (5)	116
Sabita (Check)	3469	2015	2742	127
Expt. Mean	3959	2314	3136	120

Figures in parenthesis indicate rankings.

water depth of 80 cm for 14 days at 30 DAS. One week after the releasing of late, survival percentage was recorded. Even though, NDR 914189, NC 487-77 and TCA 48 recorded better survival than FR 13A, they were of elongating types while FR 13A was non-elongating type character more desirable for higher yields.

(iii) *Evaluation and selection of segregating population :* 6459 segregating and fixed breeding lines from 315 cross combinations were direct seeded (in 2-3 lines each) with only basal dose of 40:20:20 kg/ha NPK. The crop was exposed to excess water stress at the vegetative stage. Selections made from the breeding material are listed in Table 3.

Evaluation of germplasm for submergence tolerance

Two hundred forty, photosensitive, long duration lines from CRRI genetic stock were exposed to submergence (20-25 cm above the plant height) at 25 days after germination for 12 days. Interestingly plants of all the entries emerged above the water level and almost 99 per cent of the entries survived. The possible physiological reasons might be (i) water was quite clear (borewell water), (ii) the sky was almost overcast during the 12 days of submergence, such environment might have made the plants elongate above the water level. However, during the subsequent wet season, the exposure of the same 240 entries to turbid water might throw some light on their ability to survive under submergence.

Table - 3 : No. of breeding lines evaluated and selected in the shuttle breeding programme

Generation	No. of crosses	No. of lines evaluated	No. of plants selected	
			Single Plant	Bulk
F_2	60	1733	301	154
F_3	134	4025	2027	123
F_4	21	467	217	90
Fixed lines	100	150	--	150
Donors	--	84	--	84
Total	315	6459	2445	601

C.R.R.I., CUTTACK-753006
ORISSA (INDIA)

Evaluation of 18 (AYT) cultures for their physiological tolerance to waterlogged conditions indicated that the seedling survival (under complete submergence for 12 days at 25 DAG) of IET 13537 and IET 11901 were on par with Utkalprabha (check) i.e. 30 per cent while the culture, IET 13119 was on par with other check, Sabita i.e. around 25 per cent.

The highest grain yield of IET 13119 (354 g/m2) was mainly due to its grain number per square meter, *in spite of its low 1000* grain weight (18.0 g). The grain yield of IET 11896 (320 g/m^2) was mainly due to its panicle number and 1000 grain weight, while that of IET 11901 (330 g/m^2) was due to its grain number per square meter, similar to check varieties, Sabita (318 g/m^2) and Utkal Prabha (316 g/m^2) and the rest of the entries recorded lesser grain yield than checks Table 4).

CROP MANAGEMENT

Effect of different agronomic management practices on submergence tolerance and productivity of rice

The effect of different agronomic practices viz., method of stand establishment

Table - 4 : Effect of water logging on the performance of AYT cultures (1994 DRR Trial)

Cultivars	Grain yield (g/m^2)	Panicle no/m^2	1000 grain wt.(g.)	Grain no/m^2	Seedling survival (%)
IET 13119	354	114	18.6	18991	26
IET 11901	330	126	24.0	13817	31
IET 11896	319	132	26.7	11962	19
IET 11910	278	158	24.3	11451	14
IET 13116	267	185	22.4	11981	24
IET 11904	245	154	24.2	10157	13
IET 11271	241	175	25.1	9611	15
IET 11272	234	159	23.3	10060	19
IET 13120	212	124	27.7	8271	18
IET 11893	207	179	23.3	8902	7
IET 13537	203	173	22.4	12852	34
Sabita	327	130	24.4	13426	25
Utkal prabha	316	216	18.2	17403	35
Mean	272	158	23.4	12222	27
C.D. (5%)	60.5	32.9	1.28	--	2.6

(direct seeding on 25 May and transplanting on 28 July), plant populations (normal and 50 per cent more), N fertilizer (0 and 40 kg N/ha) and quality of seeds (lighter 19.4 g/1000 seeds and heavier, 21.9 g/1000 seeds) or seedlings (nursery seedlings grown with or without application of 100 kg N/ha in the seed bed) on submergence tolerance of rice (cv. Gayatri), was studied. The crop grown under intermediate deepwater conditions was subjected to simulated flooding of 90 ± 3 cm water depth for 10 days at 100 days after germination/40 days after transplanting.

Direct-sown crop tolerated flooding better and produced higher grain yield (2.51 t/ha) than the transplanted crop (2.32 t/ha) as the latter experienced excess water stress soon after planting. The adverse effect of simulated flash-flooding was partially migrated by the use of heavier density seeds (10.9 per cent more yield than higher seeds) and with basal application of 40 kg N/ha (21.3 per cent more yield than with no N). The transplanted crop raised from taller (80 cm) and vigorous (1.65 g dry weight/seedling) N fertilized seedlings established better and produced significantly higher yield (+0.44 t/ha) than with dwarfer (59 cm) and weak (0.79 g/seedling) seedlings receiving no fertilizer in the seed-bed. There was no beneficial effect due to top dressing of 20 kg N/ha at 110 days after sowing or 50 days after transplanting in addition to 20 kg N/ha applied basally under the natural unsubmerged conditions. However, N applied after termination of flash-flooding improved the yield of the submerged crop significantly due to better crop recovery and thus compensated for the loss in crop stand and vigour to some extent.

Effect of tillage, weed control method and N fertilizer on growth and yield of rice

The effect of off-season tillage (summer ploughing in mid-March) versus conventional practice of ploughing the fields with pre-monsoon showers just before sowing (20 May) or after accumulation of water (for transplanting on 27 July) was studied on the rice variety Gayatri under upto 40 cm water depth. Different weed control practices viz., no weeding, chemical weeding (thiobencarb @ 2 kg/ha within a week after sowing), post-establishment intercrop cultivation (*beaushening* 50 days after sowing) and puddling (for transplanted crop) were also included along with N fertilizer levels (0 and 40 kg N/ha as basal).

Off-season tillage ensured good crop stand and vigour through better seed germination and prevented early weed infestation in direct-sown crop resulting in significantly higher grain yield than conventional tillage. Herbicide application controlled all the major weeds effectively except joint-vetch *(Aeschynomene indica)* and improved yield by 26.2 and 34.3 per cent under summer ploughing and conventional tillage respectively compared with

no weeding. *Beaushening* was also equally effective as herbicide application under summer ploughing but the yield advantage was much greater in the conventional tillage, due to higher crop-weed competition resulting from higher accumulation of weed biomass. Weed infestation was minimal in the crop transplanted after through puddling. Due to shallower depth of water at planting (18 cm) and thereafter during the crop growth period (20-35 cm), the grain yield of transplanted rice was significantly more (2.77 t/ha) than the direct-sown crop (2.25 t/ha). Basal application of 40 kg N/ha improved the yield significantly when weeds were controlled effectively either by chemical or cultural means (*beaushening* and puddling) but there was no effect of N fertilizer on rice growth under unweeded conditions, particularly under conventional tillage. Therefore, adequate weed control was essential for higher efficiency and better utilization of applied N fertilizer.

Effect of seed size and seed rate on performance of rice

Seeds of rice variety Gayatri were screened in common salt solution (1.2 specific gravity by dissolving 300 g common salt in one litre of water) to obtain different grades such as lighter seeds (19.4 g/1000 seeds), medium seeds (21.2 g/1000 seeds) and high density seeds (22.9 g/1000 seeds). These seeds having nearly 100 per cent germination under laboratory conditions were sown in the field on 19 May at varying rates viz., 200, 400 and 600 seeds/m^2. A common basal dose of 40 kg N and 20 kg P_2O_5/ha was applied. Water depth during crop growth period varied between 15 and 40 cm.

Seedling emergence increased with increasing seed rate but was similar between seeds of different grades (40 per cent). Seedling vigour was apparently better in the early stages in plots sown with heavier seeds than with lighter seeds. The grain yield with heavier and medium seeds was comparable (2.69 t/ha) but significantly more than with lighter seeds (2.15 t/ha). Although panicle weight was same in the crops sown with seeds of different grades, panicle number/m^2 was higher with heavier density seeds. Apparently some of the weak seedlings from lighter seeds might have died after emergence due to non-availability of sufficient carbohydrates. Interaction effects revealed that grain yield increased with seed rate upto 600 seeds/m^2 with lighter seeds and upto 400 seeds/m^2 with medium seeds. However, the effect of different rates of heavier seeds on grain yield was not significant.

Performance of mixed-crop system of early and late maturing rice varieties

Rice varieties of different maturity groups and plant heights Gayatri (semi-dwarf, 165 days) and CR 260-77 (semi-tall, 170 days),

Annada (dwarf, 105 days) and Vanaprabha (semi-tall, 95 days) were direct-sown on 18 May either in pure stand or the late and early varieties were inter-cropped in alternate lines (1:1 ratio) and 2:1 ratio. A seed rate of 400 seeds/m^2 in pure stand at 20 cm row spacing and 600 seeds/m^2 in mixed cropping (in relative proportion of late and early varieties) at 15 cm row spacing was followed, using a common basal dose of 40 kg N and 20 kg P_2O_5 ha. The early varieties were harvested in the first fortnight of September after which the late variety grew in a wider space until maturity in mid-December when water level had almost completely receded.

In pure stand, the long duration varieties, Gayatri and CR 260-77, produced twice more yield (3.9-4.0 t/ha) than the early varieties, Annada and Vanaprabha (1.8-2.1 t/ha). However, in mixed stand, the yield of Gayatri and CR 260-77 was 69 and 88 per cent of their yield in pure stand under 1:1 ratio and 2:1 ratio respectively. On the other hand, Vanaprabha and Annada produced only about half of their yield in 1:1 ratio and less than 40 per cent in 2:1 ratio. Higher productivity with late varieties was due to their occupying greater space after harvest of early varieties in September, leading to higher panicle weight. The overall grain yield in fixed cropping system was 13.6 per cent more compared with the sole crop yield of late variety alone. Vanaprabha performed relatively better than Annada but both the long duration varieties were equally good in mixed cropping stand.

Effect of green manuring with dhaincha *(Sesbania aculeata)* on the performance of direct-sown and transplanted rice

Green manure crop of dhaincha *Sesbania aculeata)* was sown on 23 May either in pure stand or in alternate rows along with either of the two rice varieties, Seema (semi-dwarf) and Utkalprabha (semi-tall) at 15 cm row spacing. Incorporation of dhaincha was done manually at 55 days of growth in between the inter-row spaces of rice when 35 cm water had accumulated in the field.

However, pure crop of dhaincha was incorporated using a mould-board plough, following which rice was transplanted at 20 cm row spacing. Sole crop of rice with and without basal application of 40 kg N/ha through urea fertilizer were also maintained separately under direct-sown and transplanted conditions for comparison.

At the time of incorporation, fresh biomass accumulation by dhaincha was 18.8 t/ha in pure stand and 15.9 t/ha in the intercropping system, equivalent to the addition of 85.4 kg and 69.8 kg N/ha respectively. Although initial growth of rice was affected slightly when grown along with dhaincha due to more vigorous growth of the latter, rice plants recovered after incorporation of dhaincha

due to increase in row spacing and release of mineralised N to the plants. Green manured rice produced the same yield as with 40 kg N/ha applied through urea fertilizer under both direct-sown and transplanted conditions. However, despite greater addition of biomass and N through dhaincha in pure stand, the yield of transplanted rice was lower (1.6 t/ha) than the direct-sown crop (2.32 t/ha), due to poor crop establishment in higher depth of water. The grain yield of Utkalprabha (2.37 t/ha) was significantly more than that of Seema (1.90 t/ha) under transplanted condition.

Varietal tolerance to flooding at different growth stages

Submergence tolerance of seven photosensitive rice varieties, Gayatri, Jagannath (semi-dwarf), Panidhan, Tulasi (semi-tall), Amulya, Champaisali (tall) and FR 13A (semi-tall, check) was tested in a field experiment under the natural intermediate deepwater condition.

The crop was direct sown on 25 May and subjected to simulated flash flooding of 90 ± 3 cm water depth after 10 days at 60 days after germination (active tillering stage) and/or 80 days after germination (maximum tillering stage). Water accumulated in the field from the first week of July and rose to a maximum depth of 65 cm in the first week of September. However, water level fluctuated between 35-55 cm during most of the crop growth period. Varieties of shorter height were submerged completely during the period of flash-flooding whereas tall types elongated with rising water level and thus could escape complete submergence.

