CENTRAL RICE RESEARCH INSTITUTE

CUTTACK

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The Central Rice Research Institute, located in the heartland 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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FOREWORD

The weather and crop conditions during 1988 were favourable for the growth of rice, which resulted in a record production of approximately 70 million tonnes of rice in the country. In the light of the recommendations of the G. V. K. Rao Committee, the research activities of the Institute have been reorganised. Thrust areas have been identified and a mission-mode approach is being planned so that a given project in the thrust area is completed within a time frame. The thrust areas are :

- Collection, evaluation and conservation of rice germplasm.
- Generate appropriate technology for increasing and stabilising productivity of rice-based cropping systems in the rainfed ecosystems of eastern India - both in uplands and lowlands.
- Conduct basic and strategic research on crop improvement and resource management, information from which may help formulating applied research programmes for effecting a further increase in the productivity of rice. This includes high-tech areas like biotechnology, simulation modelling, remote sensing, bioclimatology, integrated pest management, etc.
- Outreach programmes consisting of farmers' participatory research and on-farm testing of the technology developed at the Institute.
- Training on research to rice research workers and on production technology to Subject Matter Specialists.

We are in the process of working out the details of these programmes in the thrust areas, with emphasis on multi-disciplinary participation and it is hoped that this will be available in a final form to reorient the work from the beginning of VIII Five Year Plan.

(S. PATNAIK)
Director

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INTRODUCTION

History and Development. In view of the pivotal role of rice in the agricultural economy of the country, the Government of India took a decision to establish a Central Rice Research Institute. For this purpose, Dr. K. Ramiah was appointed in early 1946, as Officer on Special Duty, to select a suitable centre for its location in one of the rice growing States of the country. Based on his recommendations, the Central Rice Research Institute was established at Cuttack in Orissa, and started functioning since 1946. The Government of Orissa facilitated the starting of the institute, by placing its central farm of about 60 hectares at Cuttack, at the disposal of the Government of India, to form the nucleus of the project. This was made possible due to the farsightedness and effort of the then Premier of Orissa, the Maharaja of Parlakhemundi and the then Director of Agriculture, late Dr. P. Parija. Dr. K. Ramiah assumed charge in August, 1946, as the first Director of the Institute.

With the reorganisation of National Research activities, the Institute was brought under the administrative control of the Indian Council of Agricultural Research (ICAR) in 1966.

The main objectives with which the Institute was started were :

- To carry out research on basic and applied aspects in all disciplines of rice culture in order to devise ways and means of optimizing hectare yields of rice
- To generate information for planning adaptive research in the rice growing tracts in the country, before giving out specific recommendations for use by rice farmers
- To serve as a centre of authoritative information on matters concerning rice production, protection and conservation
- To train research and extension workers.

The Institute's functions are carried out through eleven divisions/sections viz. (i) Plant Breeding and Genetics, (ii) Genetic Resources, (iii) Biochemistry and Rice Technology, (iv) Physiology, (v) Agronomy, (iv) Soil Science and Microbiology, (vii) Entomology and Nematology, (viii) Plant Pathology, (ix) Agricultural Engineering, (x) Communication and Training and (xi) Agricultural Economics and Agricultural Statistics.

Upland Rice Research. About 6 million hectares are cropped to upland rice, where the main constraints are lack of suitable varieties resistant/tolerant to moisture stress, problems in stand establishment, weed infestation, and low inputs on account of risk. In order to evolve appropriate varieties and technologies for these lands, a station of this Institute was started at Hazaribagh, Bihar in 1980, to work exclusively on upland rice. Results obtained during this year are included in this report.

Lowland Rice Research. About 17.5 million hectares are grown to lowland rice where the average productivity is about 1.4 t/ha. The main constraints in this situation are lack of suitable varieties and low inputs. In order to evolve appropriate technologies for this type of land situation, a station of the Institute was started at Kharagpur, West Bengal in 1986, exclusively for research on rainfed lowlands.

Extension Activities. The Institute has two Operational Research Projects – one for rice-based cropping system in a cluster of three villages, of Cuttack district and the second for Integrated Pest Management in rice, operating in eight villages of Cuttack and Puri Districts. These programmes include testing, identification and popularisation of suitable upland and lowland rice varieties and the component technology. Both the programmes have also the component of rice-based cropping system where other crops like groundnut, tuber crops, and grain legumes have been successfully tested. Rice-cum-fish culture and composite fish culture technologies were also introduced in this farming system.

From work conducted during the past five years, it has been possible to develop rice varieties and component technology for rainfed upland and lowland ecosystems. Five rice varieties of 65-100 day duration suitable for rainfed uplands and seven photoperiod sensitive varieties suitable for rainfed lowlands were released during the year. The varieties and technologies tested in farmers' fields gave average yield of 3.06 to 4.75 t/ha on upland alluvial soil and 2.15 to 3.13 t/ha on upland laterite soil. In the rainfed lowland ecosystem the average yields were 3.50 to 5.08 t/ha.

Progress of research and development work conducted at the main centre at Cuttack and at Hazaribagh and Kharagpur is briefly enumerated in this report.

HIGHLIGHTS

Genetic Resources

Local land races of rice were collected from unexplored rainfed lowland areas of Mayurbhanj and Bolangir districts of Orissa. *Oryza granulata* was collected from the Simlipal reserved forest area of Mayurbhanj (Orissa) and Papanasam (Tamil Nadu). Collections were also made through seed exchange programme. Sufficient seeds of 3500 accessions were produced for preserving in the cold store of National Bureau of Plant Genetic Resources, New Delhi. Eighteen accessions were identified as resistant to blast. In addition, two accessions of wild species, *O. meridionalis* and one accession of *O. eichingeri* were also resistant to blast.

Plant Breeding and Genetics

Fourteen rice varieties developed at CRRI and found to be suitable for different land situations were released by the Orissa State Seed Sub-Committee or Central Variety Release Committee for general cultivation in different states. These varieties included :

i) two extra-early varieties;Heera (CR 544--1-2) and Kalyani II (CR 666-36-4) with a duration of 65-70 days and yield potential of 2.5 to 3.0 t/ha for areas receiving low rainfall of 700-800 mm during the crop season,

ii) three early varieties: Annada (CR 222-MW 10), Tara (CR 404-48), and Vanaprabha (CR 289-1045-16) with a duration of 90-100 days and yield potential of 4.0 t/ha for areas receiving rainfall of 800-1100 mm during the crop season,

iii) three varieties: Kshira (CR 401-7), Padmini (CRM 25) and Moti (CR 260-136-321) with a duration of 135-140 days and yield potential of 4.0 to 5.0 t/ha for unsubmergible medium lands, and

iv) six varieties: Gayatri (CR 210-1018), Dharitri (CR 260-136-321), Tulasi (CR 260-171), Kalashree (CR 260-292), Panidhan (CR 260-30) and CR 1014 with a yield potential of 4.0 to 5.0 t/ha for rainfed lowland areas with water depth ranging from 0-50 cm.

In addition, several breeding lines have been developed for different situations :

i) *Semi-deep situation (0-75 cm)* : CR 581-9, CR 383-10, CR 626-26-2-3, CR 617-16-10-2 and CR 301-3066 with a yield potential of 4.0 to 5.0 t/ha.

ii) *Gall midge resistance* : Of the six high yielding cultures developed for resistance to gall midge using Orumundakan source, two cultures (CR 309-277-74 and CR 309-268-54) were highly promising in the Minikit programme conducted in the Srikakulam district of Andhra Pradesh in *kharif*, 1988 where a new biotype of gall midge occurs in endemic form.

iii) *Coastal saline areas* : Six cultures viz., CRM 30, CR 639-6, CR 639-12, CR 311-134, CR 666 and CR 310-10 with a duration of 120-150 days and yield potential of 4.0-5.0 t/ha were consistently promising in coastal saline areas of Orissa, West Bengal and Andhra Pradesh.

iv) *Cold tolerance* : Two high yielding cultures; CR 628-2-10 and CR 628-2-62 with a duration of 110-115 days in *rabi* and 90-100 days in *kharif* from the cross Rylloned x Palman.

Plant Physiology

In monthly plantings, higher yields in June

and July plantings in *kharif* season and January and February plantings in *rabi* season were associated with higher solar radiation and low night temperature during reproductive and ripening periods of growth.

A 3-fold variation in net assimilation rate (NAR) and 1.5-fold variation in photosynthetic rate (Pn) were noticed in 60 each of traditional and high yielding varieties. Dry matter production and yield were positively associated with NAR at seedling stage which, in turn, was associated with specific leaf weight. These characters help in selecting productive types at seedling stage.

Ten promising cultures for intermediate water depth conditions were characterized by high dry matter at flowering and harvest and higher harvest index. Foliar spray of GA, IAA or their combinations enhanced grain yield under waterlogged conditions.

Nitrogen enhanced Pn and LAI. However, leaf weight rate of 25% appears to be the threshold value at flowering for N response in yield.

Cultivar Ptb 10 and Swarnaprabha (tall varieties) were more tolerant to graded shading than Ratna and Pallavi (dwarf HYV).

Foliar spray of boron alone or in combination with 2,4-D induced resistance to lodging in lodging-prone Vanaprabha. Triacontinol as foliar spray delayed senescence and increased yield.

Biochemistry

Based on eating quality and aroma, 9 long slender scented rice genotypes (IET nos. 10363 to 10366, 10368, 10649, 10650, 10651 and 10655) nominated by the DRR, Hyderabad, were graded as nearer to Basmati 370. Application of 60 kg N/ha during growth of scented rice had no adverse effect on quality attributes including aroma.

Among non-scented rices evolved at this Institute, CR 544, CR 404-62 and CR 666 were most promising with regard to quality attributes.

Rice seedlings showed less acid phosphatase activity when grown on *laterite soil* than on alluvial soil.

Varieties Ratna and Annapurna, harvested at high moisture, were subjected to four processing conditions (immediate threshing after harvest, threshing after leaving the harvest in the field for seven days, threshing after leaving the harvest in the field and stacking for 21 days followed by sun-drying and threshing after oven drying). Delayed and improper processing associated with rain resulted in decreased head rice yield, discolouration of grains, infestation by fungi, and production of mycotoxin. Maximum grain deterioration resulted when the crop was stacked. Under identical processing conditions, Ratna performed better than Annapurna in milling, head rice yield, and resistance to infestation by fungi. Immediate oven or sun-drying seems to be the best way to prevent deterioration of the rice grain.

In another trial with rice var. Savitri, head rice yield declined significantly from 72.4% from the crop immediately threshed and sun-dried to 69.9% after delayed processing and 64.9% after stacking. Delayed processing and stacking significantly reduced grain hardness (breaking) from 4.5 to 3.5 kg. Milling (4.5-6.0%) resulted in grain protein loss by 10.4%.

Agronomy

Management of intermediate (15-20 cm) and semi-deep (51-100 cm) lowlands. In on-farm trials under intermediate deep rainfed lowlands, Panidhan, Tulasi and CR 260-77 yielded 4.0 to

5.0 t/ha as compared to 1.50 to 1.85 t/ha yield with local checks.

Application of 20 to 40 kg P_2O_5/ha increased the yield of direct seeded CR 1016 by two-fold under simulated flash flood condition. For a transplanted crop under excess water situation, application of fertilizers at 100 kg N and 20 kg P_2O_5/ha to the nursery increased the yield of Gayatri by 250% over that of the conventional practice of planting seedlings from unfertilized nursery.

Under intermediate deep water situation, tall (190-200 cm) and heavy panicle weight (3-5 g) type cultures yielded 3 t/ha. Early sowing (before the end of May) was superior to delayed sowing. Pre-emergence application of butachlor at 2.0 kg/ha increased the yield by 9-15%.

Beaushening increased the yield of direct-seeded Gayatri (450 seeds/m^2) by 15% with further increase by 10% following green manuring with *Sesbania aculeata* or *S. rostrata*.

Janaki and Jaladhi performed well in semi-deep lowlands with continuous waterlogging till harvest.

Management of rainfed uplands. In on-farm trials, Annada (105 days) yielded 4.5 to 5.5 t/ha. Dibble seeding behind plough was superior to broadcast seeding.

Direct seeding in furrows with single basal application of NPK was ideal for extra-early cultures, CR 666-7 (65 days) and Vanaprabha (85 days).

Integrated control of weeds with a stale seedbed along with butachlor, thiobencarb or propanil at 2.0 kg/ha or oxadiazon at 0.5 kg/ha was on par with manual weeding thrice.

Management of shallow submerged lowlands/ irrigated medium lands. For late planted situation Gayatri was the most promising. In on-farm trials, Padmini (4.0-4.5 t/ha) was the most promising after jute crop.

Combined use of organic manures with inorganic fertilizer at 37.5 kg N/ha was comparable to 75 kg N/ha as inorganic fertilizer.

Badshahbhog, a scented rice yielded 2.84 t/ha with significant response up to 30 kg N/ha.

In on-farm trials, CR 1002 and Moti yielded 5.5 to 6.0 t/ha. Direct-seeded crop was comparable to transplanted crop with considerable saving on labour and monetary inputs.

Sequence crops found suitable in rainfed lowland rice fallows were sweet potato (85-16), greengram (Pusa 65), maize (Ganga 5) and groundnut (RSHY 1).

Soil Science and Microbiology

Studies showed that green manuring can be practised both in direct-seeded and transplanted rice, but was more beneficial in transplanted rice. Green manuring with *Sesbania aculeata* supplied 74-88 kg N/ha of which 32-40% was utilised by rice crop as against 14-32% utilization from chemical fertilizer. Direct measurement of denitrification loss of applied ^{15}N indicated significant loss of N until 9 days after fertilizer application. Rice variety Savitri was more tolerant to nitrogen stress condition than CR 1014, Pankaj, Tulasi and Mahsuri. Soil application of cadmium decreased the grain yield and left cadmium residues above permissible level in the grain. The deleterious effect of cadmium was ameliorated by lime application.

Application of P (8-24 kg P_2O_5/ha) increased the fresh weight and fixed N of *Azolla caroliniana* and rice yield especially when applied in split. Iron and molybdenum also were stimulatory, particularly when P was not applied or applied at 8 kg P_2O_5/ha. *A. caroliniana* outperformed *A.*

rubra, *A. filiculoides* and *A. pinnata* when grown with urea at 0, 40 and 80 kg N / ha. Application of N, P and growth regulators (gibberellic acid and kinetin) increased the percentage germination of *A. caroliniana* sporocarps.

Heterotrophic nitrogen fixation in soil was low under stress conditions of high salinity (>4 dS/m). Nitrogen fixation increased upon leaching of saline soil or organic matter addition.

Plant Pathology

Cultures CR 572, CR 574, CR 10R-157, CR 115-6 and eleven IR 50 mutants were identified as tolerant to blast. Lemon grass *Cymbopogon flexuosus* was highly tolerant to sheath blight pathogen. Certain lines from interspecific crosses Jaya x *Oryza barthii* and PR 106 x *O. barthii* were resistant to bacterial blight. CR 30-26-1, CR 404-14, CR 380-26-39 and CRM 25 were tolerant to rice tungro. Likewise, varieties Swarnaprabha, Biraj, Vanaprabha, Khitish, Jaladhi 1, CR 575, ADT 36 and Vikash possess durable resistance to rice tungro.

Leaf extracts of *Aegle marmelos* and *Ocimum sanctum* inhibited rice blast fungus *Pyricularia oryzae*. Seed treatment with tricyclozole (4 g/kg) controlled foliar blast while Validacin, Rhizolex and Topsin controlled sheath blight. Heavy metals reduced the severity of blast and brown spot. Induced resistance through the formation of phytoalexins aganist blast and brown spot may not be effective against bacterial blight and sheath blight. The seed was the potent source for the propagation of sheath rot pathogen. The systemic nature of false smut disease was established.

Entomology

In evaluation of germplasm and elite breeding lines for resistance to gall midge, several entries (ARC 1128, Choorapundy, CR 157-39-9, RP 2235-85-62-8, IR 38, etc.) were totally free from gall midge infestation when susceptible entries suffered 100 per cent damage. Also, three Orumundakan sources and several varieties have been identified as resistant to the new biotype of gall midge in the north coastal Andhra Pradesh.

Also several varieties and cultures have been identified as resistant to other important pests such as brown planthopper, and gundhi bug.