Flooding at maximum tillering was found less detrimental than early flooding as judged from lower tiller mortality (8 per cent) and less decrease in dry matter (28 per cent) compared with active tillering stage (tiller mortality 26 per cent and dry matter decrease 34 per cent). Grain yield decreased by 20 per cent and 9 per cent when the crop was subjected to flooding at active and maximum tillering stages respectively compared with that of natural submergence conditions. However, submergence at both the stages decreased the yield substantially (44 per cent). The rice varieties Panidhan, Amulya and Champaisali exhibited better tolerance to flooding and recovery thereafter as evidenced by their less tiller mortality (13 per cent) and lower decrease in dry matter (30 per cent). Thus, these varieties with grain yields 2.62, 2.37 and 2.45 t/ha respectively out-yielded others. The adverse effect of flooding on grain yield of FR 13A was marginal (5 per cent), whereas Jagannath got a greater set back in yield by 49 per cent.

Therefore, semi-dwarf to semi-tall plant types like Gayatri and Panidhan with limited elongation are more suitable than the tall

elongating and flood escaping types like Amulya and Champaisali in the flood-prone intermediate lowland areas.

Effect of organic manures on soil fertility and productivity of rice

A field experiment was conducted in the wet season, 1994 to study the comparative effects of poultry manure, sewage sludge, compost and straw on growth, yield and N uptake by rice. All these organic manures were applied alone or in combination with urea in the ratio 1:1 on the basis of total N applied at the rate of 40 kg/ha. A separate no nitrogen control and full dose of nitrogen in the form of urea were taken as checks. All the chemical nitrogen was applied behind the plough at the time of seeding rice. The organic manures were applied and mixed with the dry soil before sowing rice.

The dry matter yield and N uptake by rice at maturity indicated beneficial effect of sewage sludge as compared to compost. The application of rice straw alone at the rate of 40 kg N/ha did not improve the yield of straw, grain and N uptake by rice. However, application of all these organic manures alone resulted in lower N uptake by rice in comparison to urea. But the combined use of organic manures and urea improved the dry matter yield and N uptake by rice over the application of organic matter alone. The effect of combined use of poultry manure and urea together in the ratio 1:1 (N basis) was superior to application of urea or poultry manure. There was no extra advantage of the combined use of urea and compost or sewage sludge over the application of urea alone in respect of dry matter yield and N uptake by rice.

Rice-fish integrated farming systems

A farming system involving rice, freshwater fish and prawn crops after rice, vegetables and fruit crops on bunds were taken up in a field of hectare for the second year. Among the four rice cultivars grown, Panidhan recorded the highest grain yield (3.5 t) followed by Utkalprabha (2.8 t), Seema (2.4 t) and Tulasi (2.0 t/ha). The yield was comparatively low in the case of Tulasi and Seema due to high levels of bacterial leaf blight incidence (58.8 per cent and 51.9 per cent respectively) at the late vegetative stage followed by stem borer infestation (22.7 per cent and 30.9 per cent) at the heading stage. Fish fingerlings of Indian major carps (catla, rohu, mrigal), common carp and freshwater prawn juveniles of *Macrolrachium rosenbergii* and *M. malcolmsonii* were grown in equal proportion at 7,000 nos/ha. Sampling of the stock recorded a good growth of both fish (150 to 500 g) and prawn (30-100 g).

Different vegetables and fruit crops were grown on bunds all around. A tier system of vegetables farming was done putting creepers on eight raised bamboo platforms over the two side trenches. Among the different kharif season vegetables grown on bunds, okra recorded a productivity of around 8 t/ha and ridgegourd of 5 t/ha. Among different varieties of winter vegetables grown on bunds under pot irrigation from the refuge/trenches, the productivity per ha of some of the crops was in the order of around 99 t for radish, 83 t for tomatoes, 37 t for carrot, 29 t for bean and 16 t for cauliflower.

Fruit crops on bunds included dwarf banana, papaya and TD varieties of coconut.

SEMI DEEP WATER ECOSYSTEM

SEMI DEEP WATER ECOSYSTEM

CROP IMPROVEMENT 154

- Promising lines for semi-deep situation
- Varietal improvement for semi-deep lowlands

CROP MANAGEMENT 155

- Optimum time of sowing for different rice varieties
- Effect of different methods of establishment on performance of direct-sown and transplanted rice
- Plant population and N fertilizer requirement of rice
- Transformation and efficient utilisation of prilled area in lowland rice
- Evaluation of seedling vigour as influenced by seedling fresh weight and plant height
- Evaluation of quality traits of varieties/cultures
- Biochemical basis of submergence tolerence

CROP IMPROVEMENT

Promising lines for semi-deep situation

Based on the performance in the all India Coordinated Programme and final testing during wet season, 1994 in the semi-deep situation, the culture CR 580-17-1, selected from the cross of Mahsuri x CR 94-1512-6 was recommended by the Rice Workshop (1995) for pre-release multiplication and eligible for Variety Identification Committee (VIC). The culture had semi-tall height, stiff straw with medium grains and built-in-tolerance to gall midge and GLH. The culture also performs well in shallow water and late planted condition. It yielded around 4.5 t/ha under average management.

Varietal improvement for semi-deep lowlands

A set of 15 fixed cultures from 5 cross combinations were tested for their submergence tolerance and yield potential under semi-deep (50-100 cm depth) situations. The performance of some of the promising cultures are given in Table 1.

Table - 1 : Performance of promising cultures under semi-deep with semi-deep water conditions

Culture No.	Flowering period		Yield t/ha	Tolerance to insect/disease
CR 580-17-1	October	4th week	4.24	GM, RTV
CR 679-4	November	1st week	4.09	GM, GLH
CR 580-5	November	1st week	4.58	GM, RTV
CR 771-1	October	4th week	3.52	GM, RTV
Sabita (check)	October	3rd week	3.05	–

CROP MANAGEMENT

Optimum time of sowing for different rice varieties

A field experiment was conducted using six promising rice varieties from different states of eastern India viz., LPR 312 (Assam), Matangini (West Bengal), Janaki (Bihar), CR 581-9 (CRRI), Jalnidhi (Uttar Pradesh) and Champaisali (local, Orissa). These were sown at different times at 10 days interval from 10 May (early sowing) until 10 June (delayed sowing).

Water accumulated in the field from the last week of June and rose to the maximum depth of 123 cm in the first week of September. However, water level fluctuated between 70-90 cm during major part of the crop growth period.

Seedling emergence was found better (62-88 per cent) in the late sown crop because of light showers immediately after sowing. However, the early sown crop had relatively lower seedling emergence (49-53 per cent) due to delayed and less frequent rains after sowing.

The grain yield of all the varieties decreased progressively with delay in sowing beyond 30 May because late sown crops despite good initial crop stand failed to withstand immediate excess water stress. Sowing on 10 June recorded the lower grain yield (1.5 t/ha) compared with sowing before 30 May(1.8-1.9 t/ha). On the other hand, grain yields among different varieties varied significantly. The variety, Janaki out-yielded 2.6 t/ha other varieties. The varieties CR 581-9, LPR 312, Jalnidhi and Matangini were comparable with each other. The results suggest that sowing during 15-25 May with suitable varieties like Janaki and LPR 312 is essential for realizing higher productivity of rice under semi-deepwater situations.

Effect of different methods of establishment on performance of direct-sown and transplanted rice

Rice variety Panidhan was established either through direct seeding in dry soil on 25 May using 400 and 600 seeds/m^2 or transplanting after accumulation of water on different dates 7 July (water depth 14 cm), 27 July (46 cm) and 16 August (63 cm). The nursery-grown seedlings and tillers uprooted from direct-sown crop with 600 seeds/m^2 were taken for planting. Seedling emergence was 50-52 per cent. However, better panicle growth was recorded in direct-sown crop with 600 seeds/m^2. Transplanted crop with clonal tillers also showed better panicle growth than that with nursery seedlings.

Direct-sown crop out-yielded (2.45-2.58 t/ha) the transplanted crops (0.21-1.65 t/ha). This might be ascribed to better initial estab-

lishment of direct-sown crop before water rose to the highest depth in the field. No significant decrease in the yield of direct-sown crop with 600 seeds/m^2 was observed after removal of 70-90 tillers/m^2 at 50 days after germination (DAG). However, when tillers were removed at 70 and 90 days significant decrease in the yield was observed compared with the undisturbed crops (no tiller removal). The yield of undisturbed crop sown at 400 and 600 seeds/m^2 was on par.

Transplanting resulted in low and unstable yields because the water depth at planting varied from 14-63 cm on the different dates and fluctuated between 60-70 m during crop growth period. This resulted in greater plant mortality and poor crop stand. However, transplanting with clonal tillers was found superior to that with nursery seedlings. This might be attributed to greater seedling height (59-112 cm) and dry matter (0.6-3.6 g) of clonal tillers compared with the height (65-88mm) and dry matter (0.4-1.3 g) of nursery seedlings at the time of planting. These could have helped the clonal tillers to acclimatize in flooded lowland environment quickly in the filed, whereas the nursery seedlings collapsed when transferred from a favourable upland nursery environment to the unfavourable flooded lowland environment.

The results show that dry sowing with 400 seeds/m^2 or transplanting with clonal tillers removed from a 50-day-old crop sown with 600 seeds/m^2 is beneficial for situations where direct seeding is not done earlier.

Plant population and N fertilizer requirement of rice

The effect of varying seeds rates from 100-800 seeds/m^2 (equivalent to 20 to 160 kg/ha) along with N levels (0, 30 and 60 kg N/ha) was studied on rice variety Nalini. The crop was direct-sown on 17 May and N fertilizer was applied either in single basal dose through prilled urea or 2/3 basally and 1/3 at active tillering (50 days after germination) stage through placement of urea supergranules (USG).

Water accumulated in the field from the last week of June and upto a increased maximum depth of 101 cm in the first week of September. However, it fluctuated between 70-85 cm during major part of the crop growth period.

Seedling emergence was 40-50 percent and increased with increasing seed rate from 100-800 seeds/m^2. The grain yield was significantly higher (2.14 t/ha) at 400 seeds/m^2 than at 100 of 200 seeds/m^2 but further increase in seed rate upto 800 seeds/m^2 was not found beneficial. Increase in panicles/m2 at higher seed rate was associated with lower panicle weight. Yield response to N was obtained upto 30 kg N/ha and split application was of no advantage over the single basal

application. The grain yield was low (1.5-2.5 t/ha) due to high incidence of stem borer (20-30 per cent).

Transformation and efficient utilisation of prilled urea in lowland rice.

A laboratory study simulating initial aerobic soil condition of rainfed lowland direct sown rice revealed that about 22 per cent of applied urea was nirified during the initial period of 3 weeks following urea application. The nitrification was appreciably retarded with the use of nitrification inhibitors, Their decreasing order of effectiveness being: hydroquinone, alcoholic extract of neem cake and dicyandiamide. The results suggest blending of urea with the best inhibitor for better N use efficiency.

Experimental data on mea adsorption in alluvial soils of Cuttack fitted well to Freundilch equation, X/make [141]. The K values indicating the affinity of adsorption were 0.071,0.158 and 0.130 for loamysand, sandy loam and clay loam, respectively. The l/n values which were inversely related to energy of adsorption were estimated to be l/0.935, l/1.057 and l/1.82 for loamy sand, sandy loam and clay loam, respectively. The results indicated weaker energy of urea and sorption in soils of coarse texture.

Results obtained from the field experiment on method of urea application revealed that the relative germination counts % of rice were 93,83,74 and 45 with seed furrow placements of (i) solid urea (ii) solution urea, (iii) solid urea mixed with single superphosphate (SSP) and muriate of potash (MOP) and (iv) suspension of urea, SSP and MOP, respectively.

Although the effect of different methods of urea application on crop yield was not significant due to adverse rain water accumulations in the year under report, the date pooled over the last four years clearly showed that basal band placement of prilled urea in solid or suspension form with or without SSP and MOP or point placement of urea mudlmps in reduced soil zone at tillering stage of crop were significantly superior to surface broadcasting of prilled urea at active tillering stage.

Evaluation of seedling vigour as influenced by seedling fresh weight and plant height

For the second consequetive wet season seedlings of (Tulasi and Panidhan) different grades of fresh weight of 1.0g, 0.6g and 0.3g were raised through different seedbed management practices and were exposed to eomplete submergence 10 days after planting (after establishment of seedlings). The infor-

mation on grain yield and other physiological parameters confirmed the results obtained during wet season of 1993.

Evaluation of quality traits of varieties/ cultures

Three promising cultures from semi deep water ecosystem were analysed for quality characters. They were M.S Kernels with 65-69 per cent head rice yield, intermediate alkali value (4.00, 3.00) and around 20 per cent amylose content. As regards quality characters we recommend these cultures for promotion if yield performance is satisfactory. Quality attributes are given below :

Culture	Head Rice %	KLAC	Vol.	Elong. Ratio
CR 581-9	65	9.7	3.7	1.65
CR 580-17-2	69	8.8	3.5	1.66
CR 580-5	65	9.0	3.7	1.71

Biochemical basis of submergence tolerance

Dehydrogenase was extracted and activity studied using tetrazolium chloride at 510 m/u (AOD/10 embryes).

(i) Dipping the seeds in water, reduces dehydrogenase activity in general, but embryos of tolerant cultivars showed more activity than that of susceptible.

(ii) Dipping seed even up to five days, increases dehyderogenase activity in FR 13A where as Mahsuri showed the reverse trend. As dehydrogenase is associated with life processes, activity of this enzyme may be associated with tolerance to stress.

DEEP WATER ECOSYSTEM

DEEP WATER ECOSYSTEM

CROP IMPROVEMENT

- Assessment of genotypes tolerant to deepwater conditions
- Screening for better yield contributing characters
- Crossing programme for developing of YSB and Ufra tolerant cultures.

CROP MANAGEMENT

- Flood tolerance in relation to important characteristics of flood water
- Effect of seed rate and method of establishment on performance of different rice varieties
- Evaluation of deep water rice varieties for grain quality

CROP PROTECTION

- Screening of rice varieties against foliar blast
- Occurance of diseases in farmers' field in deep-water ecosystem
- Population dynamics and role of DD 136 in the IPM of YSB

CROP IMPROVEMENT

Assessment of genotypes tolerant to Deepwater conditions

A set of 300 exotic collections received from IRRI was grown in deep water condition where the highest water level was maintained at 1.6 m. Most of the varieties in the group were from Bangladesh and only 30 accessions belonged to Srilanka and Indonesia. They were grown along with identified checks at Chakia, Jalamagna and Jalanidhi.

In total 70 accessions were found to be tolerant to the above deep water condition which were at par with Jalamagna. All the tolerant genotypes were having capability of nodal tillering, nodal rooting and culm elongation. Variation in plant height was observed within 1.8 to 2.3 m.

The same set was grown in another condition where the maximum water level was maintained upto 2.6 m. Except Jalamagna, the identified check, none of the genotypes could survive.

Screening for better yield contributing characters

In deep water ponds, 400 varieties/lines were grown for screening under deep water situation. Out of this, only two varieties Jalamagna and TCA 4 survived (upto 2-7m water depth) whereas the others died.

Crossing programme for developing of YSB and Ufra tolerant cultures

During dry season, F_2 seeds of the crosses made earlier were grown in the green house along with their parents. Further some more crosses were made which are as follows:

1. Co.32 x Jalanidhi
2. Mut 6 x Co.1013
3. Kwan-Fu-1 x Jalanidhi
4. Daenglaem x Jalanidhi
5. -do- x TCA 88-82
6. -do- x NDGR 421
7. -do- x NDGR 429
8. -do- x Co. 1013
9. Samsen Polo (Ys 386) x Jalanidhi

CROP MANAGEMENT

Flood tolerance in relation to important characteristics of flood water

i) Attempts were made to increase algal flora by adding phosphorus @ 20kg/ha in enclosed polythene chambers inside field tanks, at CRRI.

The plants with added P showed higher per cent of survival than plants without added P. They dry matter increase was also more in P added plants under submergence. These results were more pronounced in the submergence tolerant genotype FR 13A than in IR 42 susptible genotype. The plants of submergence susceptible variety died after 3 weeks of release of submergence treatment while there was about 90 per cent survival in the variety FR 13A.

The above positive effects may be attributable to the highest oxygen concentration around the plants of FR 13A than IR 42 i.e., after 24hr. after submergence. Further studies are needed to confirm the causes related to the effects on submergence tolerance.

ii) As regards P response, the sensitive variety IR 42 showed response upto 6 ppm while the tolerant type FR 13A did not respond beyond 3 ppm.

The data on oxygen concentrations between the levels of P did not show much variation. So further investigations are needed.

iii) Effect of water pH of alkaline side exhibited deleterious effects on survival percentage of the plants while acidic side was more beneficial than neutral pH.

Further studies are envisaged to find out if any flaws were there in experimental procedures, or the artifacts were defective.

iv) For characterisation of flood water, observations made in the farmers' fields during first flooding date (23.7.94) revealed that dissolved oxygen concentration was half of the air saturated water i.e., around 4 ppm and light penetration at 80 cm depth was zero.

Effect of seed rate and method of establishment on performance of different rice varieties

Five rice varieties viz., Jaladhi-1, Janaki, Jalpriya, LPR 425 and LPR 96-10 were direct-sown on 21 May either in continuous lines (drilling or single seeding) or hills (dibbing or bunch seeding 15 cm apart) in rows spaced at 20 cm, using either a normal seed rate (400 seeds/m^2) or 50 per cent more (600 per cent seeds/m^2). Water accumulated

in the field 25 days after germination and depth increased progressively, reaching a maximum of 153 cm at 65 days after germination. Water depth during most of the crop growth period remained between 90 and 110 cm.

The fast elongating and floating type rice varieties, Jaladhi-1 and LPR 425 grew well with rising water level but there was considerable plant mortality in Janaki and LPR 96-10. Moreover, the less tall Jalapriya was submerged completely for more than 15 days at 50 days stage due to its limited elongation ability and thus perished. The variety Jaladhi-1 flowered in the beginning of November and was less affected by stem borer (10-20 per cent white ear heads at maturity), leading to the highest grain yield (2.1 t/ha). The flowering of LPR 425 coincided with cloudy and rainy period in the end of October which probably led to greater stem borer damage (30-40 per cent) and thereby lower grain yield the yields of Janaki and LPR 96-10 ranged between 0.5-1.0 t/ha due to poor crop stand and greater incidence of stem borer. There was no significant difference in grain yield due to different seed rates and methods of sowing.

Evaluation of deep water rice varieties for grain quality

Twenty two cultures/varieties were collected from different sources and grown at Institute farm. They were analysed for quality attributes. Among all the entries only Jalapriya was a long slender cultivar and the rest were short bold. All the entries posses intermediate alkali value and good volume, expansion. Amylose content ranges from 19 to 23 per cent. The detailed analystial observation is given in Table-1. Among the varieties LPR-97, LPR-96, NDGR-413 and Jalapriya excellent grain quality traits.

Table - 1 : Evaluation of deep water rice varieties for quality characters

Variety	Hulling recv. (%)	Mill-ing (%)	Head rice (%)	Length (mm)	Breadth (mm)	L/B	Classi-fication	Abdo-minal white	Alkali value	Water uptake (mm)	Kernel length (mm)	vol. expn.	Elonga-tion ratio	Amy-lose (%)
LPR 56-49	76.9	65.25	37.27	5.45	2.27	2.40	SB	Occ.P	4.8,3.8	335	9.2	4.2	1.68	22.0
LPR 97	78.0	69.60	60.90	5.63	2.66	2.12	SB	P	4.6,3.6	283	9.6	4.0	1.70	20.7
MDCR 421	75.0	67.20	39.0	5.40	2.52	2.14	SB	A	5.0,4.0	288	9.4	4.0	1.74	22.1
LPR - 2	74.0	66.20	46.1	5.37	2.64	2.03	SB	P	4.5,3.5	298	9.4	4.0	1.75	22.1
TCA-269	77.0	68.30	30.6	5.46	2.66	2.05	SB	A	4.3,3.3	195	9.6	4.0	1.75	21.8
LPR-85	75.0	62.0	25.82	5.66	2.44	2.32	SB	A	2.6,1.6	293	10.0	4.0	1.76	22.1
Jalapriya	74.0	60.80	36.23	6.30	2.00	3.15	LS	A	2.6,1.6	180	11.0	3.8	1.74	19.6
TCA-4	79.0	69.20	29.76	4.66	2.57	1.81	SB	A	4.6,3.6	175	8.2	4.0	1.75	19.4
Kariwa-9	75.0	64.1	25.3	5.84	2.66	2.20	SB	Occ.P	5.0,4.0	295	10.2	4.0	1.74	20.4
LPR-96	78.0	68.6	61.6	5.39	2.66	2.03	SB	Occ.P	4.5,3.5	235	9.4	4.0	1.74	22.4
RDA-16-6	76.0	63.3	20.53	5.30	2.69	1.97	SB	P	5.0,4.0	320	9.2	4.0	1.73	23.2
LPR 246	76.0	63.1	33.8	5.56	2.64	2.10	SB	Occ.P	4.3,3.3	248	9.6	4.0	1.72	22.1
LPR 256	76.0	58.6	25.8	5.46	2.40	2.28	SB	A	5.0,4.0	243	9.4	4.0	1.72	20.9
LPR 101	77.0	70.0	40.5	5.71	2.39	2.39	SB	A	4.0,3.0	205	9.8	3.8	1.71	25.0
NDGR 41	77.0	67.1	37.8	5.54	2.84	1.95	SB	P	4.3,3.3	260	9.6	4.0	1.73	21.6
LPR 95-2	77.0	68.2	54.7	5.52	2.60	2.12	SB	A	4.6,3.6	135	9.6	4.0	1.73	20.5
Jalamagna	78.0	62.3	28.0	5.36	2.61	2.05	SB	P	4.3,3.3	175	9.4	4.0	1.75	21.2
Jaladhi	79.0	63.5	10.9	5.69	2.68	2.12	SB	A	4.8,3.8	235	9.6	3.8	1.68	20.2
LPR 4	77.0	62.6	4.3	5.41	2.76	1.96	SB	A	4.5,3.5	185	-	-	-	19.0
LPR 9	75.0	67.4	35.6	5.27	2.50	2.11	SB	A	4.0,3.0	160	9.2	4.2	1.74	19.5
LPR 50	77.0	68.9	46.0	5.22	2.61	2.00	SB	Occ.P	4.6,3.6	175	9.0	4.2	1.72	21.6
NDGR 413	76.0	67.2	60.4	5.45	2.58	2.11	SB	Occ.P	5.0,4.0	205	9.4	4.0	1.72	21.2

SB Short Bold
LS LOng slender

A Absent
P Present
Occ.P Occasionally present

CROP PROTECTION

Screening of rice varieties against foliar blast

A set of 26 deep water rice varieties/ cultures were dibble seeded using 2-3 seeds per hill in CRRI farm during wet season of 1994. A basal dose of 100 kg N/ha was applied.