Buprofezin exhibited strong killing effects on the nymphs of brown planthopper.

Ratoon crop provided ideal microenvironment for the growth of rice pests in comparison with normal crop.

Adverse effect of pesticide spray on parasitism and parasite population was noticed for 3 to 4 days, but later their population could build up restoring the original parasitism level. *Telenomus dignoides* was the dominant egg parasite in both *rabi* and *kharif* seasons. *Platygaster oryzae* preferred the rice gall midge over all other midge species.

Agricultural Engineering

Several agricultural machines for use in rice culture have been developed and tested. A three-row bullock-drawn seed-cum-fertilizer drill and one 10-row tractor mounted seed-cum-fertilizer drill for dry sowing paddy were designed, fabricated and tested. A batch type paddy dryer with 0.3 t holding capacity was designed and is under fabrication. A small puffing machine was developed to puff parboiled rice (muri), paddy (khai) and flaked rice. A low cost and low capacity expeller to extract oil from non-conventional oil seed in a small batch for use in tribal and rural areas was designed and developed.

A survey of wind profile and wind mills was made in farmers' fields in Cuttack and Balasore

districts. Also, a survey on energy requirements in agricultural sector was made in the village Barabati in Cuttack district. Also, energy requirements for the field preparation in rice cultivation under wetland conditions were studied in *kharif* season. Tractor drawn disc puddler required highest energy for puddling, but least human energy.

Central Rainfed Upland Rice Research Station, Hazaribagh

Forty new collections were added to the existing germplasm. RR 145-22 and RR 160-10 were promising among early maturing cultures (80 days). CR 314-5-3 (IET 8787) was nominated for minikit trials in various states. Seven drought resistant exotic germplasm, 15 advanced breeding lines and 14 fixed cultures were resistant to blast. Four IR 50 mutants exhibited moderate resistance to leaf and neck blast. Nitrogen fertilizer above 60 kg N/ha and closer spacing (15 x 15 cm) restricted the bacterial blight in susceptible high yielding varieties under favourable uplands.

Seed treatment with tricyclozone followed by Kitazin application was the most effective for blast management.

Based on two-year data, advance seeding consistently gave better yield than normal sowing during erratic (*kharif*, 1987) and sub-normal (*kharif*, 1988) monsoons. Paddy yield (Kalinga III) increased with increase in P application. Rice-pigeon pea cropping pattern was better at 3:1 ratio than at 2:1 ratio in terms of monetary return.

WEATHER CONDITIONS

The year 1988 witnessed an excess annual rainfall of 192 mm over normal rainfall of 1518 mm. Despite an excess rainfall of 338 mm from June to September, there was no flash flood since it was well distributed. The monsoon set in early during the first week of June, but withdrew unusually earlier by first week of October, providing favourable weather conditions at reproductive and maturity stages of the lowland rice crop. Therefore, the productivity of rainfed lowland rice was high, with record yields of 7.5 to 8.5 tonnes/ha from high yielding varieties in farmers' fields. On the whole, the weather condition of this year was favourable for rainfed/irrigated upland and lowland rice. Rainfall for the year 1988 is presented in Table 1.

Table 1. *Rainfall for the year 1988 as compared to average rainfall of thirty years from 1958 to 1987*

Period	Month	Average rainfall (mm) from 1958-1987	Rainfall (mm) during 1988	Deviation from normal
Winter	Jan	12	0	-12
	Feb	27	15 (2)	-12
	Total	39	15	-24
Pre-monsoon	Mar	34	9 (1)	-24
	Apr	31	34 (3)	+3
	May	72	61 (4)	-11
	Total	137	105	-32
South-West monsoon	Jun	148	296 (15)	+148
	Jul	345	424 (21)	+79
	Aug	367	356 (14)	-11
	Sept	268	390 (18)	+122
	Total	1128	1366	+338
Post-monsoon	Oct	185	125 (4)	-60
	Nov	23	1	-22
	Dec	5	0	-5
	Total	213	126	-88
Grand Total		1517	1612	+194

Figures in parentheses indicate number of rainy days.

GENETIC RESOURCES

GR. 01. Collection of Rice Germplasm

Collection from Orissa. Mayurbhanj and Bolangir districts of this State were further explored in collaboration with the National Bureau of Plant Genetic Resources (Base Centre at Cuttack) for collection of cultivated and wild rices. Two hundred and five seed samples of local cultivars were collected from Baripada, Khunta, Syamakhunta, Rasagovindpur, Suliapada, Sarasakana, Bangariposi, Bisoi, Joshipur, Karanjia, Raruan and Sukruli blocks of Mayurbhanj district. These varieties are of medium and late duration, maturing in 140 to 160 days and include cultivars having scented kernels, cluster grain, long sterile glumes and purple foliage. One hundred and twentyfive samples were collected from Saintala, Titlagarh, Bongamunda, Tureikela, Khoprakhol, Patnagarh, Luisingha, Agalpur, Birmaharajpur, Ulunda, Sonepur and Tarbha blocks of Bolangir district. The varieties collected were mostly of late duration grown in rainfed medium or lowlands with variation in plant height, grain size, husk and kernel colour. Eight samples have also fine and scented kernels.

(A. R. Panda and N. Dixit, NBPGR)

Other collections. Important traditional rainfed lowland and upland rice varieties of West Bengal and Arunachal Pradesh were received while collection from Arunachal Pradesh includes primitive cultivars and local land races which are grown in jhum lands. Seed samples of 603 local cultivars, collected mostly from Himachal Pradesh, Madhya Pradesh and Uttar Pradesh were received from the NBPGR. Twentyone high yielding rice varieties released in States [Andhra Pradesh (6), Kerala (3), Pondichery (1), Tamil Nadu (2) and West Bengal (9)] have been added to the existing collection of elite germplasm.

(A.K. Murty)

Exotic varieties. Seed samples of 1018 accessions were received from IRRI, Philippines. The samples include varieties resistant to major diseases and pests like blast. bacterial leaf blight, rice tungro virus, brown planthopper and white backed planthopper and varieties tolerant to soil salinity, alkalinity and other adverse soil conditions. The material is being multiplied for distribution to rice research organisations in India for utilization in varietal improvement programmes. Six traditional deep-water rices were obtained from Habiganj Rice Research Station of Bangladesh.

(A. K. Murty)

Collection of wild rices. In a collaborative programme of NBPGR-CRRI-IRRI for collection of wild rices from central and southern States of India, parts of Kerala and Tamil Nadu (Cochin to Madras) were thoroughly surveyed. Interestingly, wild rices are conspicuously absent in this region although habitats for their occurrence are available. However, sporadic occurrence of the wild species, *O. rufipogon* in Nagarcoil and *O. granulata* in Papanasam was observed. Samples of these species were collected.

During the survey of Mayurbhanj district, a sample of *O. granulata* was collected from the Simlipal forest region. The plants are perennials and 50–60 cm tall. They perennate by means of short horizontally-growing rhizomatous stems. They were growing in shady places besides small streams where the soil is well-drained. Thirtytwo accessions of 18 species of wild rices were introduced from IRRI, Philippines. Twentynine ac-

cessions which survived, are being maintained in pots.

(S. D. Sharma, S. R. Dhua and N. Dixit)

GR. 02. Conservation and Evaluation

The entire collection of rice germplasm was grown in the field in two or three row observation plots for the purpose of rejuvenation and supply of seeds to indenting agencies. A special effort was made this year for seed multiplication of 4,000 accessions so as to keep sufficient quantity of seed in the cold store of NBPGR. Seed samples (100-150 g each) of 1,600 accessions, thoroughly cleaned and sun-dried, have already been transferred to the NBPGR for preservation in long-term cold storage. Similarly, stubbles of the wild species of *Oryza* were multiplied with a view to raise larger populations in the field and get enough seed for preservation in cold storage.

(A. K. Murty, S. D. Sharma, D. P. Ghorai, S. R. Dhua and A. R. Panda)

Characterization. Morpho-agronomic traits were recorded for 3,500 accessions in the field. A proforma for recording varietal descriptions, as per international code, was prepared to facilitate management of data through computerisation. The proforma includes 48 characters of the culm, leaf, panicle spikelets and kernels. Thirtyeight of the 48 characters were recorded in the field. Considerable variability was observed for all the characters studied. The flowering duration, pigmentation of the leaf sheath and secondary branching of the panicles were analysed in detail. The basal leaf sheath was grouped into five classes viz. green, purple lines, light purple, purple and mixtures. The most frequently occurring class was green (approximately 80%), the others occurring with almost the same frequency. The secondary branches in the panicles were few to many with occasional clustering of grains. Most of the land races studied have intermediate panicle type.

(S. R. Dhua, A. K. Murty, S. D. Sharma, D. P. Ghorai, A. R. Panda and R. N. De)

Evaluation for resistance to blast disease. A set of 800 accessions was screened for resistance to blast disease. Some of the accessions of wild species introduced from IRRI were evaluated for their reaction to the blast disease. Accessions of *O. longistaminata* and *O. latifolia* were highly susceptible while two accessions of *O. meridonalis* (Acc. 101146 and Acc. 101147) and *O. eichingeri* produced no symptom of the disease. Other accessions of *O. meridionalis* (Acc. 101411), *O. alta, O. glaberrima, O. nivara, O. punctata, O. minuta, O. australiensis* and *O. barthii* produced susceptible type of small lesions.

(Urmila Dhua and S. R. Dhua)

Four thousand and five hundred accessions were sent to the DRR, Hyderabad for evaluation against major diseases and pests. Also, a set of 2500 accessions from this lot was provided to the Plant Pathology Division of this Institute for screening against bacterial leaf blight and blast.

GR. 03. Documentation and Exchange

Exchange of rice germplasm. Eighty accessions of living plants (stubbles) of different species of wild rices were made available to DRR, Hyderabad and the OUAT, Bhubaneswar. Pollen grains of 50 wild rices, belonging to different species were provided to the scientists of the National Botanical Research Institute, Lucknow for palyntological studies. Six hundred and twentyeight seed samples were supplied to different agencies and research organisations in India and abroad. The foreign countries which received germplasm from the Institute are Italy, (3), Korea (14), Philippines (2), New Caledonia (4) and United Kingdom (9).

(A. K. Murty, S. D. Sharma and S. R. Dhua)

Elite germplasm and speciality types. Around 1000 accessions of important rice germplasm were multiplied in small plots to cater to the needs of researchers.

(A. K. Murty)

GR. 05. Production of Nucleus and Breeder Seed (NSP)

Nucleus seed. Two hundred and nintynine kilograms of nucleus seeds of 66 popular rice varieties was produced in small quanitities (3-10 kg each) by panicle to row method for conservation of genetic purity, rejuvenation, breeder seed production, museum and exhibition purposes.

Breeder seed. Six thousand three hundred and twentyfour kilograms of breeder seeds of six rice varieties viz. Annada, IR 36, Kalinga III, Ratna, Sattari and Savitri was produced under the National Seed Project. The crop was certified six times by the Seed Monitoring Team in *rabi* and *kharif* seasons. Nucleus seeds (223 kg) and breeder seeds (3708 kg) of different varieties were distributed to various seed producing agencies and research organisations in the country.

(D. P. Ghorai)

PLANT BREEDING AND GENETICS

PB. 01. Varietal Improvement for Rainfed Lowland Conditions

Breeding for shallow submergence (0-30 m) water depth with built-in resistance to major pests and diseases. Kshira (CR 401-7) was released in Orissa. This variety matures in 135 days with an yield potential of about 6t/ha and has built-in resistance to gall midge, BPH, WBPH, GLH and RTV. Kshira is specially suitable for BPH-endemic areas.

Some promising cultures with built-in resistance to major insect pests and diseases for irrigated medium lands and shallow rainfed lowlands have been nominated for State/Central Minikit Programme for multilocational testing (Table 2).

(J.K. Roy)

Screening for bacterial leaf blight. None of the 50 accessions belonging to exotic collections from germplasm (EC 204936 to EC 205000) tested were found resistant to bacterial leaf blight.

In another experiment, 24 representative lines with known genes for resistance to bacterial blight were grown for assessing their disease resistance using one local isolate of the bacterial blight pathogen.The seeds of these entries were supplied by IRRI. Except DV 85 and BJ 1, all other entries were susceptible. Results showed that (1) isolates of the pathogen, *Xanthomonas campestris* pv. *oryzae* of India are more virulent than Japanese or IRRI isolates and (2) varieties DV 85 and BJ 1 which originated in the subcontinent were resistant.

(M. Nagaraju)

Varietal improvement for intermediate water depth (0--50 cm) . Based on the performance under intermediate water depth (0-50 cm) in the *kharif* season at CRRI, two long duration photosensitive cultures CR 580-17 (6.1 t/ha) and CR 581-9-5 (6.6 t/ha) have been nominated for State Minikit Programme under rainfed lowland situation.

(J.K.Roy)

Five hundred fixed lines from crosses, CR 1018 x MR 87, CR 1009 x MR 87, CR 1009 x Cuttack Chandi, Haldiamagura x CR 1009, (360 x T 141) x Mahsuri, CR 1018 x CR 1014 and GEB 24 x Mahsuri were grown under rainfed lowland

Table 2. *Promising cultures for shallow rainfed lowland*

Culture	Total duration (days)	Yield (t/ha)	Resistance/ tolerance to
CR 407-6-62	115	4.5	GM,GLH
CR 404-24	120	4.5	GM, GLH, RTV
CR 407-4	135	6.1	GM, RTV, GLH
CR 407-6-1	130	5.3	GM, WBPH, GLH
CR 403-2-2	135	5.5	GM, BPH, WBPH, RTV

conditions. Fortyfive most promising uniform breeding lines with medium height, good tillering habit, better panicle expression and good grain quality were selected. The selected cultures were photosensitive, and flowered during 4th week of October to 2nd week of November. CR 673-475, CR 673-420 and CR 673-431 are very promising.

(K. Srinivasulu and J. N.Reddy)

Four varieties, Moti, Kalashree, Tulasi and Panidhan were released by the Government of Orissa for different lowland situations. Kalashree has purple pigmentation in leaf base and superfine grains.

In a trial with 25 long duration lines from the cross CR 256/CR 260 against five checks, five cultures yielded 10 to 17% more than the highest yielding check, Gayatri (4.7 t/ha) and had better grain quality (medium to long slender) than that of Gayatri (short bold). New cultures of CR 716 (CR 260 x Pankaj) are also promising.

(C. Gangadharan)

Varietal improvement of photosensitive varieties for typical aman lands. Twentyfive elite lines from 20 cross combinations were grown under direct-seeded and transplanted conditions. These cultures flowered in mid-October when transplanted. Under direct-seeded conditions, the duration was reduced by 20-25 days in some cultures which flowered in the last week of September. The yields were comparativly less under direct-seeded condition.Under direct-seeded conditions, CR 663-3125, CR 661-179, CR 667-1073, CR 662-3318 and CR 662-2259 yielded between 3 and 3.8 t/ha against 3.2 t/ha of the highest yielding check Mahsuri. Under transplanted conditions, CR 661-179 gave the highest yield of 4.9 t/ha followed by CR 668-1001 (4.7 t/ha) and CR 668-956 (4.65 t /ha) as against the yield of highest yielding check, Mahsuri (4.0 t/ha).

(M. Nagaraju)

Varietal improvement for late-planted conditions. Fifty photosensitive cultures from crosses Pankaj x CR1014 , Pankaj x T 141, Vijaya x T 141, CR 130-136 x Jagannath, IR 20 x N P -9, Jagan-

Table 3. *Promising cultures under intermediate water depth*

Culture	Grain yield (kg/plot) (1.98 sq.m)	Yield (t/ha)	EBT/ Sq.m	50% flowering date	Harvest index	Photosynthetic rate of boot leaf at flowering
CR 626-26-14-1	0.885	4.47	152	24/10	19.6	37.2
CR 671-19	0.815	4.11	156	8/11	18.1	36.0
CR 491-51	0.782	3.95	126	6/11	29.6	36.0
CR 617-16-10-2	0.772	3.90	147	7/11	30.9	39.1
CR 491-46	0.740	3.74	111	31/10	33.1	37.4
CR 491-15	0.735	3.71	108	9/11	31.6	38.3
CR 626-26-2-3	0.735	3.71	128	4/11	28.5	42.7
CN 571-231-236 15-1 (check)	0.710	3.59	128	1/11	28.8	38.3

nath x T 141, CR 130-54 x CR 130-136 and CR 1014 x CR 130-44 were grown under normal and late planting (September 1st week) conditions in *kharif* season. Yield of these cultures ranged from 3.5 to 6.0 t/ha in normal planted condition. Cultures CR 686-75, CR 682-166 and CR 685-236 were promising under late planting.