Three weeks old seedlings were inoculated with freshly harvested blast spores from local isolate (Race 1C 17) which was collected from CRRI campus. The observations were recorded on the type of lesions and percentage of leaf area damaged. The foliar blast was scored as per the Standard Evaluation Scoring (SES) system developed by IRRI (1974). The type and number of lesions were scored. Of the 26 varieties screened against blast, 11 showed low percentage of leaf area damaged. These varieties were resistant upto rapid tillering phase to flower initiation. The varieties Lunishree, Nalini, Nagheri and Panidhan were found highly resistant to blast (Table-2)

Nine varieties and six cultures- Gayatri, Jalbao, Sabitha, Pankaj, Hathipanjari, Utkalkacheri, Dalbao, Madhukar, Jagannath, CN 670-570-18-1, CN 705-18, CR 706-18, CR 626-26-14-1, CN 571-236 and CR 626-26-13-1 showed a significant infection vari-

Table - 2 : Deep water rice varieties/cultures showing low percentage of leaf area damaged due to blast (resistant varieties)

Variety	Days after sowing									
	30	35	40	45	50	55	60	65	70	75
Dalcao	0.5	0.5	0.6	2.2	2.2	2.7	2.9	4.9	4.9	5.2
Jagannath	0.2	0.2	0.5	3.2	4.8	4.9	5.5	5.7	6.0	6.7
Jaladhi-I	0.1	0.2	0.2	0.3	1.4	1.5	1.8	1.9	3.2	3.6
Kekoabao	0.1	0.1	0.2	0.6	0.7	1.8	1.8	2.1	2.2	3.6
Lunishree	0.1	0.1	0.1	0.1	0.2	0.4	0.4	0.6	1.1	1.2
Madhukar	2.4	2.6	2.6	2.6	2.8	2.8	3.5	3.6	3.6	3.7
Nalini	0.2	0.3	0.6	0.6	0.6	0.7	0.8	1.5	1.2	1.2
Nagheri	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
CN 541-231-236	0.2	0.2	0.2	0.3	0.5	0.5	1.9	2.0	2.0	2.2
BAM-6	0.1	0.1	0.2	0.2	0.4	0.5	0.5	1.4	2.4	2.4
Panidhan	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2

ation in leaf area damaged. The varieties Gayatri, Hathipanjari, Pankaj, CR 626-26-14-1, CN 570-570-18-1 and CN 579-369-13 showed less than 1 per cent variation upto 65 days while Gayatri, Jalbao, Jagannath, Utkalkacheri and Jaladhi-II showed less percentage of variation upto 40-60 days. Two cultures CR 626-26-14-1 and CR 569-369-13 and 2 varieties Sabitha and Hathipanjari were classified as susceptible at 75 days after sowing. However, in these varieties the resistance appears to be breaking down at higher inoculum pressures occurred due to compounding disease development. The varieties exhibiting resistance tolerance at 50-65 days after sowing are also suitable for cultivation in deep water ecosystem. In such varieties the blast disease could be controlled by seed treatment with chemicals. This factor is considered an important component for developing a forecast and appropriate IDM package.

Occurrence of diseases in farmers' fields in Deep water ecosystem

The farmers' field were monitored for occurrence of different diseases in Deep water ecosystem. The water level varied from 70-120 cm.

Bacterial leaf blight was found to be the major disease in the observed fields of Ersama, Kujang, Brahmagiri and Bhubaneswar. High degree of BLB infection was recorded in the variety CR 1016 (65.0 per cent) and 30 per cent of sheath blight infection was recorded in the variety CR1006; Savitri and CR.1016 were found to be highly resistant with 'O' grade of infection. Twenty per cent blast infection was recorded in the variety Gayatri. Very little infection was noticed in the variety Panidhan(2 per cent) (Table-3)

Population dynamics and role of DD-136 in the IPM of YSB

From January second week the stem borer started appearing in the fileds and a small brood was observed in the last week of January,94. Thereafter the brood declined and again started in good numbers from 3rd week of February with small peak in March, the moths declined again and another peak of brood emergence occured in April and in May. The biggest brood incidence occurred which caused low incidence in June and July 94. But due to rain and early flood in June and July and water stagnation upto August the stem borer incidence was found low and moths started appearing from the first week of October and a very big peak was seen in November which damaged heavily to the deep water and low land crops. From January 4th week moths started appearing in field and damaged the early dry season crops. From February 2nd week onwards the stem borer incidence increased in field and it came

Table - 3 : Occurence of diseases in farmers fields under DWR ecosystem

Loration and varieties		% Infection			Water depth in the field (cm)
		BLB	Sheath blight	Blast	
Ersama	CR 1016	65.0	15.0	--	70
	Mashuri	30.0	--	--	70
	Panidhan	34.0	15.0	2.0	100
	Local variety	30.0	45.0	--	70
Kujanga	Savitri	75.0	--	--	50
	Mashuri	34.0	25.0	--	50
	CR 1006	60.0	30.0	--	100
	Talasi	45.0	5.0	--	90
Brahmagiri	Janaki	35.0	20.0	--	100
	Gayatri	53.5	20.0	20.0	100
	Local variety	35.0	15.0	20.5	100
Bhubaneswar	CR 1016	65.0	--	--	50
	Local variety	40.0	15.0	--	30

down in the 4th week of March showing a peak in 3rd week of March,94. Meterological data and water regime data have been collected and borer incidence and borer incidence have been correlated.

Deep water areas in Erasama and Pattamundai areas have been surveyed for stem borer incidence in the months of November, December and January. In Erasama heavy incidence of stem bore was found at flowering stage in local varieties like Katakichandi, Lalamandir, T 141, Harishankar, Baunshagaja, Kalapakhia, Kalamula, Machchakanta, Betanashia Bhotia, Kalajani, Muthaguli, Bada kalamula, Rahaspanjara, Kalapakhia etc. 40-55 per cent WEH. Even in Lunishree which was introduced there in 1994 wet season only in 3 patches ranged from 20-35 per cent WEH. In Ambigue village the stem borer incidence ranged From 50-70 per cent. But in this area late planted Debashish and Malabati, CR 1018 and IET 5656 showed below 5 per cent

WEH. In the village Kiada variety Tulasi which was planted in July showed very less bore infestation (below 5 per cent WEH) but crop planted in August 2nd week showed 15-20 per cent WEH.

Pattamundai area was visited in December 1st week 1994. In village Osengera varieties Hadagada, Dalua Rahaspanja, Nali Ukhuda and Haladigundi were being cultivated where 10-20 stem borer incidence in heading stage was observed but in other areas of Pattamundai like village Nimpur, Basua etc. where CR 1014, T 1242 and Badshabhog, Bhobani Ukuda and Bhabuki were cultivated showed very less incidence below 5 per cent.In variety Padmini, the borer incidence was about 15 per cent.

SUPPORTING RESEARCH

SUPPORTING RESEARCH

- Transfer of alien genes resistant to biotic stress
- Cytological studies
- Callusing efficiency and regeneration
- Development of suitable protocol for anther culture
- Wide hybridization
- Evaluation of mutant for yield
- Assessment of breeding material received fro DRR (National) and IRRI (INGER) programme
- Development of mapping populations for molecular mapping of gall midge resistant genes against different biotypes (Rock fellar biotechnology Project)
- Suppression of stem borers by *Bacillus thuringiensis* and characterization of plant Bt. stains

Transfer of alien genes resistant to biotic stress

The wild rice *O. eichingeri* a single plant with 20 per cent pollen fertility could be isolated from a large number of somaclones of *O. sativa*(c.v. Swarnaprabha)/BC_1 hybrid from *O.Sativa* (c.v. Swarnaprabha)/*O. eichingeri sativa*(c.v. Swarnaprabha) through embryo rescue technique.

Cytological studies

The cytological studies of F_1 hybrids of *O.sativa/O. punctata*(2n) recorded pairing of 2-3 chromosomes.

Callusing efficiency and regeneration

Seeds of 12 indicas, 4 japonics and 1 javanica were tested for callusing efficiency in MS medium. The variety Varylava (javanica) showed highest callusing efficiency followed by japanicas and indicas. Though callusing efficiency of indicas was poor, Lunishree, CR 1014 and Annada showed good response to callus development. Other indica varieties did not show any response.

In another experiment mature seeds and immature green seeds of indica varieties, Ratna, CR 1014, IR 64, Padmini and Lunishree were screened for callusing efficiency. Lunishree and Padmini had shown maximum callus induction and regeneration. Callus was initiated within 3-5 days in mature seeds and 7-10 days in green seeds of all the treatments. MS media supplemented with 2.0 mg/l 2-4D and 1.0 mg/l Kinetin was found to be best regeneration of green plantlets was more in case of green immature seed treatment.

Development of suitable protocol for anther culture

An experiment was conducted to develop suitable protocol for anther culture using fresh anther, anthers pretreated at 8°C for 7 days and 14 days in three different media. It was found that pretreating the anthers at 8°C for 14 days in P_2 medium was the ideal method for another culture.

In one of the experiments modified N_6 media containing 2 mg/l 2-4-D and 40g/l sucrose, 250 mg/l colchicine was found to be effective in inducing callusing.

In another experiment, calli were regenerated in MS medium supplemented with BAP 1.0mg/l casien dehydrolysate 500 mg/l and 5 per cent coconut water.

Wide hybridization

In wide hybridization of two cultivated rices PR 106 and pusa Basmati and *O. punctata, O. nivara, O. longistaminata, O.latifolia, O. meridionalis, O. barthii*, and

O, rufipogon, except for O. Runctata/PR 106, F_1 was fertile. Embryo culture technique was employed for getting successful F_1 for this cross.

Evaluation of mutant for yield

The yield performance of shy mutant 336 (Saturn Monoharsali dwarf mutant) was studies along with variety 'Moti' in 4 different spacings and 3 replications. It was observed that 20 x 10 cm spacing was suitable for the mutant and it yielded 0.4 t/ha more than that Moti (3.34 t/ha)

Assessment of breedling material received from DRR (national) and IRRI (INGER) programme

(a) **National Coordinated programme:** Six coordinated yield evaluation trials were conducted during wet season, 1994 to study the performance of elite cultures in different trials at Cuttack. The most promising entries from different trials are given in Table-1.

(b) **International Testing programme (INGER):** Two screening nurseries, one

Table 1. Performance of promising cultures at CRRI

Ecosystem/trial	Culture/ Variety	Total duration (days)	Yield (kg/ha)
Rainfed upland (AVT-VE)	CR 544-1-3-4	72	3197
	Rewa 3-45	86	2904
	Heera		
Rainfed shallow lowlands (AVT/IVT-SHW)	OR 912-10-190	153	5193
	CR 683-195	156	5152
Semi-deep (AVT/IVT-SDW)	CR 626-26-2	154	3360
	CN 580-869	170	2867
	CN 580-17-1	166	2195
Aromatic grain (AVT-BT)	RP 3238-33-15	142	4231
	T. Basmati	129	2298

for rainfed lowland (IRLON) with 50 entries and another for deep water (50-100 cm depth), IDRON with 37 test entries were conducted during wet season, 1994. Varieties viz. CN 707-7-3, IR 60277 in lowlands and DWCT 82, CN 705-18 in semi-deep water were found promising. However, their flowering period was 2nd week of October and hence were earlier for the location.

Development of mapping propulations for molecular mapping of gall midge resistant genes against different biotypes (Rock fellar Biotechnology Project

A set of new crosses were made between TN.1 (highly susceptible variety for all biotypes) and ARC 6605 (resistant to biotypes 1 and 3), Phalguna (resistant to biotypes I and 2 and PTB. 10 and T 1477 (resistant to biotypes 1,2,3 and 4) to develop F_2 mapping populations.

Suppression of stem borer by *Bacillus thuringiensis* and characterization of potent Bt stains.

Forty four different strains of *Bacillus thuringiensis*, 5 different mutants and 10 genetically modified strains of Bt with different markers were collected and maintained. The Bt strains from the samples of the formulations viz., Diepl, Bactospeine, Bicasp, Biolep, Biobit and Delfin have been isolated and maintained. Four Bt Strains were collectd from different indigenous sources and 2 Bt strains were isolated from CRRI soil. Thirteen *E. coli* strains with various markers and 2 Bt phages have also been procured.

In a preliminary study, four standard Bt strains, 4 indigenous collections and 2 indigenous isolates were tested in the laboratory against yellow stem borer. The result were inconclusive.