(D. Chaudhary)

Two hundred breeding lines were grown under late planting condition at the end of September by raising nursery in the 1st week of August. Ten breeding lines from the crosses (360 x T 141) x Mahsuri, GEB 24 x Mahsuri, CR 1018 x MR 87, CR 1018 x NC 1281 and CR 1009 x MR 87 have recorded yields of 4.0 to 5.5 t/ha against 3.4 t/ha by the best check variety Utkal Prabha.

(K. Srinivasulu and J.N. Reddy)

Evaluation of CRRI cultures for different lowland situations. In *kharif* season, 108 CRRI cultures along with 12 check varieties were grown (direct-seeded) in two replications under three different situations as given below. In all the three situations, the germination date was 6.6.1988.

Submergence tolerance at seedling stage. Twentysix day-old seedlings were submerged under 75 cm water depth for 12 days in an improved controlled field tank to know the comparative performance of the cultures for submergence tolerance at seedling stage. The spacing was 15 x15 cm . The thinning operation was done within one week of germination and 2-3 seedlings/hill were maintained. Survival percentage (hill basis) was recorded after 20 days of complete release of water. The mortality ranged from 11 to 100%. Only 14 cultures showed survival percentage of more than fifty. Promising cultures are CR 617-16-10-2 (79% survival), CR 622-21-1 (71%) and CR 670-37 (67%) against the checks, CN 571-231-236-15-1 (89%) and CR 383-10 (70%).

Evaluation under intermediate water depth (30-50 cm) . In this trial, the water depth remained between 20 and 50 cm during most of the crop growth period. The spacing was 20 x 15 cm . Fertilizer was applied at the rate of 30 N and 20 P only as basal dose. The grain yield showed significant positive correlation (r = 0.76 **) with harvest index, but not with photosynthetic rate of boot leaf at flowering. The promising cultures are given in Table 3.

Evaluation under semi-deep situation (0-100 cm). In this situation the water depth remained between 50-90 cm in most of the crop growth period. The crop was submerged twice at early vegetative stage. The fertilizer was applied at the rate of 30 N and 20 P only as basal dose. The spacing was 20 x15 cm. Out of 120 cultures, only 20

Table 4. *Promising cultures under semi-deep situation*

Designation	Grain yield (t/ha)	EBT/ sq.m	50% flowering date
CN 579-363-3-1 (check)	0.91	36	4th Nov.
CR 626-26-2-3	0.89	35	4th Nov.
CN 571-231-236-15-1(check)	0.80	37	4th Nov.
CR 383-10 (check)	0.78	33	8th Nov.
CR 617-16-10-2	0.59	33	8th Nov.
CRM 30	0.58	27	4th Nov.

Table 5. *Performance of different genotypes against gall midge population of Srikakulam district at different locations (Rep. 2),* kharif, *1988 (A. P. A. U. Ragolu)*

Varieties/ cultures	Grain yield (t/ha)						
	ARS, Ragolu	Panuku-valasa	Pedda-pella	Venkanna-pet	Nara-yanpuram	Mean yield (t/ha)	Mean G. M. inci-dence(%)
Local evolved and high yielding varieties							
Phalguna	5.48	2.37	4.38	4.10	4.19	4.10	40.9
IR 36	3.08	2.26	3.44	4.92	4.06	3.55	6.9
IR 62	4.86	2.50	5.40	4.95	4.44	4.42	22.9
Pothana	3.41	2.53	4.24	2.97	4.00	3.43	22.5
Surekha	4.00	2.19	4.40	2.70	3.56	3.37	37.8
Swarna	5.66	2.35	6.02	3.77	4.83	4.52	34.9
Pratibha	4.60	2.47	4.06	4.35	4.19	3.93	32.9
CRRI Cultures							
CR 3311-34	4.46	3.70	4.98	4.34	4.64	4.43	Nil
CR 309-262	4.46	3.70	4.53	4.50	3.87	4.21	Nil
CR 308-408	5.29	4.01	5.00	5.45	4.38	4.65	Nil
CR 308-38	5.32	3.73	5.49	4.30	4.38	4.65	Nil
CR 309-268-54	4.53	4.41	4.95	5.60	4.00	4.70	Nil
CR 309-277-74	4.79	3.52	5.31	4.88	4.51	4.60	Nil

cultures including 5 checks survived. The promising cultures are given in Table 4.

(R. N. De and G. Ramakrishnayya)

Varietal improvement for rainfed semi-deep waterlogged areas. During *kharif* season, 61 lines (22 lines evolved for semi-deep situation and rest for intermediate water depth) derived from 18 cross combinations and five check varieties were direct-seeded on May 26 in a field tank. The lines represent semi-dwarf to very tall plant types. The seeds were dibbled at 15 cm between hills and 20 cm between rows, in plots of 12 m^2 for each culture. A basal dose of 15 kg N and 15 kg P_2O_5 per ha was applied. Observations on plant height, length of leaf sheath and leaf blade were recorded periodically.

On July 14, the water level was 77 cm and all the lines survived. As the water level increased to 88 cm on July 22, 3 semi-dwarf lines died and 18 lines showed nodal differentiation with one or two nodes. The elongation capacity of leaf sheath and blade, not of internode, was important for survival of the crop at early stages of growth.

When water level was raised to 97 cm on August 5, 33 lines were completely submerged and died and another 15 lines partially died. Elongation of internodes with 2 to 6 nodes was

observed in all the survived lines except Boethalipakhia (a local cultivar) which could survive at this stage also by elongation of leaf sheath and blade only. Number and length of internodes varied among the promising lines. Shorter and more number of internodes as in PN 56 are desirable for semi-deep conditions to prevent lodging after receding of water. Studies showed that tall to very tall (more than 140 cm height) lines were only adaptable to semi-deep situation. Elongation ability of leaf sheath and blade was important up to 50 days of growth and thereafter nodal differentiation was found desirable. Cultivar Boethalipakhia is a good donor for leaf sheath and blade elongation. Early nodal differentition, nodal tillers and nodal roots (desirable traits of deep water rice) are not desirable for semi-deep situation.

(M.J.B.K. Rao)

Breeding varieties for coastal saline areas. Some selections found highly suitable for growing in salinity-affected coastal areas of eastern India, were tested under All India Coordinated Rice Improvement Programme in *kharif*, 1988. The mutant CRM 30 (IET 10678) evolved by gamma irradiation from variety Nonasail ranked first in yield (mean yield of 3 entries : 4.15 t/ha against 2.76 t/ha with Pokkali) in the salinity affected test centres at Machlipatnam (Andhra Pradesh), Motto (Orissa) and Canning (West Bengal). It can also be grown under waterlogged conditions (up to 50 cm water depth).

Six saline tolerant cultures from the crosses , Orumundakan x CRM 6-106 (CR 309), Orumundakan x Damodar (CR 308) and Orumundakan x Dasal (CR 311) were highly resistant to gall midge as against up to 40% incidence in local popular varieties grown in 5 locations in gall midge endemic areas of Srikakulam district of Andhra Pradesh in *kharif*, 1988 (Table 5).

(P.N. Sreedharan)

PB. 02. Utilisation of Tissue and Anther Culture Techniques in Rice Breeding

Anther culture. A total of 78 gametoclones of the variety Savitri were evaluated in the field for their agronomic characteristics. The variation was low for the three characters tested i.e. maturity, culm length and grain shape. Most of the clones yielded less than the parent.

The gametoclones of IR 36 were also evaluated against the parent for their agronomic utility. None of the clones appeared to be superior to the parent in yield. Variation was observed for the hull colour in some variants.

Tissue culture. A total of 120 somaclones of Annada were evaluated in the dry season under field condition for variation in culm length, panicle and grain characters. Based on this study, 15 primary somaclones were selected and further evaluated for their yield in the wet season. None of the somaclones outyielded the parent though some of the clones showed higher grain test weight.

Experiments were conducted to compare the earlier findings on the success of axillary shoot induction in cytoplasmic male sterile stocks (CMS stocks). The results confirm that axillary shoot induction is possible in media containing optimum levels of auxin and cytokinins.

(N.P. Sarma and G.J.N. Rao)

PB.03. Cytogenetical Studies in Rice

Complete set of 12 primary trisomics in Sona and Ratnagiri were maintained through vegetative and seed propagation. A large number of crosses were made with *O. punctata, O. glaberrima* and *O. nufipogon* using trisomics as female parents. Only 5 F_1 hybrids were obtained with *O. glaberrima.*

(R.N. Misra)

PB. 04. Genetical Studies in Rice

Inheritance pattern of grain length, breadth, thickness and grain weight in crosses, Pakistan-Basumati/IR 1469 and Pakistan Basumati/ Paizam-242. Parents, F_1 s and 500 plants of F_2 from each cross were grown during wet season, at CRRI. At maturity, three seeds from each plant were measured for grain length, breadth and thickness. Hundred-grain weight was also recorded.

In Pakistan Basumati x IR 1469, grain breadth showed over dominance in F_1 and F_2. In Pakistan Basumati x Paizam 242, F_1 values for grain breadth, thickness and test weight were more than those of mid-parent and in F_2 maximum frequency was towards higher parent values.

There were no significant correlations among grain length, breadth, thickness and test weight in parents Pakistan Basumati and IR 1469. In Paizam 242 positive association was recorded between length and thickness and negative correlation between thickness and test weight. In Pakistan Basumati, direct effect of grain length on test weight was positive. In IR 1469, direct negative effect of grain length on test weight was high. In Paizam 242 direct negative effect of thickness on test weight was maximum and its indirect effect through grain length was high.

Positive association of grain breadth with length and test weight was observed in the F_1 of Pakistan Basumati x IR 1469. Direct effcect of grain breadth was maximum on test weight. On the other hand, there were no significant associations among four characters in F_1 of the cross Pakistan Basumati x Paizam 242.

In F_2 populations of two crosses, significant positive association amongst all characters except between grain length and breadth was recorded. Direct positive effect of grain length and breadth on test weight was of equal magnitude.

(M.J.B.K. Rao)

PB. 05. Varietal Improvement through Induced Mutation

A mutant isolated from CR 1014, with superfine grain was released in Orissa as Padmini.

Another superfine grain mutant CRM 23, selected from the variety JBS 508 matures within 100 days with a yield potential of 3.5 to 4 t/ha and can be grown in both *rabi* and *kharif* seasons. This variety has a dormancy period of 20 days.

A productive hybrid selection (CR 631-5) from the cross between two mutants viz. CR 70 mutant with CRM 25 has superfine grains and long panicle with yield potential of 5.0 t/ha. It is photosensitive and suitable for waterlogged conditions. In a field trial, it yielded 5.5 t/ha at Motto (Balasore district of Orissa) under waterlogged conditions in *kharif*, 1987.

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PB. 06. Development of Hybrid Rice

Studies on cytoplasmic genetic male sterile lines. Of the 33 CMS lines received from IRRI (including six from China), only five(V 20A, Zhen Shan 97A, IR 48629 A, IR 48630 A and IR 54752 A) were stable and promising at CRRI, Cuttack. Seed set in the CMS lines in the seed production plots (A : B = 4 : 2) was 20% for V 20A, 18% for ZS 97A, 18% for IR 48629 A, 15% for IR 48630 A and 25% for IR 54752 A (without supplementary pollination).

Thirteen CMS lines have been developed so far at CRRI, Cuttack viz. CRMS-1 from Ratna, CRMS-2 from Dunghansali, and CRMS-3 (Madhu A), CRMS-4 (Sarasa IA), CRMS-5 (Sarasa II A), CRMS-6 (Pusa 33 A), CRMS-7 (Pragati A), CRMS-8 (MW 10A), CRMS-9

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(Hema A), CRMS-10 (Krishna A), CRMS-11 (Rajeswari A), CRMS-12 (Bharati A) and CRMS-13 (Kiran A) from WA Source.

Inheritance of anther size and stigma exsertion was studied in four crosses (involving restorers and maintainers of WA cyto-steriles) viz. Karuna x Kiran, Savitri x Madhu, N 22 x Madhuri and Red Annapurna x Suphala. F_1 of all the crosses had long anthers and the F_2 population segregated for long (more than 2.2 mm) and short (up to 2.2 mm) anther at 3:1 ratio which shows that long anther is controlled by monogenic dominant genes. Similarly fully exserted stigma was controlled by a single dominant gene in three crosses (Red Annapurna x Suphala, Jalagaon 5 x Suphala and Karuna x Kiran). Results from the linkage studies in two crosses (Karuna x Kiran and Red Annapurna x Suphala) indicated that there is no linkage between long anther and fully exserted stigma.

Inheritance studies in 18 cross combinations involving three CMS lines [V 20A (WA type), Pankhari 203 A (TN 1 type) and Wu 10 A (BJ type) showed that six partial and effective restorers each for V 20 A and Pankhari 203 A are governed by two dominant fertility restorer genes. The six partial restorers of WU 10A were governed by a single dominant gene. The penetrance and expressivity of the fertility restorer genes are influenced by the environment and nature of CMS lines used.

The fertility restoration of induced genetic male sterile lines was governed by two pairs of recessive genes in Samalei MS and Annada MS and by a single pair of recessive genes in Ratna MS and Annapurna MS.

Identification and evaluation of maintainers and restorer lines. Seeds of 8 purified restorer lines (IR 46 R, IR 64 R, IR 29723-143-3-2-1 R, IR 13419-113-1 R, IR 28178-70-2-3 R, IR 21916-128-2-2-3 R, IR 19058-107-1 R, IR 25912-63-2-2 R, IR 29512-81-2-1 R and IR 193-92-211-1 R) are being multiplied for sharing with the different hybrid rice centres in India.

Studies on heterosis for development of hybrid rice. (i) Heterosis, heterobeltiosis and standard heterosis were studied in 136 F_1 s hybrids resulting from a Line x Tester mating design. For yield, heterosis ranged from 27.1 to 112.3%, heterobeltiosis from 36.2 to 95.4% and standard heterosis from 29.6 to 76.6%. Positive heterosis, heterobeltiosis and standard heterosis ranged from 0.6 to 112.3%, 1.3 to 95.4% and 1.6 to 76.6%, respectively.

In a separate study, 104 hybrids showed significant positive heterosis (15.2 to 112.3%), whereas 77 hybrids showed significant positive heterobeltiosis (13.5 to 95.4%). Positive significant standard heterosis was observed in 50 hybrids (11.7 to 76.6%). More than 20% heterosis, heterobeltiosis and standard heterosis were recorded in 99, 63 and 23 crosses, respectively. Amongst the crosses, Zhen Shan 97A x Tetep was the top yielder followed by V 20 A x Pokkali, V 20 A x Tetep and V 20 A x Jayanti.

(ii) Heterosis studies on physiological and biochemical traits showed that in general, F_1 hybrids showed higher total dry matter and leaf area index than the parents. The F_1 hybrid, V 20A x PR 106 showed highest total dry matter and leaf area index. Average photosynthetic rate in two F_1 hybrids (V 20A x Himdhan and V 20A x Tetep) exceeded the better parent. The rate in F_1 hybrid, Zhen Shan 97A x Tetep exceeded the mid-parental value while V 20A x Himdhan showed highest photosynthetic rate.

Total (reducing and non-reducing) sugars were more in the root and stem of the hybrids compared to the parents. This indicated that synthesis of total sugar content in the leaf of the

hybrid dropped at the time of heading. Protein content was higher in the hybrids than in the parents. This showed that the nitrogen metabolism in the hybrids was high. The total amino acid contents in the root, leaf and stem were more in hybrids than in the parents. Catalase activity was more in the hybrids than in the parents. Low peroxidase activity was observed in the hybrids than in the parents.

(P.J. Jachuck; S.N. Ratho and R.N. Rao)

A promising hybrid line CR 588-322, selected from a cross V 20A x IR 9852-39-2 yielded 4.0-4.5 t/ha with a duration of 115-125 days. This culture with a medium slender grain ranked seventh in the Zone-6 of the Preliminary Variety Trial-2 of DRR in *kharif*, 1988.

(N.P. Sarma and G.J.N. Rao)

PB. 07. Varietal Improvement for Rainfed Upland Conditions

Sixty promising breeding lines and productive mutants were evaluated for yield and duration during *kharif* season under direct-seeded upland conditions. Rainfall distribution was normal and crop was not exposed to moisture stress. Cultures CRM 6-5-90 (4.1 t/ha), CR 693-57 (3.5 t/ha) and CR 693-575 (3.5 t/ha) yielded better than the checks, Subhadra (3.0 t/ha), Annada (2.7 t/ha) and Kalinga III (2.9 t/ha).

(D. Chaudhary)

Kalyani II (CR 666-36-4), released in Orissa in 1988 , is probably the world's earliest rice variety. It matures in 62 days under direct-seeded condition. Yields of this variety in some locations of major rice growing states were as high as 4-5 t/ha .

(C. Gangadharan)

Fifty breeding lines from the crosses, Annada x Kalinga III, N 22 x Shankal, Kalinga III x White gora, CR 289-1008 x MW 10 and Ryllored x Palman were grown in *rabi*. The cultures viz. CR 635-9 , CR 634-1, CR 636-7, CR 569-1021, CR 628-2-38, CR 635 -49, CR 634-2, CR 677-23, CR 634-41, CR 670-4 and CR 635-20 were promising with yield potential of 4.0 to 5.0 t/ha and duration of 80-130 days.

Two hundred fixed lines were grown under rainfed upland condition in *kharif* season. Two promising cultures, CR 636-66 (3.9 t/ha) and CR 636-86 (3.8 t/ha) gave higher yield against the best check variety, Annada (3.5 t/ha).

(K. Srinivasulu and J.N. Reddy)

Table 6. *Promising cultures of different duration groups*

IET No.	Cross	Total duration(days)	Yield (t/ha)	Trial
11488	Ratna x ARC 5981	130	4.6	MRVT-2
11510	RP 79-5 x Phalguna	142	4.6	"
Ratna	Check	125	3.5	"
11452	CR 57-MR 1523 x IR 36	131	5.6	MRVT-3
11474	Vikram x IET 5845	135	5.4	"
Jaya	Check	128	4.8	"
11371	Pankaj x T 141	136	6.3	MRVT-4
10663	Pankaj x Swarnadhan	155	6.2	"
Savitri	Check	161	6.4	"

Heera (CR 544-1-2) with a duration of 68 days under direct-seeded condition was released in Orissa.

Tara (CR 404-48) with a duration of 100 days under direct-seeded condition and having resistance to gall midge, BPH, WBPH, GLH and RTV was released in Orissa.

Several sister-lines of Heera were also found suitable for rainfed uplands/drought-prone areas with a duration ranging from 65 to 90 days and yields ranging from 2.57 to 4.59 t/ha.

These cultures took 7 to 10 days more when grown in the *rabi* season and gave 10 to 15% more yield compared to *kharif* season.

(J. K. Roy)

PB. 08. Assessment of Breeding Material Received from Different Sources (Coordinated Trials)

National coordinated trials (DRR Programme). During *kharif*, 1988, three coordinated trials (MRVT-2, MRVT-3 and MRVT-4) with 203 breeding lines having built-in resistance to pests/diseases received from DRR and six checks were conducted under unprotected conditions to assess their yield potential (Table 6) and reaction to major pests and diseases, prevailing at CRRI, Cuttack. The incidence of pests and diseases was very low.

International trials (IRTP & SAARC Programme). The coordinated trials viz. IRYN-VE, IRYN-E and IRRSWYN (M) of International Rice Testing Programme (IRTP) and the first SAARC multilocational trial for rainfed lowlands were conducted during *kharif*, 1988.

The promising entries, suitable for different land situations are IR 50 (IRYN-VE) and IR 4228-2-1-3-2-2 (IRYN-VE) for rainfed uplands, IR 31787-85-3-3-3-2 (IRYN-VE) and IR 3593-125-3-2-3- (IRYN-E) for medium lands and MR 15013-40-10-1-1 (SAARC- M) and RP 1486-833-1 (IRRSWYN-M) for rainfed lowlands.

(J.K. Roy and R.N. De)

PLANT PHYSIOLOGY

PH. 03. Photosynthesis and Productivity in Rice (National Fellow Project)

Considerable variation (3-fold) in net assimilation rate (NAR) at vegetative stage and photosynthetic rate (Pn) (1.5-fold) at flowering stage occurred among 60 each of traditional and high yielding varieties (HYV). The varieties exhibiting higher efficiencies are given in Table 7.

In general, Ptb 10 (local) and Swarnaprabha (HYV) recorded the highest NAR and yield in both wet and dry seasons. Local cultivars were generally efficient in dry matter production (DMP), LAI and Pn at vegetative stage while HYV were efficient at flowering and post-flowering stages. DMP depends on LAI in HYV and NAR in locals. NAR (20-40 D) had high positive association with specific leaf weight (SLW) suggesting its usefulness as a primary selection index for high NAR varieties. NAR is associated with CGR and RGR at 40 D-F and Pn at flowering stage. NAR at seedling stage (20-30 DAS) showed correlation (at 5%) with DM and yield indicating the scope for selection of productive types on the basis of seedling NAR. Pn at early stages is not always associated with that at later stages and varieties like Swarnaprabha showed better efficiency at reproductive and ripening stages. Pn is highly associated with Cs, Chl %, N_{LA} among which N_{LA} showed direct effect indicating its superiority over the other characters as a selection parameter for high Pn varieties (Fig.1). Pn showed negative relation with LAI, DM and yield whereas canopy or hill photosynthesis showed high positive relation with the above three parameters suggesting the dominating influence of LAI on dry matter and yield over that of Pn. The total duration showed negative association with Pn, the order being early > medium > late, while the yield was in the order, late > early > medium. The lowest yield in medium types is mostly due to high spikelet sterility %. Early types are more efficient at initial stages of growth, while the late types recorded high dry matter and sink size during the later growth stages ultimately recording high grain yield. In general, the major constraints for yield are low grain number/panicle in early, high sterility % in medium and low panicle number/m^2 in the late duration varieties. Among selected varieties, Swarnaprabha (early), CR 157-190 (medium) and Savitri (late) showed high productivity which is associated with low initial vigour, high DM at flowering and harvest with high HI. Pn increased with N up to 90 kg/ha with corresponding increase in N_{LA}; at higher N

Table 7. *Varieties with high efficiency in net assimilation rate at vegetative stage*

Parameter	Group	Early	Medium	Late
NAR	HYV	Swarnaprabha	Prabhat	Samalei
	Traditional	Panki	Bam 11	FR 13A, Bam 3
		B. gora	T 141	
Pn	HYV	Ratna	CR 157-190	CR 1018

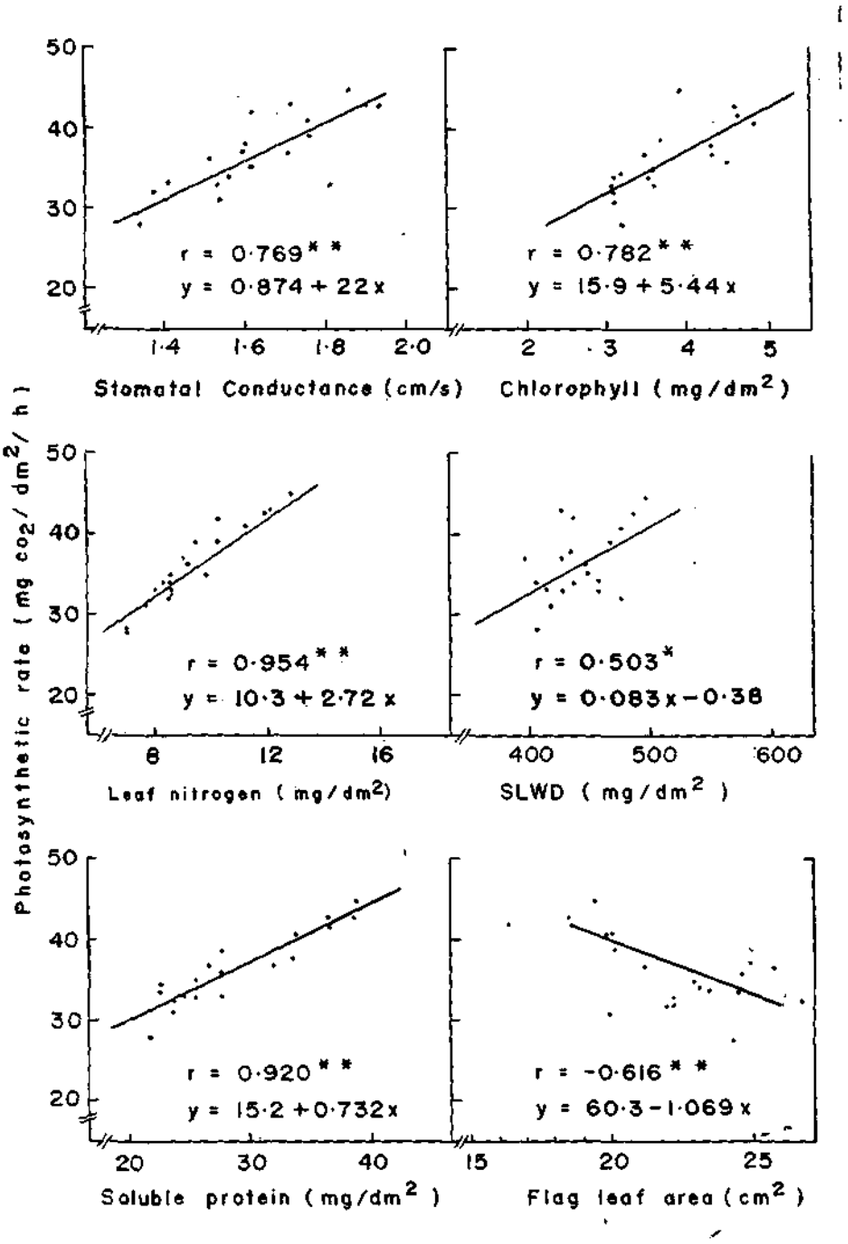

Fig.1 *Association of photosynthetic rate with different leaf characters in early rice varieties*

rates (> 90 kg/ha), leaf expansion was more pronounced than increase in N_{LA} leading often to lower Pn. Yield levelled off beyond 60 N especially in wet season and Swarnaprabha consistently gave highest yield at such moderate N levels. The Pn was also high in Swarnaprabha at lower N rates, because of high N_{LA} content. Pn and associate leaf characters, hill Pn, TDM, N uptake, CGR and yield were higher in dry season than in wet season while LAI, LAR, Chl %, N_{GA} and spikelet sterility were more in wet season . Pn and associate leaf characters decreased from 30 to 50 D and increased marginally at flowering. LAI, SLW, hill Pn, N uptake and CGR increased, whereas NAR, RGR, LAR and soluble N decreased with stage of the crop. Among selected 20 varieties, Co 41, Ptb 10, Swarnaprabha and Adt 32 showed highest Pn at all stages, while LAI, TDM, N uptake and CGR followed the reverse order at vegetative stage. However, at reproductive and ripening stages, Swarnaprabha is superior to others followed by Ptb 10, Co 41 and Adt 32. Irrespective of high light intensity, a mid-day depression in Pn of the boot leaf was apparent. Pn increased during the day up to 10 a.m., decreased during mid-day and then increased from 1.30 p.m.to 3.30 p.m. before a steep decline at 5.00 p.m. Ptb 10 consistently showed highest value during the entire day. Light saturation for photosynthesis was observed at 40 K1x in the low light adapted varieties like Swarnaprabha as compared to about 50-60 K1x in Ratna adapted to high light intensity. Swarnaprabha consistently showed high Pn in the low light developed leaves at lower light intensities while Ratna was superior to Swarnaprabha only at high light intensities. In the F_1 hybrids from the conventional crosses the low Pn parent was dominant. Heterosis for LA was high (20-30%) in th hybrids derived from cms lines. There is a need to identify best restorer combinations for specific cms lines to get high heterosis in both Pn and LA.

(K.S. Murty and V.P. Singh)

PH. 04. Climate in Relation to Growth and Yield of Rice

Influence of natural solar radiation and temperature. Monthly planting experiments conducted from January to September (planted in the last week of each month) with two early varieties, Ratna and Swarnaprabha showed that January and February plantings in *rabi* season and June and July plantings in *kharif* season gave higher yield in both the varieties. Higher yields from planting in these months were attributed mostly to more solar radiation and low night temperature during flowering and ripening periods of the crop. Swarnaprabha yielded more than Ratna in all the plantings mostly due to more grains/m^2 and higher harvest index.

Low light adaptability of late duration cultures. Screening for low light adaptability at seedling stage and later stage of growth of 31 late duration cultures both in greenhouse and field during *kharif* season revealed that the seedlings of the varieties suitable for low light conditions are characterised by less reduction of total dry weight per seedling, high total dry weight, taller plants and larger leaf area. Higher percentage (60%) of survival in complete darkness for seven days could also be taken as a parameter for screening seedlings for low light conditions. Yield of the plants grown under shade were associated positively with TDM at flowering ($r = 0.511^{**}$), harvest index and grain number per unit area at harvest ($r = 0.841^{**}$ and 0.547^{**} respectively) and negatively with sterility percentage ($r = -0.684^{**}$). Multiple regression coefficient showed that TDM at flowering both at normal light and shade positively contributed to yield by 52.4 and 27.7%, respectively. In multiple

regression analysis, TDM at harvest and harvest index were only responsible for yield up to more than 99% both in light and shade. Higher yields were obtained with FR 13A (7.1 t/ha), B 76 (6.4 t/ha) and T 90 (6.3 t/ha) under normal light , and with AC 2811 (2.4 t/ha), BR 8 (2.3 t/ha), B 76 (2.2 t/ha) and FR 13A (2.0 t/ha) under shade.

(G. Sahu)

PH. 05. System Analysis and Simulation Modelling for Rice Crop Growth and Production

Quantification of different physiological parameters. Calculation of daily canopy photosynthesis : (1) Effect of temperature on PLEA, (2) Effect of temperature on PLMX (max. photosynthetic rate) and (3) Quantification of PLMX and initial light use efficiency (PLEI) were properly defined in the programme. The programme also takes care of the dead leaves in the canopy (as they only reflect radiation but neither absorb nor transmit radiation). Data for SLW, radiation and ambient CO_2 concentration are fed into the programme as dynamic variables. The model automatically integers the defined parameters with their quantifications and calculates daily canopy photosynthesis at a given place of the globe. Attempts are made to sub-divide a canopy into different vertical profiles and introduce more intricate yet governing traits like leaf angles and radiation characters.

Simulation modelling on light stress conditions. The photosynthetic measurements were recorded at lower radiation levels of the day from 8.00 to10.30 a.m. at maximum tillering and primordial initiation for 6 varieties (Swarnaprabha, Co 41, Ptb 10 , Adt 32, Ratna and MW 10).The initial slope (hyperbola) pattern pertaining to photosynthetic response in relation to radiation differed distinctly in normal and shade adaptable varieties. This relationship in the model (LIQ.CSM) is described as PLEA = PLEI* AFGEN (PLETT, TPAA). PLEI is the initial efficiency use of absorbed light by individual leaves as PLEA. PLETT is the effect of temperature on photosynthetic curve and TPAA is temperature average. Computation of canopy photosynthesis depends essentially on the quantification of PLEI value more precisely under reduced light intensities (Table 8) . Distinct variation was noticed in PLEI which was finally

Table 8. *Maximum photosynthetic rate at different light intensities and PLEI*

Variety	PLEI ($kg/ha/h/J.m^{-2}\ sec^{-1}$) (monitored from 8.00 to 10.30 a.m.)	PLMX (kg/ha/h) (normal light)	PLMX (kg/ha/h) (reduced light simulated)
Swarnaprabha	0.41	42	32
Co 41	0.39	42	30
Ptb 10	0.38	39	27
Adt 32	0.36	38	24
Ratna	0.39	41	29
MW 10	0.38	40	23

Mean of 4 replications and 2 stages by ADC IRGA- (Portable Model)

reflected in their maximum photosynthetic rate (PLMX). Shade adaptable varieties like Swarnaprabha, Co 41 and Ratna showed higher PLEI value than MW 10, Ptb 10 or Adt 32 under low light . Thus, PLEI is one of the shade adaptable parameters which is further confirmed from the behaviour of the model.