CROPPING SYSTEM

CROPPING SYSTEM

EVALUATION OF DIFFERENT COMPONENT CROPS AND THEIR MANAGEMENT PRACTICES IN RICE BASED CROPPING SYSTEM 180

- Onfarm evaluation of cropping systems (lateritic soils)
- Rice based cropping systems at Bhairpur village (Alluvial soils)
- Crop diversification in upland rice (monocropped areas)
- Optimization of plant population in rice-pigeonpea
- Mixed row intercropping
- Deferred sowing of groundnut in rice-groundnut system
- Liming in rice-pigeonpea system
- Effect of liming on soil fertility and crop growth in rice and rice based cropping system
- Effect on intensive rice cropping on the changes in soil properties and productivity
- Performance of sesamum varieties in summer season and their response to nitrogen
- Evaluation of sesame varieties for oil content.
- Performance of groundnut varieties during summer season.
- Effect of sulphur on winter groundnut in rice fallows.
- Utilization of residual,irrigation and ground water by summer groundnut under a shallow water table condition
- Water management in groundnut and tomato rice based cropping system
- Wheat-mustard intercropping
- *Mustard varieties evaluation trial*
- Effect of nitrogen application schedules on different mustard varieties
- Performance of maize varieties in dry season
- Performance of different tomato varieties under varying ages of seedlings
- Energy requirements for the cultivation of tomato under different tillage implements and soil earthing treatments
- Comparative performance of sub-surface, drip and furrow irrigations of plastic malched and bare soil for production of marketable tomato
- Efficiency of bamboo staking compared with wire netting and polyethelene mulching for control of rotting of tomatoes
- Weed growth in tomato fields
- Performance of different dryseason crops in rainfed rice-fish system
- Important viral diseases of crops under rice based cropping system
- Estimation of nematode population in rice-wheat crop rotation
- Estimation of nematode population in rice - tomato crop roation
- Performance of botanical extracts against diseases of groundnut
- Characterisation of cutworm sps. in rice-groundnut

EVALUATION OF DIFFERENT COMPONENT CROPS AND THEIR MANAGEMENT PRACTICES IN RICE BASED CROPPING SYSTEM

On farm evaluation of cropping systems

Farmers in eastern India can inerian their incomes through multiple cropping. Cropping systems research under FSR/E at Khuntuni (latertic only) during post-rice season of 1994 was carried out with special emphasis on increasing cropping intensities. Different rice based cropping systems were tested in the FSR/E villages. At Mahurapur, mustard tomato, chillie, brinjal, beans, sweet potatoes, cauliflower were tested after wet season upland rice. A crop of potato was newly introduced in this area. It was found that tomato and potato were the best sequence crops in these uplands with supplementary irrigation through the spring nearby the field. A varietal trial on mustard with 15 cultivars was undertaken in Mahurapur village after the wet season rice. The crop was fertilized with NPK @ 40:40:40 kg/ha. Half N coupled with full dose of P and K were applied basally ;at sowing in furrow. The left over dose of N was top-dressed just before the first irrigation which was given 30 days after sowing. The mustard variety Pusa Bahar gave the maximum yield of 1.58 t/ha in 105 days.Mustard Hybrid 1, RII 30 and Varuna with an yield of more than 1.2 t/ha were significantly superior to the other varieties.

The most remunerative crop was tomato, which fetched the farmers a total income of Rs.44,218/ha. Cauliflower, pumpkin, sweet potato, potato and maize were other remunerative crops and produced a net income of more than Rs.20,000/ha. By growing these crops, the economy of poor farmers could be improved.

Rice based cropping systems at Bhairpur village (alluvial soil)

Field demonstration was undertaken on the farmers fields at Bhairpur (alluvial soil), during dry season 1994 just afater the wet season rice harvesting in the upland ecosystem. Several crops with newly developed varieties were introduced. It was observed that tomato gave the highest monetary return to the farmers (Rs.29,500/ha). The other crops which were next to tomato were sweet potato, cabbage, cauliflower and cucumber. Mustard and toria varieties were also included in this demonstration. Mustard gave a net income of Rs.7,000/ha whereas, it was only Rs.4,075/ha from toria group of varieties. The extra expenditure on sowing of mustard varieties was Rs.1,000/ha. Similarly, by growing mustard varieties, farmers can get an extra income of Rs.2,000/ha over toria varieties. A new mustard variety, RH 30 from Chaudhary Charan Singh Haryana Agricultural University, Hissar and four mustard hybrids (MH 1, MH 2,MH 4) from the IndianAgricultural Research Institute

(IARI),New Delhi introduced in this locality which performed very well under supplementary irrigated condition. The major problem of growing mustard crop was of aphid infestation. To control this pest, monocrotophos was sprayed once on toria varieties and twice on mustard varieties. The aphids were controlled effectively. Another benefit from mustard was bee keeping. A farmer could get an extra income of Rs.5,000/ha from mustard just from selling honey by maintaining bee-hives.

Crop diversification in upland rice (monocropped areas)

Potential to increase cropping intensity through intercropping/sequence/relay cropping in the monocropped areas was studied. Intercropping of pigeonpea with Vandana was more remunerative. Yields of dry season crops were higher in sequence cropping than relay cropping.

Optimization of plant population in rice-pigeonpea

Rice rows spaced 20 cm apart in the interspace of 1.0 m between two rows of pigeonpea produced highest rice equivalent yield and monetary returns. Broadcast of rice seeds at the normal seed rate in interspace (75 cm) between 2 rows of pigeonpea (cv. BR 65) or sowing seeds in 4:1 row ratio at 80 and 120 per cent seed rate with pigeonpea (2 rows spaced 1.0 m) having plant to plant spacing of 20 and 30 cm respectively produced rice equivalent yield and monetary returns comparable to the above mentioned treatment.

Mixed row intercropping

Reducing the risks of yield loss due to drought by growing rice with pigeonpea was attempted. Rice varieties having dissimilar growth habits were used. Rice equivalent yield and monetary returns were high in Sneha (75 days, semi dwarf), Vandana (90 days, tall), pigeonpea combination at 2:2:1 row ratio. Pooled mean of 2 years indicated the superiority of this combination.

Deferred sowing of groundnut in rice groundnut system

Two years' results showed that grain yield of rice increased with delay in sowing of groundnut upto 30 days after rice emergence. Reductio in groundnut yield was non-significant. Hence, higher returns were obtained with this treatment.

Liming in rice-pigeonpea system

Application of lime increased the grain yield of pigeonpea substantially in preliminary trials. Growth and yield of pigeonpea were significantly affected. Plant height, leaf area, branches/plant and number and weight of pods were affected. There was no effect of liming on test weight. Effect of liming on rice was however, variable.

Effect of liming on soil fertility and crop growth in rice and rice based cropping systems

The experiment was conducted using 500, 1000, 1500, 2000 and 2500 kg lime/ha to graph information on the relationship between lime application, nutrient availability of the soil and rice productivity in acid uplands. The crop was affected by white ant and grubs. Their population increased in limed plots. Rice yield was maximum when lime was applied @ 500 kg/ha.

Effect of intensive rice cropping on the changes in soil properties and productivity

A long term experiment was initiated during wet season 1969 with an objective to find out the effect of intensive rice cropping without and with compost and fertilizers combinations, namely, control, nitrogen, nitrogen + phosphorus, nitrogen + potassium and nitrogen + phosphorus, nitrogen + potassium on grain and straw yields, nutrient uptake and its effects on the soil properties and sustainability.

There was a significant response to application of compost and nitrogen both in terms of grain and straw yields. A significant response to application of phosphorus in terms of grain yield when P was applied along with potassium was observed. However, there was response to application of phosphorus even without application of potassium in case of straw yield.

Averaged over compost treatments the grain yield ranged from 4.01 t/ha with control to 4.9 t/ha with treatment receiving NPK and straw yields ranged from 4.76 t/ha with NPK treatment. Simple addition of compost 5 t/ha increased the grain yield by 0.77 t/ha. Averaged over fertilizer treatments application of compost annually gave 0.51 t/ha more grain and 1.2 t/ha more straw which were significantly superior to no compost treatment.

Treatment receiving NK though significantly superior to control was on par with simple nitrogen application. Averaged over compost treatment, NP and NPK were on par showing no effect of potassium. Minimum grain yields of 3.62 t/ha was obtained with control, whereas maximum grain yield of 5.11 t/ha was obtained with treatment receiving NPK blended with compost.

Performance of sesame varieties in summer season and their response to nitrogen

Sesame is an important remunerative oilseed crop grown in rice based cropping system in summer season. A varietal evaluation trial was conducted with six varieties (Kalika, Kanak, OMT 10, Usha, Uma and Vinayak). The crop was sown during the first week of February and irrigated three times. Among the varieties - Kalika was the most promising with a seed yield of 0.85 t/ha followed by Usha (0.8 t/ha). The number of pods per plant was also higher (32 and 31 respec-

tively) in these varieties.

Results on the response of four sesame varieties (Kalika, Kanak, Usha and Vinayak) to four levels of nitrogen (0, 30, 60 and 90 kg/ha) indicated progressive increase in yield with increasing N application from 0 to 90 kg/ha (0.42 to 1.06 t/ha). N response (kg seed/kg N applied) was highest (7.43) at 30 kg N/ha level.

Evaluation of Sesame varieties for oil content

Six sesame available cultivars were analysed for oil content. They were ground with sand in mortar and pestle washed with diethyl ether and oil was extracted with petroleum ether (40-60°C) for 12 hrs in soxhlet apparatus. The oil contents different varieties were OMT - 39.4 per cent, Usha - 39.9 per cent, Kanaka - 40.8 per cent, Kalika - 44.6 per cent, Uma - 45 per cent and Vinayaka - 49.4 per cent.

Performance of groundnut varieties during summer season

To identify a suitable variety of groundnut during summer season under irrigated condition in rice fallows, an experiment was conducted with advanced cultures (INS 9301, 9302, 9303, 9309, 9310, 9311, 9312 and 9313) and a local popular variety AK 12-24. The crop was sown on January 21 and given four irrigations. Among the varieties - INS 9309 was the most promising with a pod yield of 3.65 t/ha which was 44.4 per cent higher than that of AK 12-24 (check). The next high yielder varieties were INS 9313 and 9302 with pod yields of 3.17 and 3.15 t/ha respectively. Shelling per cent was the highest (71.2) in INS 9312, which was closely followed by INS 9303 (70.3). Test weight (g/100 seeds) was highest in INS 9303 and 9312 (51.5). These varieties matured in 117 days.

Effect of sulphur on winter groundnut in rice fallows

The performance of winter groundnut (sown in November (first week) was tested under 5 levels of sulphur (0, 20, 40, 60 and 80 kg/ha). The source of sulphur used was gypsum (18.6 per cent sulphur). There was a good response to sulphur application. The pod yields obtained under 0, 20, 40, 60 and 80 kg sulphur were 0.55, 1.28, 1,54, 1.64 and 1.84 t/ha, respectively.

Utilization of residual, irrigation and groundwater by summer groundnut under a shallow water table condition

Summer groundnut (AK 12-24) was grown after wet season rice on a medium land. In the event of a well distributed rainfall of 57.6 mm received during the month of April, the pod yield was significantly influenced by irrigation treatments.

Observations were made on a few excavated intact root systems. The rooting depth was shallow (<35 cm) and highly variable. The rooting pattern also varied widely. In some plants the secondary roots were uniformly distributed throughout the length of the main root, whereas in others, their distribution were restricted within 2-3 cm from the base of the plant.

Detailed measurements of soil moisture profile showed that (a) soil moisture profile readily responded to the lowering of water table (from 77 to 119 cm) and the increase in both atmospheric evaporativity and crop growth; (b) the effects of irrigation (6 cm) on moisture profile were evident even after 7 days of irrigation, and (c) the average soil moisture content of the profile during the growing season steadily decreased by more than 9 per cent.

A knowledge of hydraulic properties of the profile soil is essential for correctly estimating the percolation and evapotranspiration losses of water and also the ground water condition. Undisturbed soil cores were collected from different depths of the soil profile with the help of a specially fabricated soil core sampler. Water retention characteristics of these core samples will be determined by hanging water column and pressure plate methods.

Saturated to near saturated (at 1 cm tension) hydraulic conductivity of the cores has been determined. Results obtained so far clearly indicate that high values of the saturated hydraulic conductivity are largely due to the contribution of continuous macropores only. A sintered glass disc and a thin bed of fine sand were coupled together to generate a controlled flow of water through soil cores at a constant tension of 1.0 cm of water. The variability of near saturated hydraulic conductivities is much less as compared to the large varietions of saturated hydraulic conductivities. Therefore, the former may serve as a better parameter in computation of unsaturated hydraulic conductivity functions.

Water management in groundnut and tomato rice based cropping system

Experiment on methods of irrigation and irrigation scheduling was conducted for groundnut and tomato after wet season rice. During kharif, irrigation scheduling at different probability of rainfall gave optimum yield of MW 10 variety.