(S.K. Nayak)

PH. 06. Growth and Productivity in Late Duration Cultures under Waterlogged Situations

Lowland pool trial. To evaluate the performance of the late duration, lowland cultures developed at this Institute , a pool trial was conducted during *kharif* with 120 entries under intermediate water depth. Ten cultures viz., CR 670-37, CR 671-19, CR 499-7, CR 491-47, CR 626-26-10, CR 626-26-D-2-3, CR 617-16-D-10-2, NC 492, CN 579-363--3-1 and CN 571-231-236-15-1, produced more than 5 t/ha grain yield and were characterised by higher total dry matter (TDM) at flowering, harvest and higher harvest index (25-36). In general, the cultures which had recorded high TDM (about 200 g/ m^{-2} from flowering to harvest) gave more than 3 t/ha grain yields under waterlogged conditions.

(G. Ramakrishnayya and R.N. De)

Evaluation of UVT 5 cultures (All India coordinated trial). IET 10009 (CN 644 x Patnai 23), IET 10008 (CN 644 x Patnai 23), IET 10030 (Velki x Mahsuri) and IET 10115 (Jhinga-sail x CN 644) gave better grain yields (3.6-4.0 t/ha) than the local check CR 292-5258 (3 t/ha). Further, these cultures had higher grain number m^{-2} (28,000--36,000) than the check (27,000), but had moderate EBT m^{-2} (180-230 as coompared to 250 in check). However, these cultures possessed higher TDM at flowering and at harvest (13-17 t/ha) and greater DMP from flowering to harvest.

Seedling stage drought tolerance. Drought tolerance of waterlogged late duration cultures (UVT 5, and CR cultures) at seedling stage was studied during *rabi.* The cultures CN 540, CR 292-5258, CR 260-77, IET 9071, IET 10016, IET 10021 and Jagannath showed a fair degree of tolerance to induced soil moisture stress by displaying high leaf water potential (5-14 bars) and relative water content (50-91) almost at par with drought tolerant types like CR 143-2-2 and Lalnakanda 41. Consequently, these cultures recorded high stomatal conductance (1.5-2.2 cm s^{-1}) and photosynthetic rate (24-35 mg CO_2 dm^{-2} hr^{-1}). The cultures, IET 9071, IET 10016, IET 10021, CN 540 and CR 292-5258 also gave optimum grain yields (3--4 t/ha) during *kharif,* 1987 and look promising for growing under rainfed lowland conditions normally prone to seedling stage drought.

(G. Ramakrishnayya)

Photosynthesis in selected late duration cultures at flowering stage. The photosynthetic rate (Pn) of 80 cultures from lowland pool trial (PH. 06.01) at flowering ranged between 22 and 47 mg CO_2 dm^{-2} h^{-1}. However, the cultures with grain yield of more than 5 t/ha had Pn values ranging between 30 and 40 mg CO_2 $dm^{-2}h^{-1}$

(G. Ramakrishnayya and V. P. Singh)

Carbohydrate and soluble amino acid contents. Carbohydrate and soluble amino acid contents were determined in four waterlogged cultures at seedling stage under submergence. The starch content in the culm of less tolerant type Jagannath was higher than in the culm of moderately tolerant and more tolerant types before submergence. This trend was reversed after 10 days of submergence. The trend of the series remained unchanged. In Jagannath, reducing sugar was also more in culm and root than in tolerant types, before submergence. Upon submergence for 10 days, reducing sugar content

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decreased by 5% in culm and about 25% in root of Jagannath; the culm sugar increased especially in the highly tolerant type NC 492 (30%). However, in plants, reducing sugar content decreased considerably in all the four types.

(G. Ramakrishnayya, R.N. De and S.B. Lodh)

Foliar application of growth substances. In a study on the effect of exogenous application of IAA and GA on the tolerance of rice cultivars to semi-deep water situations, the plant height increased in all the treatments (different combinations of IAA and GA) except in treatment receiving 100 ppm IAA alone. The maximum elongation was recorded with 100 ppm GA spray alone. At harvest, all the seven treatments including the treatment receiving 100 ppm IAA alone recorded higher grain yield than the control. The grain yield was highest in the treatment with 50 ppm IAA + 50 ppm GA. The increase in grain yield after spraying of growth substances was mainly due to higher panicle number/unit area.

(D.P. Bhattacharjee)

PH.07. Selection and Characterisation of Varieties with Increased Light Harvesting Efficiency (PL-480 Project)

Varietal variation. During dry season (December-May), 53 high yielding varieties were evaluated for photosynthesis (Pn) and productivity. Nearly two-fold variability was observed in Pn 26.8 to 41.8 mg dm^{-2} hr^{-1} at 30 days after planting (DAP) and 24.2 to 45.0 mg CO_2 at flowering stages of growth. Cultivars Ptb 10, Co 41 and Ratna recorded high Pn values of more than 40 mg CO_2 m^{-2} h^{-1}. Positive correlation between Pn at 30 DAP and flowering ($r = 0.950$ **) indicated that the varieties were consistent in this trait which is a varietal character. Stomatal diffusive conductance was positively correlated with Pn ($r = 0.934$ **), which can be used as a technique for preliminary screening of varieties for high Pn. No correlation was observed between Pn with either dry matter production (DM) or yield while its relation with leaf area index was even negative ($r = -0.294$). The leaf area index at flowering was positively correlated with TDM at flowering ($r = 0.887$ **), TDM at harvest ($r = 0.472$ **) and grain yield ($r = 0.364$ **) . The product of Pn and leaf area also showed positive association with the above attributes indicating that the positive influence of canopy photosynthesis with productivity and yield was through LAI. The dry matter production during reproductive and ripening stages of growth was positively associated with yield ($r = 0.452$** and 0.385** respectively) through their association with spikelet and grain number/m^2 respectively ($r = 0.291$* and 0.428*).

During wet season (June-December), 15 early, 24 medium and 22 late traditional local varieties were evaluated for photosynthesis and productivity. The range of variability in Pn was 25.9–54.0 and 17.0–44.8 in early, 17.6–65.8 and 11.0–58.5 in medium and 21.3–63.9 and 14.6–50.9 in late duration varieties at 30 DAP and flowering, respectively. Cvs. Ptb 10 and Swarnaprabha (early), Jaya and Zinya 63 (medium), Anamica and AC 2178 (late) recorded more than 45 mg CO_2 dm^{-2} h^{-1} at 30 DAP. Data on average value of characters of early, medium and late varieties revealed no appreciable differences either in LAI or Pn or biomass production at 30 DAP. The bioproductivity and yield increased with increase in duration, because of increased leaf area and solar radiation received by the crop. The sterility of spikelets as high as 55 to 59% in early and medium group was due to low solar radiation during reproductive and ripening stages of growth. The late duration varieties recorded high grain yield because of high LAI, sink capacity and solar radiation during the filling period.

Influence of nitrogen on photosynthesis, bioproductivity and yield. Six early high yielding varieties Ratna, Pallavi, Adt 32, IR 36, Pusa 33 and Swarnaprabha were grown in a replicated trial (3 replications) in both dry and wet seasons under three levels of nitrogen (30, 60 and 120 kg N/ha). Increased levels of N increased leaf area index and photosynthetic rate in all the varieties at all stages of growth in both the seasons. In general, leaf area development was much less in dry season than in wet season and the leaf weight ratio at flowering did not exceed 25.0% in dry season even at 120 kg N/ha, the threshold value for N response. In wet season, the grain yield response to nitrogen was up to 60 kg N/ha only, while in dry season the grain yield increased up to 120 kg N/ha.

Influence of low light (shading) on photosynthesis and productivity in rice

Stages. Two levels of shading, 50 and 25% of normal light (NL) were given to 4 cultivars of rice (Ratna, Pallavi, IR 36 and Swarnaprabha) during vegetative, reproductive and ripening stages of growth with a control (normal light throughout). Shading during any period of growth reduced grain yield compared to control and the reduction was of higher order in 25% NL than in 50% NL. Least reduction in grain yield was noticed in shading during vegetative stage, while spikelet and grain number were reduced in shading treatments at reproductive and ripening stages respectively. The reduction in grain yield due to shading was higher in Ratna and IR 36 than in Pallavi and Swarnaprabha.

Nitrogen response. Ratna and Swarnaprabha were grown at 4 levels of N (30, 60, 90 and 120 ppm) and two light regimes (normal light and 50% NL) . At vegetative stage the effects of shading were less, and the influence of graded levels of nitrogen was markedly more, while during the ripening period the reverse was the case.

Plant type. Two high yielding plant type varieties (Ratna and Pallavi) and two traditional tall varieties (Ptb 10 and Swarnaprabha) were grown in 4 light regimes NL, 75, 50 and 25% NL. The dry matter and grain yield were reduced linearly with decrease in light regime. Low light , in general, enhanced vegetative growth resulting in reduced harvest index. Cv. Ptb 10, a traditional local was tolerant to low light, charac- terised by maintaining same harvest index and leaf area in all the shading treatments.

Different light intensity. In a study on the effect of gradual reduction in light intensity (75, 50, 25% of NL) (40 DAP-Hvt.) on four early varieties (Ratna, Pallavi, Swarnaprabha and Pusa 33) in dry and wet sesons, the adverse influence of low light was more pronounced at 25% NL than at 75% NL in the increasing order : stomatal frequency (SF), N_{LA}, soluble protein, SLW, Cs and Pn in the leaf characters, RGR, TDM, CGR and NAR (40 D-flowering) in growth parameters and in 1000-grain weight, panicles/m^2, grains/m^2 ,TDM and yield at harvest. However, N %, LAI, Chl a, Chl b, at flowering and sterility % at harvest increased gradually with reduction in light intensity. In general, Swarnaprabha showed less reduction in different parameters at all low light treatments.

Physiological efficiency of restorers. Twenty-six restorers generally used as male parent with various cytoplasmic male sterile (cms) lines to produce hybrid rice were tested for their physiological efficiency. Restorers varied among different parameters. IR 29512-18-2-1 R with highest total dry matter (at flowering and harvest), leaf area index and crop growth rate recorded the highest yield (641 g^{-2})

(Ch.N. Rao and V.P. Singh)

PH. 08. Chemical Regulations in Rice

Induction of lodging resistance. Induction of lodging resistance was effected in Vanaprabha,

a lodging prone variety with foliar spray of boron (20 ppm at tillering + 10 ppm at booting), 2,4-D (10 ppm) + boron (20 ppm), boron (10 ppm) at tillering and 2,4-D (10 ppm) at booting. Higher lignification in culm vascular tissues over untreated control was visually observed.

Regulators for crop productivity Triacontinol (melissyl alcohol, commercial product Tomco Tria B, and HICO 110 R) which reportedly delays senescence and enhances partition efficiency to targetted organs in cereals was tried with appropriate surfactants to penetrate the silicified leaf tissue. Higher LAI, delayed senescence and grain numbers were noticed at various dosage (2 ml/l, overall spray 1–3 times) levels.

(T.R. Dutta and Ch.N. Rao)

BIOCHEMISTRY

BIO. 01. Evaluation of Rice Varieties for Biochemical and Technological Qualities

Scented rice. Twentyone long slender scented rice genotypes of Basmati 370, nominated by the Directorate of Rice Research, Hyderabad and grown at Kapurtala and Kaul, were analysed for certain quality characters (Table 9) and better ones were subjected to objective panel test for consumers' preference. Based on chemical indices related to quality characters, IET nos. 8365, 10361, 10362, 10367, 10369, 10648, 10652, 10653 and 10654 were rejected. The cultures with IET nos. 10363, 10364, 10365, 10366, 10368, 10649, 10650, 10651, 10655 and Basmati 370 were subjected to organoleptic test for determining eating quality for the following criteria: (1) appearance of cooked rice, (2) tenderness (on touching) of cooked rice kernels, (3) consistency of cooked rice, (4) smell of cooked rice kernels, (5) chewing characteristic, (6) taste and (7) overall acceptability. Depending on eating quality and scent, the IET nos. 10363, 10364, 10365, 10366, 10368, 10649, 10650, 10651 and 10655 were graded nearer to Basmati 370.

Effect of fertilizer treatment on quality attributes of promising scented rice cultures. Four promising scented rice cultures *viz.*, (i) Basmati 370 (Pakistan), (ii) IET 8579, (iii) Basmati 370 and (iv) IET 8580 were grown by the Division of Agronomy of this Institute during *kharif*, 1987 under four nitrogen levels (N_0, N_{30}, N_{60}, and N_{90}) in triplicated trial.The corresponding samples were analysed for quality characters. Application of N fertilizer (i) reduced head rice recovery by about 2 and 5% at 60 and 90 kg N/ha respectively, (ii) increased elongation ratio and (iii) increased amylose content. There was no adverse effect of nitrogen fertilizer on alkali value,

Table 9. *Quality characters of long slender scented rice (Basmati 370 type)*

Description of culture	Head rice (%)	L/B ratio	Kernel colour	Alkali value	Water uptake	Vol. Expansion	Elongation ratio	Amylose (%)
10363 Pusa 167/Karnal local	59.0	3.79	White	5.0,4.0	305	4.0	1.67	16.04
10364 Pusa 167/Karnal local	60.0	3.94	-do-	4.0,3.0	300	4.4	1.67	17.25
10365 Chambal/Basmati 370	570	3.87	-do-	6.0,5.0	405	3.7	1.50	16.60
10366 Sona/Basmati 370	63.0	3.53	-do-	6.0,5.0	415	4.0	1.60	16.30
10368 Sona/ Basmati 370	53.5	3.77	-do-	3.0,2.0	235	3.7	1.57	17.51
10649 Pusa 167/Karnal local	65.0	3.57	-do-	6.0,5.0	365	4.0	1.74	17.51
10650 Pusa 167/Karnal local	67.0	3.71	-do-	4.0,3.0	295	4.2	1.81	17.00
10651 T(N)1/Basmati 370	65.5	3.75	-do-	3.0,2.0	250	4.1	1.65	17.25
10655 Pusa 150 mut./NR 130-2	53.5	3.65	-do-	4.0,3.0	315	3.7	1.41	15.20
Basmati 370 (check)	59.0	3.48	-do-	3.0,2.0	225	3.7	1.59	15.54

Table 10. *Quality characters of certain promising rice cultures (Rainfed Upland Rice Research Station, Hazaribagh)*

Culture	Accession No.	Head rice (%)	Classification	Kernel colour	Alkali value	Water uptake	Vol. Expansion	Elongation ratio	Amylose (%)
Nagpur-22	11	57.95	SB	White	4.0,3.0	345	4.0	1.75	17.28
Brown Gora	14	49.33	SB	Red	3.6,2.6	340	4.0	1.76	19.09
Kalakari	17	43.06	SB	Red	4.0,3.0	345	3.6	1.81	19.88
Salempikit	20	65.56	SB	White	4.0,3.0	365	4.0	2.05	19.05
Panke	23	62.85	SB	Red	3.0,2.0	350	3.6	1.78	17.54
ARC 11775	429	48.65	SB	White	3.0,2.0	360	4.0	1.91	17.74

volume expansion and water uptake. Application of 60 kg N/ha during growth of scented rice has no adverse effect on quality attributes including aroma.

Non-scented rice from Hazaribagh. Thirty promising collections from Rainfed Upland Rice Research Station, Hazaribagh were analysed for quality characters. Certain short bold cultures had excellent elongation ratio and other quality characters (Table 10). Among the cultures evolved at CRRI, CR 544 and CR 666 were most promising (Table 11). Quality attributes of promising cultures, evolved or collected by different Institutes in the country, were analysed- Ranbir Basmati from Sher-E-Kashmir University of Agriculture and Technology and certain short bold cultures (1727-M-2) from Kerala Agricultural University were promising.

(S.B. Lodh, A.B. Dash and S. Das)

Non-scented rices of CRRI. Of the 15 cultures (CR 544-1-1, CR 544-1-2, CR 544-1-3-4, CR 544-1-4, CR 544-1-6, CR 544-1-7, CR 544-1-15, CR 544-1-14, CR 404-6, CR 404-12, CR 404-20, CR 404-47, CR 404-62, CR 404-14-1, and 407-6-2) evaluated with checks, CR 404-62 was identified as the best good quality rice.