During dry season, in case of groundnut (AK-12-24) irrigation was applied at 4 growth stages namely seedling to flowering, flowering to pegging, pegging to pod formation and pod formation to maturity. Three treatments i.e. 9 irrigations (1+3+3+2), 6 irrigations (1+2+2+1), 4 irrigations (1+1+1+1) were compared with control where no irrigation was applied. But due to heavy rain, irrigation could not be given in last stage. The experiment again indicated that 9 irrigations (1+3+3+2) at different above 4 growth stages gave highest yield (1.56 t/ha). Water use efficiency is also highest (37.1 kg/cm/ha) (Table 1).

In the second experiment after rice (yield: 4.8 t/ha), hybrid tomato (Maitri) was planted during November, 1994 to determine the best irrigation methods and water requirement of the crop. Four irrigation methods were tried namely alternate furrow irrigation, skip furrow irrigation, all furrow irrigation and flooding in comparison to control where no irrigation was applied. The results indicated two distinct things, one is the bigger size of tomato in irrigated plot and the other is reduced irrigation requirement in alternate furrow and skip furrow method, compared to all furrow, method wereas the yield was approximately same (55.3 t/ha) in both the cases. In case of control, the yield was 25 per cent less. Water use efficiency was highest in case of alternate furrow irrigation method (6.14 t/cm/ha) (Table 2).

Table 1 : Effect of irrigation scheduling on yield of groundnut.

Treatment	Yield (t/ha)	Water requirement (mm)	Water use efficiency (kg/cm/ha)
T1 (1+3+3+2)	1.56	420	37.1
T2 (1+2+2+1)	1.03	300	34.3
T3 (1+1+1+1)	0.59	180	32.8
T4 (Control)	0.53	0	-

Table 2 : Effect of irrigation method on irrigation requirement and yield of tomato.

Method of Irrigation	Irrigation requirement (mm)	Yield (t/ha)	Water use efficiency (ton/cm/ha)
All furrow	180	55.6	3.09
Alternate furrow	90	55.3	6.14
Skip furrow	90	47.2	5.24
Flooding	240	44.3	1.84
Control	0	42.1	--

Wheat-Mustard intercropping

Studies were conducted at CRRI using wheat and mustard as intercrops. Two varieties each of wheat (H 2285 and Kundan) and mustard (Gio 202-9 and Divya) were tested for their compatibility ;as inter crops. The sole crops of wheat and mustard produced yields of 4.0 and 1.3 t/ha respectively. A decline in yield of both the crops as compared to sole cropping was noticed when two rows of wheat were intercropped with one row of mustard. However, wheat variety HD 2285 when intercropped with mustard variety Vidya, highest land equivalent ratio (LE 1.86) was noticed indicating their better compatibility.

Mustard varieties evaluation trial

Fifteen varieties of mustard and toria were sown in the farmers fields after wet season rice during 1994. The variety Pusa Bold yielded significantly higher than other varieties. Pusa Bold gave 72 per cent higher yield than PT 303 (1.2 t/ha) and 34 per cent higher yield than Pusa Bahar. Newly introduced varieties RH 30 and Hybrid Mustard showed impact on farmers. B 9, a yellow sarson variety was also good in terms of seed yield and had a great market demand.

Effect of nitrogen application schedules on different mustard varieties

To evolve the best nitrogen application schedule for obtaining higher yield in mustard in rice fallows, a trial was conducted in winter season. The test varieties were Divya and Bio 202-9 and N applications schedules were N1 - entire N (60 kg/ha) applied at seeding, N2 - half N (30 kg/ha) at first irrigation, N3 - 30 kg N/ha applied each at first and second irrigations, respectively and

N5 - control (no nitrogen). Significantly highest seed yield (1.15 t/ha) was obtained in the treatment N2 as against 0.7 t/ha in control. Next best was N1 (1.07 t/ha). The two varieties produced similar yields (around 0.98 t/ha). Interaction data revealed that the highest yield (1.25 t/ha) was produced in the variety Bio 202-9 under N2 treatment while in the variety Divya under N5 (0.83 t/ha).

Performance of maize varieties in dry season

Eight maize varieties (hybrids and composites) were evaluated under sub-optimal management (unfertilized and unirrigated) and optimal management (fertilized with 60-30-30 NPK kg/ha and irrigated) conditions during dry season. The crop was sown during the first week of February. Highest yield (2.6 t/ha) was obtained in Vijaya Composite. Ganga 2 and Deccan 105 were the next best (2.5 t/ha). A mean yield increase of 33.8 per cent was noticed due to better management.

Performance of different tomato varieties under varying ages of seedlings

An investigation was conducted to find out the appropriate age of seedlings for planting to realize higher yield of tomato crop in rice fallows in upland in winter season under irrigated condition. The ages of seedlings tried were 15, 30 and 45 days and the test varieties were BT-2, BT-10, BT-12 and BT-18. Crop was planted during the last week of November with a fertilizer level of 60-40-40 NPK kg/ha. Highest yield was obtained when the crop was planted with 15 days old seedlings. Among the varieties, BT-18 gave the highest yield of 60.8 t/ha and 44.4 t/ha under 15 and 30 days old seedlings were used, while BT-10 performed better with 45 days old seedlings.

Energy requirements for the cultivation of tomato under different tillage implements and soil earthing treatments

Study on energy requirements for the cultivation of tomato under different tillage implements and earthing treatments using tractor and power tiller as a source of power was carried out. Different tillage treatments were T_1 - one M.B. ploughing + harrowing twice by tractor, T_2 - Two passes of cultivator + harrowing twice by tractor, T_3 - Two passes of cultivator harrowing by tractor, T_4 - One pass of power tiller operated rototiller and different earthing treatments used were E_1 - Ridge and furrow system, E_2 - Earthing up around plant and E_3 -No earthing up. Following are the salient findings of the experiment.

1) Significant difference was found in the energy required for tillage among different tillage treatments for the cultivation of tomato. Least energy required for field preparation was found to be by powertiller operated rototiller. Energy required for

field preparation under different tillage treatments T_1, T_2, T_3 and T_4 was found to be 2664.8, 1970.2, 2045.8 and 1455.3 MJ/ha respectively. Average depth of field preparation was found to be 25.1 cm, 15.4 cm, 8.1 cm and 12 cm respectively.

2) Soil earthing around plant required significantly less energy than soil earthing in the ridge and furrow system (440 MJ/ha).

3) No significant difference in yield of tomato was found due to different treatments and earthing treatments. The yield of tomato in different tillage implement treatments T_1, T_2, T_3 and T_4 was found to be 39.71, 35.09, 35.83 and 37.38 t/ha respectively. Deep ploughing by M.B. plough gave higher yield of tomato but difference was non-significant. The yield obtained in different earthing treatments E_1, E_2 and E_3 was found to be 36.97, 36.27 and 37.78 t/ha respectively.

4) Total energy required for tomato cultivation was found to be 22985 MJ/ha. Among different component of energy contributed through fertilizer (34.20 per cent) was found to be highest followed by electricity (32.82 per cent), human (22.36 per cent), diesel (8.56 per cent), machinery (1.28 per cent) and others. Total energy required under tillage treatments T_1, T_2, T_3 and T_4 was found to be 28846, 227663, 22897 and 22437 MJ/ha respectively and under earthing treatments E_1, E_2 and E_3 it was 23005, 23044 and 22908 MJ/ha respectively.

5) Total operational energy required for tomato cultivation was found to be 14648 MJ/ha. Out of which irrigation required highest operational energy (55.2 per cent), followed by harvesting (20.99 per cent), field preparation (13.56 per cent), planting (5.72 per ;cent), soil loosening and earthing (2.14 per cent), nursery preparation (1.62 per cent) and fertilizer application (0.71 per cent). Total operational energy required under different tillage treatments T_1, T_2, T_3 and T_4 was found to be 15478, 14446, 14576 and 14097 MJ/ha respectively.

6) No significant difference was observed in the total output-input energy ratio for tillage and earthing treatments for tomato cultivation. Total output-input energy ratio for tillage treatments T_1, T_2, T_3 and T_4 was found to be 1.70, 1.63, 1.69 and 1.81 respectively and or sub-treatments E_1, E_2 and E_3, it was 1.73, 1.66 and 1.73 respectively.

Comparative performance of sub-surface, drip and furrow irrigations of plastic mulched and bare soil for production of marketable tomato

Field studies were conducted for 3 winter seasons to compare performance of traditional furrow irrigation and sub-surface drip irrigation systems on unmulched (bare) and plastic mulched soil for fresh tomato production in the same plot where rice was grown during wet season. Thin wall dripper line single chamber polyethylene tubes with injection molded emitters, welded into inner wall of the tube having individual discharge rate of 1.75 l/h were used for this purpose. Emitter spacing was maintained at 75 cm x 37.5 cm (row to row x plant to plant). Emitters were buried at an average depth of 15 cm. Basal dose of N and K @ 20 kg/ha each through dripper and phosphate @ 20 kg/ha through hand incorporation (using spades), was applied. This process was repeated after 25 and 50 days of transplanting. Experiments were conducted in 5 sqm plots for each treatment with three replica each. Polythelene sheets of 40 micron meter were utilized for these experiments. Twenty two to twenty five days old seedlings of tomato (Marglobe) were transplanted during each season. Water at about 120 mm depth without any runoff in furrows and 30 mm depth at 1.75 t/ha discharge rate in drip irrigation was applied during a time interval of 60 days. This was in addition to approximately 25 ml of water that was applied per plant at the time of transplanting for plant establishment.

From studies on traditional method of cultivation of tomato in a farmer's field in Kuakhia area of Jajpur district, it was observed that almost 30-35 per cent of total harvest was not marketable due to fruit rotting caused by fungus growth. The problem gets magnified in case of late rains and fruits touching the soil. In such cases damage was as high as 50 per cent. Keeping the above background in view, field studies were conducted at Central Rice Research Institute, Cuttack for 3 winter seasons to compare the performance of bamboo staking, wire netting and polyethelene mulching with that of bare plots (control). All these plots were irrigated with thin walled drippers burried at a depth of 15 cm with drippers placed at 75 cm x 37.5 cm (row to row x plant to plant) distance. Cultural practices including transplanting, irrigation frequency and fertilization etc. remained the same as in case of previous trials.

In case of bamboo staking one split bamboo pole was fixed separately for each plant. Twigs were tied loosely with jute rope with the bamboo pole before flowering. Care was taken to avoid crowding as far as possible. Care was also taken to avoid ground touching of fruits by relying the twigs wherever required at fruiting stage. Once again, similarly before flowering G.I. wire was placed in position between rows both lengthwise and

crosswise by tying the wire at the boarder of plots with sufficient tension to withstand load of tomato plants and fruits at a height of 25 cm above the ground level. The twigs rested over the wire mesh (75 cm x 37.5 cm) without much disturbances to the natural twig arrangements. Wherever required, the twigs were trained to rest of the wires to avoid contact with the soil, while polyethelene sheets were spread on the soil surface after plants got established.

Drip irrigation increased marketable tomato yield at an average of 26 per cent over furrow irrigation. There was tremendous amount of water saving due to drip irrigation. The above crop was raised with only 25 per cent of water needed for furrow irrigation (Table 3).

Similarly, there was an average increase of 51 per cent marketable tomato in case of drip-plastic mulching over furrow-bare irrigation. The sizable increase in yield of marketable tomato in case of drip method was attributed to higher percentage of uniform fruits coupled with lower percentage of of rotten fruits. The figure got further improved by resorting to mulching where there was no direct contact of fruits with bare soil resulting in higher percentage of healthy fruits.

Efficiency of bamboo staking compared with wire netting and polyethelene mulching for control of rotting of tomatoes

It was evident that bamboo staking was the most efficient for prevention of rotting where average rotting was limited to 5 per cent of total production. But it reduced the total yield to the tune of 30 per cent to that of drip-bare, 4.6 per cent to that of wire netting and 9.5 per cent to that of plastic mulching. Polyethelene mulching was found to be the

Table 3 : Yield of marketable tomato under different irrigation treatments.