(B.B. Nanda)

Table 11. *Quality features of certain promising cultures of the Institute*

Culture	Head rice (%)	L/B ratio	Classification	Kernel colour	Alkali value	Water uptake	Vol. Expn.	Elongation ratio	Amylose (%)
CR 544-1-1	59.5	2.58	LB	White	3.0,2.0	230	3.7	1.52	18.62
CR 544-1-2	57.0	2.44	LB	-do-	3.3,2.3	225	3.6	1.57	18.88
CR 98-8081	63.0	2.60	LB	-do-	3.0,2.0	225	3.7	1.43	18.62
CR 146-7063	60.0	3.11	LS	-do-	7.0,7.0	360	4.0	1.53	16.46
CR 149-206	53.5	2.36	LB	-do-	3.0,2.0	285	3.7	1.47	18.03
CR 666-362	63.5	2.52	MS	-do-	3.0,2.0	225	4.0	1.73	18.56
CR 666-36	44.0	2.62	LB	-do-	3.0,2.0	230	4.0	1.63	19.11

BIO. 02. Studies on Oxidative and Hydrolytic Enzymes in Developing Rice Plant

Phosphorus was applied as basal dose at 0, 30 and 60 kg P_2O_5/ ha to the rice crop transplanted to alluvial soil in pots. Application of phosphorus increased phosphatase activity over the untreated control especially at maximum tillering stage. At maturity, the shoot and root phosphatase activity declined to low levels when compared to earlier growth stages.

Rice seedlings were grown in alluvial and laterite soils contained in earthen pots at 0, 250 and 800 mg P levels. The samples were uprooted and washed thoroughly before determination of acid phosphatase activity. The seedling showed lesser phosphatase activity when grown on laterite soil than on alluvial soil. But, difference in activity was not significant.

(B.B Nanda, S. Das and S.B. Lodh)

BIO. 03 Evaluation of Grain Hardness of Early Cultures, Released Varieties and its Correlation with Quality Features

Four early cultures (CR 666-20, CR 666-42, CR 666-63 and CR 666-78 of 70, 70, 68 and 100 day duration) were milled at lower (4.3–4.7%) and higher (8.0–9.4%) degrees of milling. The head rice yield in CR 666-20, CR 666-42, CR 666-63 and CR 666-78 was 49.1, 50.8, 47.9 and 31.3%, respectively at lower degrees of milling and 37.7, 45.4, 43.4 and 30.7%, respectively at higher degrees of milling. According to grain dimensions, these cultures were classified as long bold, medium slender, long slender and long bold, respectively. The water uptake (ml/100g milled rice) ranged from 150-160 in three cultures and 215 in CR 666-78. The kernel length after cooking ranged from 9.0–10.4 mm and elongation ratio from 1.32–1.58. The amylose content ranged from 16.7–17.8% after lower polish (0.5 min polishing) and from 17.2–18.3% after higher polish (1 min polishing) indicating a lower amylose content at lower polish. The brown rice protein content ranged from 5.6 to 7.3%. The protein content was highest in CR 666-42 and lowest in CR 666-78.

(M.N. Sahay and S. Das)

BIO. 06. Studies on Technological and Nutritional Qualities of Rice Grain Available from Different Agro-Practices of Harvesting, Threshing and Drying (Completed Project)

A preliminary investigation was conducted in 1981 and two final trials during 1982-87 with the following treatments: (i) Crop harvested wet, immediately threshed and grain sun-dried (12-14% moisture) at ambient temperature, (ii) Crop harvested wet, left in rows on the bund for 7 days then threshed and the grain dried as in T_1; (iii) Crop harvested wet, left in rows on the bund for 7 days, bundled and stacked in the open for 21 days, covered with tarpauline/straw, then threshed and grain dried as in T_1; and (iv) Crop harvested wet, immediately threshed and grain dried in an oven. Two trials were conducted during the period. Rice varieties Ratna, and Annapurna were used in 1st trial and Savitri in 2nd trial.

Trial I. The crop was harvested at 18 ± 0.14% moisture for Ratna and 24 ±0.29% for Annapurna. The stack was kept on floor at ambient temperature (25.7 to 33.9^{0}C). The temperature inside the stack was 30-38^{0}C. Rainfall ranged from 0 to 11.4 mm during the period of stacking. Rain before threshing wetted the grain in treatment T_2 and the stack in T_3. Discolouration of the grains was prominent in treatment T_3 for both Ratna and Annapurna. Treatment T_3 rendered the grain of Annapurna unfit for milling but had less effect on grain from Ratna. In treatments T_2 and T_3, the grain germinated. Delay in handling resulted in mold formation and germination.

Table 12. *The effect of processing conditions on yield and protein content of rice*

Treatment	Ratna						Annapurna					
	Yields (% of rough)				Protein (%)		Yields (% of rough)				Protein (%) in	
	Shelling	Milling	Head rice	Broken	Brown rice	Polished rice	Shelling	Milling	Head rice	Broken	Brown rice	Polished rice
T_1	76.4 ±0.25	71.9 ±0.70	62.0 ±0.93	9.9 ±0.55	7.8 ±0.03	7.5 ±0.03	73.7 ±0.37	70.3 ±0.36	47.2 ±0.44	23.1 ±0.79	6.7 ±0.03	5.8 ±0.03
T_2	75.1 ± 0.41	70.1 ±0.17	49.8 ± 0.64	20.3 ±0.33	7.9 ±0.12	7.7 ±0.12	72.3 ± 0.76	67.3 ±0.22	37.3 ±0.66	30.2 ±0.52	6.8 ±0.06	6..1 ±0.06
T_3	71.3 ±1.13	66.3 ±0.82	38.2 ±0.20	28.1 ±0.15	8.8 ±0.03	8.6 ±0.32	ND	ND	ND	ND	ND	ND
T_4	75.1 ±1.47	71.1 ± 0.35	60.9 ± 0.38	10.2 ±0.06	7.9 ±0.06	7.6 ±0.03	73.3 ±0.39	70.0 ±0.29	44.8 ±1.27	25.2 ±1.22	6.8 ±0.03	6.0 ±0.06

Treatments : T_1, T_2, T_3 and T_4 - See text.
ND = Not determined

Effect of milling. The hulling yield of Ratna varied within a narrow range in T_1, T_2 and T_4, but was comparatively low in T_3. The trend was similar in Annapurna with complete spoilage in T_3. The milling yield of Ratna was highest in T_1 and lowest in T_3. The trend was similar in Annapurna for treatments T_1, T_4 and T_2 respectively and complete spoilage in T_3. Thus, for both varieties treatment T_3 had a detrimental effect and treatment T_2 resulted in lower milling yield of Annapurna (Table 12). The head rice yield of Ratna was highest in treatment T_1 and lowest in T_3. The trend was similar in Annapurna with complete spoilage of grain in T_3. For both varieties, the head rice yield was lower after oven drying (T_4) compared to sun drying in T_1 indicating the importance of slow drying. Head rice and milling yields from all treatments were higher for Ratna than Annapurna. Breakage showed a reverse trend to head rice yield. Protein content of brown and polished rice did not vary among the treatments except in Ratna in treatment T_3. Ratna grain showed a slightly higher protein value compared to protein content of Annapurna in the respective treatments. The protein content of brown and polished rice of the two varieties differed considerably in all treatments and was higher in Ratna than in Annapurna. Brown rice protein was higher than polished rice protein. Protein status is thus not affected by harvesting and threshing practices. Maximum fungal colonies were observed in T_3 followed by T_1 and T_4 in Ratna. The trend in Annapurna was similar with 232,123 and 22 colonies in T_2, T_1 and T_4, respectively. Presence of *Aspergillus parasiticus*, *Penicillium islandicum* and *A. flavus* showed similar trends in total number of colonies, with maxima in T_3 and T_2 and minimum in T_4. Least development was observed in T_4 as grains were dried in the oven. In all treatments growth of *A. parasiticus* was greater than that of *P. islandicum* or *A. flavus*. The aflatoxin contents were 2, 15, and 28 ppb in T_1, T_2 and T_3 of Ratna and 3 and 16 ppb in T_1 and T_2 of Annapurna.

(M.N. Sahay)

Table 13. *Effect of processing conditions on milling yield of paddy var. Savitri(means of five replicates)*

Treat-ment*	Yield (% of rough rice)						
	Hull** (%)	Hulled rice (%)	Wt. of bran (%)	Degree of milling***	Milled rice (%)	Head rice (%)	Broken rice (%)
Unclean rough rice							
T_1	22.5	77.5	6.9	8.9	70.6	60.3	10.3
T_2	22.5	77.5	7.4	9.6	70.1	51.9	18.2
T_3	21.2	78.8	7.2	9.1	71.6	49.5	22.1
T_4	22.8	77.2	6.9	8.7	70.3	13.4	56.9
C. D. (5%)	0.9	0.9	n.s	n.s	1.1	3.7	3.1
Clean rough rice							
T_1	20.3	79.7	3.6	4.5	76.1	72.4	3.7
T_2	20.0	80.0	4.0	5.0	75.9	68.9	7.1
T_3	19.4	80.6	4.2	5.2	76.4	63.9	12.5
T_4	20.2	79.9	4.8	6.0	75.0	27.8	47.2
C. D. (5%)	n.s	n.s	0.6	0.7	n.s	2.0	2.1

* Treatments : T_1. T_2. T_3 and T_4 - As in text

** Hull content includes extraneous matter among unclean rough rice.

Trial II. The project was continued with cv. Savitri to see genetic variability and to study new parameters of hardness, cooking quality and loss of protein at different levels of milling. The crop was harvested at 20.42 ± 1.20%(d.b.) moisture. The stack in this trial was covered with straw and oven drying was conducted at 80 ± 1°C. In T_3, the temperature outside stack (height 130-150 cm breadth 80–90 cm) was 26.5-31.3°C and inside the stack was 28.5-33.0°C. There was 1.5 mm drizzle on one day and the atmospheric humidity was 77–94% during the period of stacking. One lot of normally cleaned grains was removed and classified as uncleaned rough rice, whereas second lot was thoroughly cleaned and categorised as cleaned rough rice.

The mean grain moisture before milling was 11.2–11.6% in samples from T_1, T_2, T_3, and 8.1% in T_4 of the unclean rough rice and 11.9–12.5% in samples from T_1, T_2, T_3 and 8.6% in T_4 of the cleaned rough rice. The differences in hull, hulled and milled rices are significant only in T_3 and not in T_1, T_2 and T_4 (being at par) due to associated extraneous matter (Table 13). The average hull content of unclean and clean rice was 22.25 and 19.98%, respectively indicating a difference of 2.27% due to extraneous matter during normal cleaning. In clean rough rice, significant differences were observed in bran, degree of milling, head and broken rice but not in hull and hulled rice yields. Milled rice yield did not differ significantly. Bran and the degree of milling did not reveal significant differences due to narrow variation (0.9%) in degree (8.7–9.6%) of milling, but showed significant differences due to wider variation (1.5%) in degree (4.5–6.0%) of milling. The average recovery of hulled rice was 77.8% from unclean rough rice and 80.0% from clean rough rice resulting in 2.2% lower recovery of hulled rice due to improper cleaning.

Table 14. *Effect of processing conditions on quality features of rice var. Savitri (means of five replicates)*

Treatment	Hulled rice Length (mm)	Breadth (mm)	Length /Breadth(ml)/100g lm rice	Water uptake	Volume expansion (ratio)	Kernel length after cooking (mm)	Elongation ratio	Alkali (spreading) value	Hardness (breaking) (kg)	Amylose(%) lm[a] rice	hm[b] rice
T1	5.18	2.68	1.93	310	3.8	7.82	1.57	4.9	4.5	21.7	22.9
T2	5.15	2.67	1.93	309	3.8	7.84	1.57	4.2	4.0	21.9	23.0
T3	5.05	2.63	1.92	307	3.5	7.60-	1.53	3.8	3.5	22.0	23.2
T4	5.19	2.70	1.92	304	3.5	7.62	1.54	2.6	2.3	22.0	23.2
C.D.(5%)	n. s	n. s.	n.s.	n.s.	0.1	0.17	0.03	0.4	0.4	n.s	n.s

* Treatments : T1, T2, T3 and T4 - See text.

alm = lower degree of milling (4.5 - 6.0%).

Head rice yield showed signficant treatment differences. Though the degree of milling did not show significant treatment differences in T_1, T_2 and T_3, the head rice yield declined significantly from T_1 to T_3 and further in T_4 in samples from clean rough rice. These findings are substantiated by results of grain hardness which declined from T_1 to T_4. Delayed drying leads to reduction in head rice yield and increase in broken rice as in T_2. Piling the harvested crop further reduces the head rice yield as in T_3. The head rice yield is independent of total milled rice as revealed from the data of milled rice at both degrees of milling. Biodeterioration, production of fungus and aflatoxin and grain discolouration as reported in Trial I were not observed. No significant treatment differences in length, breadth and L/B ratio were observed (Table 14). The water uptake declined from treatments T_1 to T_4. Volume expansion ratios were at par in T_1 and T_2 and among T_3 and T_4, but showed significant treatment difference from T_1 and T_2 to T_3 and T_4. Kernel length after cooking and elongation ratio showed significant treatment differences and the trend was similar to volume expansion ratio. Alkali spreading values declined significantly among the treatments. The hardness (breaking) declined from T_1 to T_4 indicating that the grains from the crop, immediately threshed and sun-dried (T_1) were harder than the grains from delayed processing (T_2 and T_3) or improper drying. Oven drying at high temperature (T_4) followed by adsorption of moisture resulted in lower breaking, hardness values (T_4) and in turn higher breakage during milling. The amylose content showed no signficant treatment differences. However, the mean amylose content of kernel was significantly less being 21.9% at lower degrees of milling compared to 23.1% at higher degrees of milling.The 't' statistics for comparison of mean values of amylose content between two degrees of milling is 11.1** at 6 d.f. Treatments caused no significant effect on protein content, whereas milling caused significant reduction in protein. The mean protein loss was 10.4 and 14.6% due to lower and higher degree of milling, respectively. Thus, additional protein loss was only 4.2% due to higher milling over brown rice protein.

(M.N. Sahay and S. Das)

AGRONOMY

AG. 12. Evaluation of Granulated Urea (6–8 mm) for Varieties of Different Duration Groups (Completed Project)

This DRR coordinated trial was conducted in *kharif* seasons of 1987 and 1988 to compare granulated urea (GU), 6-8 mm size, with prilled urea (PU) and urea supergranules (USG) applied either as a single dose or in different splits for varieties of different duration groups. A short duration (125 days) variety Ratna and a long duration (150 days) variety (Gayatri) were used in the study. Nitrogen was applied at 60 kg/ha. PU and GU were applied as all basal, two splits (2/3 basal and 1/3 at PI stage) and 3 splits (1/2 basal and 1/4 each at 21 DAT and PI stages) while USG was applied basally. A dose of 30 kg each of P_2O_5 and K_2O/ha was applied basally to all the plots uniformly.

Application of nitrogen in two splits (2/3 as basal and 1/3 at PI stage) either as PU or GU produced significantly higher grain yield of Ratna over other treatments (Table 15). But, application of nitrogen in three splits (1/2 basal, 1/4 each at 21 DAT and PI stages) either as PU or GU or single application of USG was superior to other treatments with long duration variety, Gayatri.

(K.S. Rao and B.T.S. Moorthy)

Table 15. *Grain yield (t/ha) of varieties of different durations as affected by methods of application of different forms of urea*

Treatment	1987 Varieties			1988 Varieties		
	Ratna	Gayatri	Mean	Ratna	Gayatri	Mean
Control	2.06	3.75	2.90	2.53	4.40	3.47
PU, all basal	2.43	4.16	3.30	2.82	5.19	4.01
GU, all basal	2.43	4.27	3.35	3.03	5.27	4.15
PU, 3 splits	2.43	4.82	3.62	3.49	5.98	4.74
GU, 3 splits	2.43	4.91	3.67	3.49	6.11	4.80
PU, 2 splits	2.88	4.46	3.67	3.78	5.49	4.63
GU, 2 splits	2.67	4.49	3.58	3.86	5.52	4.69
USG, all basal	2.37	4.12	3.55	3.32	5.15	4.24
Mean	2.47	4.45	3.29	5.39		
LSD (P = 0.05)	for varieties			0.20	0.37	
	for method of N application			0.22	0.31	
	for method of N application at the same variety			0.30	0.44	
	for variety at the same level of N application			0.29	0.44	

AG. 14. Submergence Tolerance and Recovery of Rice as Affected by Phosphorus Application

Field experiments were conducted under simulated flash flood conditions to assess the effect of varying levels of phosphorus (0, 20, 40, 60 and 80 kg/ha) on submergence tolerance of rice during the *kharif* seasons of 1985, 1987 and 1988. Photosensitive long duration (170 days) semi-dwarf variety CR 1016 was sown in dry soil by the first week of June in all the three years. A common level of 60 kg N and 20 kg K_2O/ha was applied along with P (as per treatment) at sowing. The crop was subjected to submergence of 90 cm water depth for 10 days at vegetative stage (75 days after germination). During rest of the growth period, the water depth ranged between 25 and 40 cm.