Treatment	Yield (t/ha)			Yield	
	1992-93	1993-94	1994-95	Mean	index
Furrow (bare)	42	39	53.8	44.9	100
Drip (bare)	52.5	49.2	68	56.56	126
Drip (plastic mulch)	61.4	60.4	81.6	67.8	151

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second best where the average rotting was limited to 9 per cent and the reduction of total yield was found to be 267 per cent to that of drip-bare and 5 per cent to that of polyethelene mulching. Considering the economics it was concluded that bamboo staking was costliest and wire netting was found to be most economical because bamboo strips got decayed after one season of use whereas G.I. wire was found to be in good condition for reuse after 3 seasons. Polyethelene sheets lasted for 3 seasons (Table 4).

Weed growth in tomato fields

From the study of weed growth under different treatments, listed in Table 5, it was found that almost 50 per cent reduction of weed growth was obtained in case of drip irrigation due to less water supply. Polyethelen mulching further depressed the weed growth drastically. But bacterial spots were found to be more in case of mulched plots. In case of bamboo staked plots this disease was found to be of minimum occurrence.

Table 4: Rotting percentage of tomato under different staking and mulching treatments.

Treatment	1992-93				1993-94				1994-95			
	M	R	T	P	M	R	T	P	M	R	T	P
Control (Furrow bare)	42	11	53	20.8	39	13	52	25	53.8	15.6	69.4	22.5
Drip(bare)	52.5	9.2	61.7	14.9	49.2	10	59.2	16.9	68	11.1	79.1	14
Bamboo staked (Drip)	50	2.1	52.1	4	46	2.4	48.4	5	52	3.3	55.3	6
Polyethelene	35	5.4	60.4	8.9	48	6.5	54.5	11.92	55	6.1	61.1	10
Polyethelene (Drip)	55	5.4	60.4	8.9	48	6.5	54.5	11.92	55	6.1	61.1	10

M = Yield of marketable tomato, t/ha.

R = Rotten tomato, t/ha

P = Percentage of rotten to total yield.

T = Total yield, t.ha.

Table 5 : Dry weight of weeds under different irrigation treatments

Treatment	Range of dry weight of weed (g/m)
Furrow, non-staked, non-mulched	130-142
Drip, polyethele mulched	15-20
Drip, bamboo staked	42-45
Drip, wire netted	30-35
Drip, non-staked, non-mulched	60-70

Performance of different dry season crops in rainfed rice-fish system

Performance of three crops like watermelon (cv. Sugar Baby), greengram (local cultivar) and sesame (cv. Vinayak and Kanak) was evaluated as sequence crops after rice under rainfed rice-fish system. Effect of date of sowing was also studied in the case of watermelon grown with two irrigations from the refuge. Both greengram and sesame were grown on residual moisture under broadcast method of sowing. Early sowing (January last week) of watermelon produced more fruits (9.0 t/ha) while delay in sowing by one, two and three weeks reduced the fruit yield in the order of 8 per cent, 23 per cent and 38 per cent, respectively. Among the two sesame varieties, Karuna was superior to Vinayak with 32 per cent higher number of pods contributing to 25 per cent increase in seed yield (0.63 t/ha). The yield of greengram was 0.66 t/ha.

Important viral diseases of crops under rice based cropping system

It was observed that there was no incidence of viral disease in rice wherever it was grown as a direct seeded upland crop following rice based cropping systems.

1. Rice-rajmah-maize for green cobs
2. Rice-groundnut-moong
3. Rice-rajmah-bhindi
4. Rice-potato-sesame
5. Rice-cucumber-maize
6. Rice-mustard-mung
7. Rice-Cucumber-Subber leafy vegetables
8. Rice-chillies/brinjal.

Rice was vulnerable to tungro in the following rice based cropping systems where rice was grown under lowland transplanted conditions :

1. Rice-maize-cowpea
2. Rice-tomato-mung/cowpea (fodder)
3. Rice-groundnut-bhindi
4. Rice-green gram
5. Rice-rajmah
6. Rice-blackgram

Estimation of nematode population in rice-wheat crop rotation

Soil samples collected at harvesting stage of the wheat crop were examined for the parasitic nematodes of rice crop. Examination of the samples showed that the root-knot nematode *(Meloidogyne graminicola)* and the root nematode *(Hirschmanniella mucronata)* population declined as a result of wheat crop (non-host).

Estimation of nematode population in rice tomato crop rotation

Plant and soil samples were collected at harvesting of the tomato crop from the field. Observations of the root and soil samples for the root-knot nametode and soil samples for the root nematodes revealed that there was decrease in root nematodes (*Hirschmanniella mucronata*) in spil and an increase in root-knot nematode *(Meloidogyne incongnita)* in soil and roots. The population of root nematodes in soil declined as a result of tomato crop (non-host).

Performance of botanical extracts against diseases of groundnut

When seeds of groundnut cultivar (AK-12-24) were soaked in ethanolic extract of *O. sanctum* and plants were sprayed with 0.1 per cent concentration of ethanolic extract at later stage, it could control yellow-rot and collar rot infestation remarkably.

Characterisation of cutworm sps in rice-groundnut

Spodoptera litura population was observed by setting sex pheromone traps in the groundnut crop of CRRI farm. The population of the cutworm started appearing from the first week of April and reached its peak in the second week of May and contributed appearing till the first week of June. Though female sex pheromone was used to collect male moths in the traps, a negligible population of females were also observed in the collected population in the trap.

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ONFIRM RESEARCH

Varietal evaluation in researchers managed trials under different locations in rainfed upland (bunded) situations (FSRE)

The researchers managed trials were continued during wet season, 1994 under unbunded upland situation in three locations at CRRI, Cuttack, Totapada and Ragadipada villages in Khuntuni of Cuttack. Twenty four varieties were replicated thrice in each location using randomized block design. The varieties CR 143-2-2, Sankar, Subhadra and Kalinga III produced more than 3.2 t/ha of grain. Varieties Birsadhan 101, Dhala Heera, CR 693-42, RR 151-4 and Vanaprabha yielded around 3.0 t/ha of grain yield. At CRRI, Cuttack, the soil was sandy loam and few days water stagnation was noticed and at Totapada the soil was sandy loam but at Ragadipada the soil was sandy with no surface stagnation of rain water. The grain yield was in ascending order (2.2, 3.3 and 4.1 t/ha, respectively). The most promising rice varieties cultures in typical uplands were CR 143-2-2, Rudra, Sankar, Subhadra and Keshari. However, CR 143-2-2 and Keshari yielded about 4 t/ha. The differences in the grain yields due to the varieties were significantly greater than local rice varieties such as L-41 and N-22.

In another researcher's managed varietal evaluation trial for termite tolerance, 26 upland rice varieties were tested with three replications on the farmers' fields at Khuntuni. The grain yield showed a remarkable variation in the yields indicating the superiority of variety RR 16-20 among the varieties tested which matured within 98 days. The other varieties, Sneha, RR 203-16, Vandana and RR 151-4 also yielded around 3 t/ha of rough rice. The short duration rice varieties were Kalyani 2 (84 days), Red Heera (85 days). Among these varieties, Sneha produced the highest grain yield of 3 t/ha.

Farmers' managed varietal evaluation trials (FSRE)

Upland ecosystems : A number of varietal evaluation trials were carried out in the Khuntuni site by several farmers using 10 rice varieties during wet season, 1994. The grain yield indicated that variety Vandana (88) days) produced the highest yield (3.3 t/ha) and out yielded the local variety Kalakeri (1.89 t/ha) by 47 per cent. Varieties RR 165-1160, RR 203-2, Sneha and Vanaprabha yielded more than 3 t/ha. However, variety Heera which matured earliest (76 days) yielded 2.3 t/ha, whereas, Dhala Heera (78 days) produced 28 per cent greater yield than Heera.

Multilocation testing

The culture RR 203-16 (IET 13630) derived from the cross White gora/Kalinga III was reported to be drought tolerant, moderately resistant to blast and resistant to RTV and WBPH in multilocation trials with an

overall yield advantage of 14.5 per cent (mean yield 1956 kg/ha) over Heera. However, the culture RR 217-1 (IET 12697) was tested at 24 locations in zone II in AVT-IME. The yield advantage was 7.4 - 53.0 per cent over Ratna and 36-89.3 per cent over Vikas in four locations.

Frontline demonstrations with Vandana and Birsadhan 101 conducted in village Meru in 40 ha area gave promising results.

Varietal evaluation under bunded uplands (FSRE)

Ten varieties were included in this on-farm demonstration carried out in 15 farmers fields in the villages of Khuntuni, Totapada, Mathurapur and Bhogra during wet season, 1994. It was noted that variety CR 749-20-2 (118 days) yielded 4.56 t/ha which was 14 per cent higher than the predominantly grown variety Annada. Varieties Sarasa, Lalat, Gaurav, Annapurna produced more than 4 t/ha of grain. Varieties IR 36 and IR 64 produced 3.6 t/ha and matured in 112 days and 120 days, respectively. New cultures, CR 636-66-91 and CR 679-1 were also tried in this demonstration. These produced a grain yield of 3.8 t/ha.

Varietal evaluation for rainfed medium lands

As the number of fields were rainfed even medium lands in each of the villages adopted for the FSR/E project, 12 recommended rice varieties were taken under this ecosystem to encourage farmers to enhance the rice yields. The total duration ranged from 140 days to 156 days from seed to seed of these selected varieties. The grain yield data revealed a significant increase in yield from varieties Moti (4.7 t/ha), CR 1006 (4.8 t/ha), Dharitri (4.8 t/ha), Seema (4.7 t/ha) and Swarna (4.6 t/ha) than the local varieties such as Saruchina (3.1 t/ha), Nagphool (3.6 t/ha) and Gangasagar (3.3 t/ha). This increase in grain yield was though high.

Varietal evaluation under rainfed lowland ecosystems

Khuntuni and other associated villages nearby did have some parts of the lands under rainfed lowland ecosystem. This lowland was only the shallow submergence (0-30 cm) depth of standing water when there was rain. However, during 1994-95, there was heavy rain during late August which kept this land even under 50 cm depth of water for 12-15 days. The crop was at its maximum growth stage and damage due to waterlogging was not much. Eighteen rice varieties recommended for this situation were undertaken to convince the FSR/E site farmers for the latest varieties performance in their fields.

The yield data revealed that varieties via., Gayatri, CR 260-77, Tulasi and Kalashree

yielded more than 5.5 t/ha of rough rice. Varieties viz., Lunishree, CR 626-7-3, CR 626-26-2-3, Utkalprabha, Jagannath, Savitri and Panidhan yielded around 5 t/ha. A local rice variety Gangaseoli (170 days duration) produced the lowest yield of 3.78 t/ha.

Effect of seeding time for rainfed uplands

Sowing the rainfed uplands is generally decided by the onset of the monsoon. More specifically where the pre-monsoon rains are adequate for land preparation, direct seeding of upland rice in early June as soon as cumulative rainfall reaches 55-60 mmm is desirable to ensure uniform and adequate plant population. An experiment was therefore, conducted on farmers fields to judge the best date of sowing which included four dates with 10 days intervals. Results obtained indicated the highest grain yield when the crop was sown on 23 June. Sowing as early as 3 June reduced the grain yield by 66 per cent and as late as 3 July by 48 per cent as compared to 23 June sowing. It was thus found that direct seeding in upland ecosystem should be done on 23 June. Early sowing experienced severe bird damage while delayed sowing faced drought at flowering stage.

Method of stand establishment

Seeds are broadcast on dry or moist soil and a ladder is dragged to cover the seeds with soil. Sowing seeds behind the plough is also practiced by some farmers. Drilling in rows 20 cm apart facilitate interculture. In most of the farmers, fields at the FSR/E site farmers sow seeds by broadcasting only with local varieties which produced low grain yields. The field trials were laid out on farmers fields with four methods of stand establishment using test variety, Vandana. Results on yield revealed that when seeds were dibbled (Punji) behind the plough, the crop yielded 77 per cent greater grain yield that broadcast (1.86 t/ha) dibble seeding behind plough was better than broadcast seeding in many ways. In this method, seeds were placed at a soil depth of 4-5 cm that saved the rainfed crop to a great extent due to deeper roots from frequent in-season drought, while in broadcasted crop seedling emerged from the seeds randomly placed on the soil surface which got severely affected by drought. Secondly, in row seeded crop weeding/interculturing operations were easier and economical since in row seeded crops implements such as finger weeder could be used. Thirdly, in dibble seeded crop the mother tillers (ear bearing main panicles) remained very high that contributed to higher yield. On the other hand, broadcast seeded crop had more number of secondary and tertiary tillers contributing to higher straw production. Dibble seeded, either behind plough or by hand tiller gave higher yield than continuous seeding. This was due to higher number of panicles/m^2 in dibble seeded practice. Another advantage was that in case of crust formation in soil surface after seeding,

the cumulative force exerted by a group of seedlings in the form of bunch, pushed the crust and made way to emerge young seedlings. On the other hand, in case of continuous seeding of individual seeds failed to exert a cumulative force, many seedlings were unable to come up due to hard crust which is generally a common feature in lateritic soil.