Rice plants subjected to submergence yielded significantly less than unsubmerged plants (Table 16). The decrease in yield was 196, 71 and 60% in 1985, 1987 and 1988 respectively. In 1985 and 1987, the interaction between submergence and P levels on grain yield was significant. Application of P made no difference in the crop grown under unsubmerged conditions. But grain yield of submerged rice significantly increased by 28 to 84% in 1985 and 33 to 49% in 1987 with P application up to 40 kg P_2O_5/ha and not beyond.

In 1988, the crop was sown in the same layout as that of the previous year. The response to P application was noted under both the conditions and interaction between P and submergence was not significant. This could be possibly due to the residual effect of P applied during 1987. The grain yield increased progressively with P appliation up to 80 kg P_2O_5/ha, but the increases beyond 20 kg/ha were not significant. Increase in yield was more conspicuous under submerged (203%) than under unsubmerged (33%) conditions, mainly because of higher initial vigour, early and synchronous tillering of the crop and higher number of panicles.

Nitrogen concentration in the plant increased under submergence. Phosphorus application increased N and P uptake before and

Table 16. *Effect of submergence and phosphorus levels on grain yield (t/ha) of rice (cv. CR 1016)*

P_2O_5	1985			1987			1988		
(kg/ha)	Submerged	Un-submerged	Mean	Sub-merged	Unsub-merged	Mean	Sub-merged	Unsub-merged	Mean
0	1.36	5.72	3.54	2.29	5.19	3.74	0.81	2.68	1.75
20	1.74	5.75	3.75	3.05	5.15	4.10	2.39	3.31	2.85
40	2.17	6.09	4.13	3.42	5.14	4.28	2.30	3.44	2.87
60	2.14	5.74	3.94	3.17	5.34	4.26	2.44	3.72	3.08
80	2.50	6.07	4.29	3.21	5.11	4.16	2.68	3.83	3.26
Mean	1.98	5.87		3.03	5.19		2.13	3.40	
L. S. D. (P = 0.05)									
Submergence levels		0.47			0.93			1.03	
P_2O_5 levels		0.27			0.32			0.43	
Interaction		0.39			0.46			NS	

after submergence as well as at harvest under both submerged and unsubmerged conditions. However, the effect of P was more pronounced under submerged condition.

The results over the three-year period indicate : application of 20 to 40 kg P_2O_5/ha was optimum for improving the submergence tolerance and yield of rice; the crop response to P application was noticed also under unsubmerged condition; and the increase in yield was more conspicuous under submerged than under unsubmerged conditons.

(M.M. Panda, M.D. Reddy and A.R. Sharma)

Effect of nursery management on growth and yield of rice under flash flood conditions. The effect of nitrogen application to nursery either alone or along with micro-nutrients like Zn and Mo, on growth and yield of rice was studied under flash flood conditions. Application of nitrogen to the nursery at 100 kg/ha either as basal or in split doses at 10 and 20 days before transplanting, Zn at 40 kg $ZnSO_4$/ha as basal and Mo at 110 g, NH_4MoO_4/ ha as spray was made over a common dressing of 20 kg of P_2O_5/ha. Seedlings (35-40 days old) were planted by mid-July with a common dose of 40 kg N and 20 kg P_2O_5/ha. Water depth at transplanting was 30 ±

Table 17. *Effect of nursery fertilization on grain yield (t/ha) of rice under flash flood conditions*

Treatment (given to nursery)	1985			1986	1987	1988		
	Gayatri (Semi-dwarf)	CN 540 (Tall)	Mean	Gayatri	Gayatri	Sub-merged	Unsub-merged	Mean
Control (no N)	0.38	4.50	2.44	0.87	0.89	0.83	2.10	1.47
Entire N (100kg/ha) as basal	1.85	4.67	3.26	2.50	1.29	2.94	3.39	3.17
50 kg N/ha as basal and 25 kg N each at 10 and 20 DBT	1.99	4.51	3.25	2.63	1.52	2.78	3.36	3.07
No basal N and 50 kg N each at 10 and 20 DBT	2.07	4.49	3.28	2.65	1.57	2.90	3.34	3.12
Treatment 3 + $ZnSO_4$ at 40 kg/ha	2.13	4.37	3.25	2.43	1.59	2.90	3.68	3.29
Treatment 3 + NH_4MnO_4 at 110 g/ha	2.30	4.38	3.34	2.33	1.82	3.06	3.46	3.26
Mean	1.79	4.49				2.57	3.22	
L. S. D. (P = 0.05)								
Varieties/submergence		0.66		0			0.43	
Nursery treatments		0.39		0.20	0.13		0.30	
Interaction		0.55					0.43	

DBT = days before transplanting.

5 cm in different years. The crop was submerged completely for 10 days at 30 days after transplatnting, and subsequently 20 to 35 cm water depth was observed in the field. In 1988, a non-flooded control was also included in the study.

Application of N to nursery inproved seedling vigour, plant height, dry matter accumulation and N concentration at transplanting, leading to a better tolerance of crop to submergence and higher productivity (Table 17). In 1985, the grain yield of semi-dwarf (90 cm plant height at harvest) variety, Gayatri increased by 3 to 5-fold due to different nursery treatments but such treatments had no effect on tall (130 cm) variety CN 540. The reduction in dry matter of Gayatri due to submergence was as high as 74% in the crop which received no nitrogen as against 26 to 47% in the crop receiving N fertilizer in the nursery. On the contrary, dry matter production of CN 540 increased by 189% and 89 to 156% without and with N application to nursery respectively during submergence, because plant parts were above water.

In 1986 and 1987, when the studies were conducted with semi-dwarf Gayatri only, the crop raised with seedlings from fertilized nursery produced 188 and 75% higher yield than the crop raised with unfertilized seedlings. The yield was lower in 1987 than in 1986 due to complete submergence of the crop immediately after transplanting for 4 days with turbid water and excessive damage by crabs.

In 1988, seedlings from fertilized nursery had a mean dry weight of 0.27 g/seedling and 1.16% nitrogen as compared to 0.18 g and 0.97% N under unfertilized conditions. Grain yield decreased (20%) significantly due to plant submergence alone. However, seedlings transplanted from fertilized nursery performed better and could produce 250 and 61% higher grain yield than that of plants from unfertilized nursery under submerged and unsubmerged plant conditions respectively. Application of Zn and Mo to nursery did not show any significant increase in yield.

The results over the four-year period indicate : application of N to nursery in a single basal dose is adequate ; the response to Zn and Mo was not significant; the increase in yield with N fertilizer to nursery was due to greater number of panicles and higher panicle weight; and an improved tall variety such as CN 540 is better suited for such conditions.

(M.M. Panda. M.D. Reddy and A.R. Sharma)

Studies on mixed row cropping of early and late duration rice varieties under intermediate deep water conditions. The possibility of growing early (80-90 days) and late (160 days) duration rice varieties simultaneously in diffferent proportions was examined for three years (1986, 1987 and 1988). The early duration popular tall cultivars viz. Kalinga-III and CR 289-1045-16 (Vanaprabha) were sown along with late duration semi-dwarf CR 1016 as seed mixtures, criss-cross seeding or parallel line seeding in 1 :1, 1 :2, 2 : 1 or 2 : 2 proportions with a common level of 40 kg N and 20 kg P_2O_5/ha applied at sowing except in 1986, when double of this rate was used. The crop was sown in dry soil condition before the onset of monsoon by first week of June. The early cultures were harvested in the first week of September. Water depth ranged between 30 and 50 cm during most of the crop growth period, though occasionally it increased to 60 cm or more for a few days.

Mixed row cropping of late and early varieties produced more grain yield (4-15%) as compared to sole cropping of late variety. In 1986, early cultures as pure stand produced 0.7 to 0.9 t/ha while late variety produced 1.34 t/ha. Sowing

the crop in parallel lines in 1 :1 ratio at 20 cm row spacing with 225 seeds/m^2 of each variety produced 2.61 and 2.63 t/ha with Kalinga III and Vanaprabha respectively. Kalinga III and Vanaprabha contributed towards 0.93 t/ha (36%) and 1.28 t/ha (49%) towards the total grain yield. In 1987, CR 1016 yielded 3.5 t/ha, while early cultures yielded 2.5 to 2.7 t/ha in pure stand. Mixed cropping of late and early cultures either in 1 :1 or 2:1 ratio resulted in 6-13% higher yield. Broadcast mixed seeding or criss-cross seeding in 1:1 ratio yielded less than parallel line seeding.

In 1988, pure crop of CR 1016 and Vanaprabha yielded 2.37 and 2.05 t/ha, respectively. Growing CR 1016 and Vanaprabha in 1 :1 ratio at 20 cm spacing with 225 seeds/m^2 of each variety produced maximum grain yield (2.73 t/ha). Closer spacing (10 and 15 cm) with either 225 or 450 seeds/m^2 of each variety produced comparable yields (2.50 to 2.59 t/ha) Sowing late and early cultures in 1 : 2 ratio was inferior to 1 :1 and 2 :1 ratios.

Panicle weight of CR 1016 was considerably higher in mixed cropping system as compared to sole cropping; but early cultures did not show any definite trend. Mixed cropping system also prevented lodging of early varieties at maturity while in pure stand, early cultures lodged partially leading to germination of seeds on the panicle itself.

The results over the past three years indicate : Mixed cropping of late and early varieties produced more yield (up to 15%) than sole crop of a late variety; the contribution of early variety to total yield ranged from 28 to 39% in case of Kalinga III and from 23 to 49% in case of Vanaprabha; parallel line seeding was better than other methods of seeding and there was no difference in ultimate yield obtained with an intra row spacing of 10 or 15 cm.

(M.D. Reddy. A.R. Sharma and M.M. Panda)

AG. 10. Management of Rainfed Uplands

Response of extra-early rice cultures to time of sowing and nitrogen application. In *kharif*, an experiment with test culture CR 666-7 of 65-day duration and Vanaprabha of 85-day duration was repeated for the second year to find out the optimum time of seeding.

Direct seeding in furrows with fertilizers during June 5 to 15 proved to be ideal. Advance seeding during the last week of May and delayed seeding beyond June 25 adversely affected the yield significantly irrespective of maturity duration of the varieties.

The response of extra early rice cultivar, CR 666-7 (65 days) to single and split application of nitrogen was studied. A single basal application of 40 kg N/ha in the seed furrows was significantly superior to single application at 7, 14, or 21 days after germination and the recommended three-split application.

(Dinesh Chandra and G.B. Manna)

Integrated effect of stale seedbed and herbicides on weed control. This experiment was conducted to prepare an ideal weed management schedule involving methods of land preparation (stale seed bed and conventional practice) and herbicide application (pre-emergence application of butachlor or thiobencarb at 2.0 kg/ha; post-emergence application of propanil at 2.0 kg/ha propanil + thiobencarb/ butachlor at 1.0 kg/ha each) besides hand-weeded checks. Test variety was Kalinga III sown in the second fortnight of June. Stale seed bed, an advanced tillage method of land preparation proved significantly superior to conventional practice of land preparation in terms of weed control. The grain yield increase with the former over the latter was 15 per cent. All the chemical weed control practices (post-emergence application of propanil and pre-emergence applica-

tion of butachlor or thiobencarb each at 2.0 kg/ha or combination of propanil + butachlor/ thiobencarb each at 1.0 kg/ha) were equally effective and comparable to hand-weeded check in terms of crop yield performance. Loss in grain yield due to unchecked weed competition was 86%.

(B.T.S. Moorthy, G.B. Manna and K.S. Rao)

Evaluation of herbicides for weed control. Herbicides, butachlor, thiobencarb, oxadiazon, pendimethalin, fluroxypyr and propanil were evaluated for weed control in a field with an upland rice variety Kalinga III sown during first fortnight of June . Pre-emergence application of oxadiazon at 0.5 kg/ha and post-emergence application of propanil at 3.0 kg/ha effectively controlled weeds (weed control efficiency : 84 and 87% respectively) and improved the crop growth and yield performance of Kalinga III comparable to hand-weeded check with three rounds of hand weeding.

(B.T.S. Moorthy)

AG. 12. Management of Shallow Submerged Lowlands

Nitrogen response of selected minikit rice cultures of early duration. This DRR coordinated trial was initiated in *kharif,* 1985 to obtain supporting information on promising early cultures recommended for minikit trials from year to year. In the current year, four short duration cultures viz. IET 7983, IET 8681, IET 7633, IET 8681 and IET 7261 were tested along with a standard check, Cauvery and a local check, Annada under irrigated transplanted condition at 0, 30, 60 and 90 kg N/ha. All the tested cultures produced significantly higher grain yield over the standard check Cauvery which yielded 2.65 t/ha . IET 7983 was significantly superior with a grain yield of 3.67 t/ha to IET 7261, IET 8681, IET 7633 and Annada, which yielded 3.02, 2.98, 2.78 and 3.26 t/ha respectively. Nitrogen application increased the grain yield significantly up to 90 kg N/ha (3.36 t/ha). The highest panicle number ($388/m^2$) and panicle weight (1.15 g) were registered at 90 kg N/ha .

(K.S. Rao and B.T.S. Moorthy)

Evaluation of different modified urea fertilizers for higher N efficiency. In a *kharif* season study with IET 7590 of 150-day duration, irrespective of the level of N at 30 and 60 kg/ha, the single basal application of coated urea formulations, Mussorie rock phosphate coated urea, neem-coated urea and gypsum-coated urea, was comparable to three-split application of prilled urea. However, split application of coated urea did not have any apparent advantage over single basal application.

(K.S. Rao and B.T.S. Moorthy)

Agronomic practices for scented rice (kharif)

Plant population requirement. A study on optimization of crop stand for the improved Basmati variety IET 8579 revealed no significant difference in grain yield among three spacings (15 x 10 cm, 20 x 10 cm and 15 x 15 cm). Closer spacing (10 x 10 cm) or wider spacing (20 x 15 cm) proved to be inferior. At closer spacing, panicle weight was adversely affected, despite production of higher number of panicles per m^2, and a reverse trend was noticed with wider spacing.

Response to N, P and K. Among six scented rice varieties tested for their yield performance, highest grain yield of 2.84 t/ha was recorded in Badshabhog, a photosensitive tall variety of 150-day duration. The two improved Basmati derivatives viz. IET 8579 and IET 8580 (photoinsensitive medium duration varieties) and T-412 (long duration type) were at par, but inferior to Badshabhog. Basmati 370 and Pakistan Basmati gave lower yields because of lodging at flowering stage. There was a significant increase in yield with increasing level of nitrogen from 0 to 30

kg/ha. There was no response of these scented rice varieties to phosphorus and potash application.

(K.S. Rao and B.T.S. Moorthy)

Evaluation of varieties for late planted situation in kharif. This experiment was repeated with modifications to include five promising varieties/ cultures *viz.* [CR 260-131, CNM 539, IET 9757, IET 7251 and Gayatri (check)]. These rice varieties/cultures were evaluated by planting on four different dates at fortnightly intervals from July 23 to September 8.

Gayatri was significantly superior to the remaining cultures with a grain yield of 5.5 t/ha followed by IET 9757 (4.14 t/ha) when planted as late as September 8 with aged seedlings of 63 days. With Gayatri, no significant difference in yield was observed between normal planting in July and late planting on September 8, while a significant reduction in yield was noted with late planting with IET 9757.