Hence, considering the total output and safe emergence of seedlings, dibbling behind country plough could be recommended for resource poor farmers who have a pair of bullock and country plough readily available with them.

Effect of fertilizers on upland rice fields

In the traditionally broadcasting seeding method, practically no fertilizer is applied because farmers fear that the nutrients will be used by the weeds instead of being available to the rice crop. With the introduction of row sowing and the use of mechanical and chemical weed control methods, applying N, improved the upland rice yields. Field trials were conducted during wet season, 1994 in the villages adopted under FSR/E project. Five levels of nitrogen coupled with and without P and K @ 30 kg/ha each were tried on rice variety Vandana. The total P_2O_5 and K_2O coupled with half dose of N (as per the treatments) was applied basally in furrows and remaining half dose of N was broadcasted at maximum tillering stage. Grain yield data revealed that even applying the total amount of N @ 15 kg/ha increased the yield by 18 per cent over unfertilized N crop. Increasing dose of N to the levels of 15, 30, 45 and 60 kg/ha, increased the grain yields by 18, 45, 71 and 75 per cent, respectively, as against to no nitrogen crop but fertilized uniformly ;with P and K. It was observed that application of P and K without N enhanced the crop yield by 43 per cent as against the crop without NPK and when mixed with N @ 15 kg/ha increased the same yield again by 18 per cent. Although the grain yield increased with increased N level up to 60 kg/ha, but significant increase in grain yield was found only when the crop was fertilized with 45 kg N/ha. The response of kg grain/kg applied N was found to be maximum (31.66) at 30 kg N only and thereafter the N response was in descending order. This increase in grain yield with NPK application was due to the synergistic effect. It was confirmed that application of NPK @ 30 kg/ha each could sustain the upland rice yield of variety Vandana with most remunerative returns. The farmers were convinced by this technology and they were satisfied that their old contention of not applying any fertilizer in rainfed uplands was untrue. This study revealed that a balance dose of all these three nutrients were beneficial under rainfed upland situations.

Response of early rice varieties to different phosphorus doses

Rice, like any other cereal, requires a considerable amount of phosphorus (P) for vigorous growth and high grain yield. Upland soils respond to phosphorus in general and lateritic soils in particular. Khuntuni soils were lateritic and acidic which needed application of P fertilizers. On the basis of previous experience of working under some soils of different sites, trials were conducted on the response of phosphorus in the soils of Khuntuni area. Five levels (0, 15, 30, 45 and 60 kg P_2O_5/ha) of phosphorus were investigated. A common dose of N @ 45 kg/ha K @ 30 kg K/ha was given in all the treatments. Two controls (absolute as well as P control) were taken up for comparison. A test variety Vandana was sown for this response study with farmers participation.

It was noticed from the grain yield data that grain yield increased significantly upto 30 kg P_2O_5/ha, and beyond this the increase was at significant. Nevertheless at a higher dose of 60 kg P_2O_5/ha a decline in grain yield was observed. The response in terms of kg grain/kg applied P was computed. The maximum response was noticed with P @ 15 kg/ha (30.7 kg grain/kg P) and when the crop was fertilized with higher rates of P this response declined drastically.

On the basis of these results, a dose of 30 kg P_2O_5/ha can be recommended to realise good yields from lateritic soils for resource poor farmers.

EXTENSION ACTIVITIES

Extension, Communication and Training Division has the modest programme of dissemination of modern rice production technology which includes advisory services, publication of extension bulletins, personal communication to extension personnel of farmers, students, village agricultural workers and village extension officers of State Government through training and visit programme (T&V).

Few useful publications of this Institute were brought during this year (1994-95). Those are :

(1) Miracle Rice Varieties of India (revised edition)
(2) Rice-fish in Rainfed Lowlands
(3) Four issues of CRRI Newsletter

Training and visit programme

A total of 951 visitors including 341 farmers, 179 Village Agricultural Workers (VAWs), 49 State Government Officers and 382 Students visited CRRI during this period (Table 1).

Table - 1 : Visit of Farmers, Extension Workers and Students to CRRI (April 1994 - March 1995)

State	No. of Farmers	VAWS	AEOS/Other Officers	Students	Total
Andhra Pradesh	11	--	--	--	11
Bihar	93	--	--	--	93
Kerala	--	--	--	117	117
Manipur	50	--	--	--	50
Madhyapradesh	11	--	--	--	11
Orissa	176	179	49	188	592
West Bengal	--	--	--	77	77
TOTAL	341	179	49	382	951

Most of the farmers (176), VAWs (179) and Students (188) were from Orissa state and farmers from other states viz., Andhra Pradesh, Bihar, Manipur and Madhya Pradesh visited CRRI during this period. At the outset of the programme, the visitors were briefed about the mandate and ongoing research activities of the Institute through audiovisual system and then they were taken around experimental fields, nethouses and display hall appraising them about new rice production technology developed by the Institute. At the end of the programme they took part in a group discussion with few scientists about the rice cultivation problems of their areas.

Participation of CRRI in Exhibition

The Institute actively participated in the Science Exhibition organised by Nayabazar High School, Cuttack on the occasion of Golden Jubilee Celebration of the School from May 8-10, 1994. The Institute opened a stall in the exhibition and displayed the seeds of new HYVs of rice and new agricultural implements developed at CRRI. This exhibition was inaugurated by Hon'ble Speaker of Orissa Assembly. Progressive farmers, students and persons interested in agriculture visited this stall and they were appraised of new technologies developed at this Institute for rice cultivation.

Participation of CRLRRS, Kharagpur in Krishi Mela and Farmers' training programme

The Scientists of CRLRRS, Kharagpur, a sub-station of CRRI participated in the Krishi Mela organised by the Agricultural Engi-

neering Division of IIT, Kharagpur from January 17-19, 1995. The seed samples of high yielding varieties suitable for this area were displayed and visitors were appraised of the technologies for growing them. More than 500 farmers visited the exhibition staff.

Farmers' training programme

A training programme was organised by the State Department of Agriculture (W.B>) in the village Shiromony of Midnapur District on 28.7.1994. About 200 farmers participated. Three staff members of our centre i.e. Shri N.C. Pande, Sri S.K. Singh, Dr. A. Dandapat participated in the training programme and appraised to the farmers about the latest varieties and management technology. A visit to the farmers compact plots (Front line demonstration) was also made by the staff members of this station alongwith State Govt. officials and farmers.

Seed multiplication of popular varieties cultures

The area of the Institute's farm not covered by experiments was grown with different popular rice varieties and elite cultures developed by the Institute for multiplication and distribution of seeds.

In the wet season of 1994, 28 varieties and 14 promising cultures were grown in an area of 28 ha. Direct seeding was done in 13 ha and in remaining 15 ha transplanting was carried out. The crop which was direct seeded in lowland areas before onset of monsoon produced higher grain yield than transplanted crop. This was due to better establishment of the direct sown crop and less mortality of seedlings.

The seeds of different rice varieties and elite cultures produced during 1994 are mentioned in the Table 2.

A total of 9.97 tones of seed materials were produced in the farm by different divisions/sections including farm section. These were supplied to various Govt. and Private agencies including progressive farmers particularly of Bihar, West Bengal, Orissa, Andhra Pradesh and Tamil Nadu.

Krishi Vigyan Kendras of CRRI

Two Krishi Vigyan Kendras of Central Rice Research Institute, one at Annapurnapur Khamar (Dhenkanal district) and the other at Kalipad (Angul district) were commissioned by Dr. Balram Jakhar, Hon'ble Minister of Agriculture, Govt. of India on March 25, 1995. Shri J.B. Patnaik, Hon'ble Chief Minister of Orissa presided over the function and Col. K.P. Singh Deo, Hon'ble Minister of Information and Broadcasting, Govt. of India was the Chief Guest. The KVK at Annapurnapur; Khamar of Dhenkanal district has an area of 20.9 acres and the other KVK at Kalipada of Angul district has an area of 50 acres presently.

Table - 2 : Quality of seeds of different HYVS/elite cultures produced during 1994-95

Variety/Cultures	Seed production (kg)
EARLY DURATION	
Heera	0175
Bandana	1062
Annada	1641
Kalinga III	0405
CR 749-20-2	0980
MEDIUM DURATION	
Sarasa	9165
Udaya	2140
Ratana	0705
IR 36	0185
IR 64	0115
LONG DURATION	
Padmini	1580
Samalai	1205
Mahshuri	1030
jagannath	0780
Utkalprabha	2152
Lunishree	0250
Kalashree	0317
Tulsi	1177
Sabitri	3005
CR-1014	1345
Seema	1715
Gayatri	4500
Dharitri	3000
Moti	3840
Panidhan	1228
Katarni	1875
Sitabhog	0135
CR 1002	1590
CR 1015	0435
CR 1012	0678
CR 1006	0430
IET 725	0036
BK 7-275	0035
CR 580-5	0620
CR 580-17-1	0565
CR 683-123	0470
CR 629-256	0055
CR 260-77	3000
CR 581-9	0100

TRAINING, CONFERENCES, SYMPOSIA AND WORKSHOPS

List of trainings, conferences and workshops attended by the Scientists from April 1994 to March 1995.

1.	"National workshop on population Genetics and Rice disease Management	June 28-30, 1994	CRRI, Cuttack	Dr. J. N. Reddy.
2.	Study tour to China under UNDP assisted project " Development and use of Hybrid rice Technology"	Sept. 16-28, 1994	China	Mr. P.J. Jachuck
3.	Research on optimising N fertilizer application to irrigated rice by systems analysis and simulation methods	Sept. 15 to December 14 1994	Research Institute for Agro biology and Soil Fertility, Wageningen, The Netherlands.	Dr. K. S. Rao
4.	Training course on "Molecular Genetics of disease resistance and Marker aided selection under ARBN"	Nov. 9-23, 1994	IRRI, Phillippines	Dr. R.N. De
5.	Training Course "ARBN Phase-1 follow up training	Nov. 9-23, 1994	IRRI, Phillippines	Dr. J.N. Reddy
6.	International workshop on "Flood prone Rice Research"	Nov. 28 to Dec. 2, 1994	Thailand	Dr. J. K. Roy
7.	82nd Session of the Indian Science Congress	January 3-8, 1995	Jadavpur University, Calcutta.	Dr. A.R. Sharma
8.	National workshop on "Crop Production Management of Rice/Jute	January 4-5, 1995	CRRI, Cuttack	DR. J.K. Roy, Mr. P.J. Jachuck, Dr.D. Chaudhury and Dr. M. Nagaraju
9.	VI Biennial Conference of Indian Society of Weed Science	February 9-10, 1995	Annamalai University, Annamalai Nagar, Chidambaram	Dr. B.T.S Moorthy
10.	International Conference on "Fragile lives in fragile environment"	Feb. 13-17, 1995	IRRI, Phillippines	Dr. J.K. Roy, Dr, Dinesh Chandra
11.	Breeders Group meeting of ICAR-IRRI *Eastern India Shuttle Breeding Programme*	March 28-29, 1995	New Delhi	Dr. J.K. Roy, Dr. J.N. Reddy

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PUBLICATIONS

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CENTRAL RAINFED LOWLAND RICE RESEARCH STATION

Singh S K (1995). Weed management in broadcast sown rainfed Lowland rice varieties. VI Biennial Conference of Indian Society of weed Science held on Feb. 9-10, 1995. (Abstract). 14 p.

Singh S K. (1995). Weed management in direct sown and transplanted rice under rainfed flooded condition. VI Biennial Conference of Indian Society of weed Science held on Feb. 9-10, 1995. (Abstract) 20p.

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1 Joined during the year

2 Retired during the year

3 Died during the year

4 On deputation

5 Transferred