(Dinesh Chandra)

Relative efficiency of manually and machine applied prilled urea and urea supergranules. The efficiency of mechanical applicators developed by IRRI for subsurface application of prilled urea (PU) and urea supergranules (USG) , was tested during *kharif* season. The treatments consisted of two levels of nitrogen (37.5 and 75 kg/ha) and two methods of application of PU [standard three splits and single application by mechanical applicator at 10 days after transplanting (DAT)], two methods of application of USG : subsurface application by hand and by mechanical press wedge application at 10 DAT basal application of granulated urea (GU) (6 to 8 mm size)] and a control.

Hand application of USG gave the highest yield at both levels of nitrogen. The placement of PU by applicator, split application of PU, mechanical application of USG and single application of GU gave comparable yields. The mean grain yields under 0, 37.5 and 75 kg N/ha were 4.15, 4.79 and 4.87 t/ha , respectively.

(C.R. Padalia and G.B. Manna)

Integrated use of organic and inorganic nitrogen fertilizers in irrigated lowland rice (second INSFFER). This INSFFER coordinated experiment, initiated in *kharif,* 1987 to evaluate the effectiveness of inorganic nitrogen fertilizers applied alone or in combination witn organic sources viz. *Azolla* compost, water hyacenth comost, green manuring with *Sesbania aculeata* and *S. rostrata* and farmyard manure, was repeated as such in 1988. There were eight treatments with a control, 75 kg N/ha as prilled urea (PU) (3 splits-50% N applied basally and the remaining 50% N in two equal splits at 21 DAT and at PI stage respectively), 75 kg N as urea supergranules (USG) applied basally and the other five treatments included combinations of organic and chemical fertilizers to supply 37.5 kg N/ha each. A long duration (150 days) variety (Gayatri) was used in this study. A common dose of 30 kg each of P_2O_5 and K_2O at planting was given to the crop.

All the tested organics in combination with PU, each source meeting 37.5 kg N/ha gave similar grain yield as that of 75 kg N/ha as inorganic N alone. The grain yield ranged from 6.16 to 6.37 t/ha. The beneficial effect of USG oversplit application of PU was not observed.

(C.R. Padalia, K.S. Rao and G.B. Manna)

Germination of rice varieties at different intervals after harvest. Seeds of different rice varieties grown during the *rabi* season and harvested in April were tested for germination at 30-day intervals after harvest at 30 ± 2°C.

Among the early varieties, germination was more than 80 per cent in CR 666-22, CR 666-7

and CR 666-49 for four months (August end), Sattari for five months (November end) and thereafter germination decreased gradually. On the other hand, CR 544-1-2 and CR 544-1-1 had good germination for eight months (December end). Among medium duration and scented varieties, IET 7261 and IET 7633 showed more than 80% germination for four months (mid-August), Basmati 370, Pakistan Basmati, IET 8580 (scented) and IET 8681 for five months (mid-September) and CRM 25, IR 36 and IET 8579 (scented) for six months (mid-October).

(M.D. Reddy and A.R. Sharma)

AG. 13. Water Management

Irrigation requirement for groundnut, greengram and blackgram grown after rice in medium land conditions. Irrigation requirement for groundnut (variety : AK 12-24), greengram (PDR 54), and blackgram (T 9) in rice fallows was determined in *rabi* season. All these crops were sown on December 30, 1987. Groundnut produced significantly higher grain yield as compared to greengram and blackgram. One irrigation given to this crop at flowering gave the maximum yield (0.82 t/ha). The other crops (greengram and blackgram) did not respond to irrigation, when yield increased only marginally with different supplemental irrigations over no irrigation (residual moisture) treatment.

(Dinesh Chandra)

Effect of different moisture regimes and levels of phosphorus on the performance of rajmash. Rajmash (*Phaseolus vulgaris*) (variety : PDR 14) was sown during the first week of December with a spacing of 30 cm in between the lines and 10 cm between the plants and a common application of fertilizer N at 60 kg/ha after the harvest of *kharif* rice. The treatments included three levels of P_2O_5 (0, 20 and 40 kg/ha) and five levels of irrigation (0, 1, 2, 3 and 4) given at seedling stage, grand growth period, pod initiation and pod elongation stages. The crop responded significantly up to three irrigations given at seedling stage, grand growth period and pod initiation stage. There was no significant difference in crop response due to phosphorus application.

(Dinesh Chandra)

Water and fertilizer management for extra-early rice cultivars grown during summer season. The extra-early test rice varieties CR 666-7 (72 days) CR 544-1-2 (85 days) and CR 544-1-7 (85 days), which are normally recommended for drought-prone rainfed uplands as autumn crop were tested for their yield performance during *rabi* season under puddle-seeded conditions with two levels of fertilizers (30-15-15 N, P and K kg/ha and 60-30-30 N, P and K kg/ha) and two levels of irrigation (continuous submergence and intermittent irrigation). Continuous submergence was superior to intermittent irrigation in terms of grain yield. The difference in yield between continuous submergence and intermittent irrigation was 0.39 t/ha at low level of fertilizer and it was 0.8 t/ha at high level of fertilizer. Water requirement under continuous submergence was 1100 mm for extra-early variety CR 666-7 while it was 1200 mm for early varieties (CR 544-1-2 and CR 544-1-7) as against 600 and 700 mm respectively with intermittent irrigation.

(Dinesh Chandra)

AG. 14. Mamagement of Rainfed Lowlands

Effect of date of sowing and N fertilization on yield of rice under intermediate deep water conditions. This experiment was conducted with two varieties (Gayatri and CR 292-8051), three dates of sowing (May 21, June 1 and June 11), and three levels of N (0, 20 and 40 kg/ha). A common level of 20 kg P_2O_5/ha was applied. Sowing on first two dates was done in dry soil condition while on the last date (June 11), 2 to 3 cm water had accumulated in the field. Water depth reached 10 cm by June 18 and 30 cm by June end.

It increased gradually to 70 cm by August 8, 73 cm by August 10 and maximum of 77 cm by September 22. Water depth ranged from 40 to 60 cm during most of the crop growth period.

Sowing of the crop early in the season in dry soil proved better and delay in sowing caused considerable reduction in yield. There was no significant difference between May 21 and June 1 sowings. However, the crop sown in muddy condition on June 11 had poor germination and produced very low yield (0.22 t/ha). The variety CR 292-8051 was superior to Gayatri and when sown on the last date (June 11) and could produce 0.41 t/ha as against negligible yield (0.034 t/ha) of Gayatri. Application of N increased the yield significantly from 0.86 t/ha at no N to 1.22 t/ha with 40 kg N/ha. The yields of the crop were low due to poor crop stand under excess moisture stress at early seedling stage as well as at later stages of growth (near complete submergence for 15 days in the first fortnight of August and again for 4 days in the later half of September).

(M. D. Reddy, A. R. Sharma and M. M. Panda)

Effect of spacing, method of sowing and weed control practices on yield of rice under intermediate deep water conditions. Two methods of sowing (line sowing and hill sowing), three row spacings (10, 20, and 30 cm) and weed control practices [no weeding, hand weeding and chemical weeding) with butachlor at 1.0 kg a.i/ha) at 3-4 days after germination (DAG)] were tested. The crop (cv. Gayatri) was sown with a common level of 40 kg N and 20 kg P_2O_5/ha. Water started accumulating in the field immediately after germination and reached up to 20 cm by 30 DAG and 57 cm by 65 DAG. It reached a maximum depth of 60 cm by 106 DAG and then receded gradually to 45 cm by 120 DAG and 10 cm by 150 DAG.

Nonsignificant differences in grain yield occurred either due to methods of sowing or row spacings. However, panicle number decreased (148 to 122/m^2) and panicle weight increased (2.06 to 2.54 g) with increase in row spacing. Grain yield was significantly higher (9-15%) with butachlor application as compared to unweeded (2.90 t/ha) or hand weeded (3.04 t/ha) plots. Butachlor applied plots were completely free of weeds at harvest whereas hand weeded and unweeded plots were covered completely by *Eriocolon* sp., a small slow growing water weed.

(A.R. Sharma and M.D. Reddy)

Response of elite rice cultures to N fertilization under intermediate deep water conditions. In this experiment, 12 elite rice cultures were grown at two levels of N (0 and 40 kg/ha).The crop was direct-seeded by May end and received a common dose of 20 kg P_2O_5/ha. Water started accumulating from mid-June and reached up to 35 cm by 30 DAG and a maximum of 75 cm by 100 DAG. It remained between 30 and 50 cm during most of the crop growth period.

The yield of all the varieties increased (2-90%) with the application of 40 kg N/ha. Among the cultures, CN 573-2-21, CN 579-363-3-1, IET 10002 and IET 10006 produced more than 2 t/ha and were significantly superior to others. Grain yield decreased linearly with decreasing plant height at harvest and semi-dwarf cultures (92 to 120 cm plant height at harvest) viz. CR 1016, CR 260-171 and CR 527-18-2 gave very poor yield. Short duration upland cultivar Kalinga III virtually failed (0.64 t/ha) under excess water situation. There was greater incidence of stem borer with the application of N fertilizer.

(A.R. Sharma, M.D. Reddy and M.M. Panda)

Twentysix elite rice cultures pooled on the basis of their performance in multilocational trials in different parts of the country were evaluated under direct-seeded condition with a

common level of 40 kg N and 20 kg P_2O_5/ha. Water accumulation in the simulated field condition started by 10 DAG and reached up to 41 cm by 30 DAG and 75 cm by 60 DAG. It reached a maximum depth of 80 cm by 100 DAG and then receded gradually to 60 cm at 115 DAG and to around 5 cm by November end (165 DAG).

The grain yield of most of the cultures was below 2 t/ha with the exception of five entries viz. IET 10084, IET 10030, IET 10029. IET 10008 and IET 10003 yielding more than 3 t/ha. This was due to their greater plant height (187 to 201 cm) and panicle weight (3.20 to 4.41 g).The panicle number per m^2 for most of the cultures ranged from 70 to 90 and rarely exceeded 100.

(M.D. Reddy. A.R. Sharma and M.M. Panda)

Performance of different rice varieties with N fertilization under semi-deep water conditions. Six varieties were grown at 0, 20 and 40 kg N/ha to test their suitability under semi-deep water situation. A common level of 20 kg P_2O_5/ha was applied along with N at sowing. The water started accumulating in the field by 10 DAG and reached up to 70 cm by 30 DAG and 122 cm by 60 DAG. It reached a maximum depth of 140 cm by 100 DAG and then receded gradually to about 50 cm at harvest. Only Janaki and Jaladhi 1 survived at all N levels and produced 0.4 to 1.1 t/ha. The CN cultures (CN 579. 363-3-1, CN 570-661-48-3, CN 566-229-19-2 and CN 573-321-7-1) survived only at 20 and 40 kg N/ha levels and produced 0.3 to 0.9 t/ha. None of the varieties except Jaladhi 1 possessed dormancy and seeds of floating panicles started germinating on the surface of water at maturity.

(M.D. Reddy. A.R. Sharma and M.M. Panda)

Survival of short, medium and long duration rice varieties after submergence. This experiment was conducted under greenhouse condition with 12 varieties : four each of early (80-90 days), medium (110-125 days) and long (140-170 days) duration during *kharif* and *rabi* seasons. The crop was direct-seeded and submerged for 10 days at 30 days after sowing.

Submergence tolerance of short and long duration varieties was greater due to their tallness as compared to medium duration varieties. In the wet season, varieties of short and long duration produced higher grain yield. The well known flood tolerant traditional variety, FR 13A produced comparable yield with Gayatri. However, among the varieties of medium duration, IR 36 and Udaya died and Ratna and Sarasa gave negligible yield (4.8 to 6.9 g/pot).

(M.D. Reddy and A.R. Sharma)

Improvement of the existing practice of beaushening for direct-seeded rainfed lowland rice. The experiment was repeated for the second year to assess the integrated role of seed rates (300 and 450 seeds/m^2), beaushening and green manuring (*Sesbania aculeata* and *S. rostrata*) practices in improving the productivity of direct-seeded lowland rice.

Beaushening operation significantly increasded the grain yield under higher seed rate (450 seeds/m^2) but not with normal seed rate (300 seeds/m^2). Green manuring of the beaushened crop with *S. aculeata* or *S. rostrata* significantly increased the grain yield over unmanured crop, both under normal and higher seed rates.

(K.S. Rao and G.B. Manna)

Cultural and chemical method of weed control in rainfed lowland rice. The relative efficiency of manual, mechanical and chemical weed control methods including traditional practice of beaushening in broadcast, row seeded and transplanted rice crop (variety Utkalprabha) was tested during *kharif* season under intermediate rainfed lowland (15-20 cm water depth) situation.

The bulk of weed population constituted *Cyperus pilosus* with a dry weight of 5.0 t/ha as recorded from the weedy check. Though the weed population was negligible in transplanted crop, an effective control of weeds in direct-sown crop either as broadcast or drilled in row resulted in a significatly higher grain yield over former practice. The weed control efficiency was maximum (90%) with traditional practice of beaushening 40 days after sowing or two rounds of interculture by finger weeder supplemented with manual weeding. Preemergence application of butachlor at 2.0 kg/ha proved moderate in weed control (weed control efficiency 79 %). The reduction in yield due to weed competition was 33.3 to 34.6%.

(B.T.S. Moorthy and K.S. Rao)

Rice-cum-fish culture : Feasibility of insecticidal application under intermediate lowland situations. Feasibility of phosphamidon application at 0.5 kg/ha under rice-fish-intermediate lowland ecosysterm was evaluated for the third year. Spraying of the insecticide either at vegetative, heading or both stages of the crop did not cause mortality of fish in confirmity with the result of the previous years. Phosphamidon spraying reduced the stem borer incidence by 27% when sprayed at vegetative stage and by 24.5% when sprayed at heading stage. However, this reduction did not influence the yield. Insecticide given at both the stages substantially increased the grain yield (12%) and N-uptake (8%) by rice. The grain yield ranged from 3.3 to 3.8 t/ha. The grain yield ranged from 3.3 to 3.8 t/ha. The fish yield was very low (68 kg/ha/90 days) due to complete inundation of the plot during the entire third week of September (water depth : 60 cm). However, the adverse effect of insecticides on planktonic biomass (25% decrease) and fish growth was observed. Dhaincha (*Sesbania aculeata*) was for the first time found suitable for growing in trenches/ ridges as a shelter as well as a barrier to fish poaching in this ecosystem as it did not adversely affect the important aquatic parameters (dissolved oxygen concentration, temperature and pH) required for fish growth.

Initial observation on rice-fish culture indicated comparable yield (113 kg/ha) and considerably higher growth (24.3 cm/277 g) of common carp in the semi-deep ecosystem over the intermediate lowlands even under 20% of the recommended stocking density within a period of around 30 weeks.

(D.P. Sinhababu, S. Rajamani, M.M. Panda and M.D. Reddy)

AG. 15. Multiple Cropping

Sequence cropping with lowland rice

Sweet potato. A trial on sweet potato in collaboration with Regional Centre of Central Tuber Crops Research Institute, Bhubaneswar was initiated with five elite cultivars (S 268, OP 219, Kanjangad local, 85-10 and Pusa safed) during January to May (110 days). The crop was grown with N at 60, P_2O_5 at 45 and K_2O at 60 kg/ha, a spacing of 60 x 20 cm and four irrigations.. The carotene rich culture 85-16 was found promising with a tuber yield of 32 t/ha followed by Pusa safed and Kanjangad local.

Greengram. Among seven elite cultivars tested including local check with N, P_2O_5 and K_2O each at 20 kg/ha and three irrigations, Pusa 105 was superior with seed yield of 796 kg/ha followed by PDM 54 which gave a yield of 711 kg/ha.

Maize. The variety Ganga 5 was grown after the harvest of lowland rice with a spacing of 60 x 25 cm, nitrogen at 60 kg/ha, P_2O_5 and K_2O each at 40 kg/ha gave a net profit of Rs.11,000/ha from the green cobs harvested at 15 weeks after sowing.

Groundnut. The trial included five elite cultivars viz. AK 12-24 (local check), RSHY-1, ICGS 11, ICGS 44, and ICGS(E) 21 grown with N at 20 kg/ha and P_2O_5 and K_2O each at 40 kg/ha. The recently evolved cultivar RSHY 1 was superior with a pod yield of 2.5 t/ha.

AG. 16. On-Farm Research

Rainfed upland . The yield potential of Annada (CR 222 MW 10/IET 6223) of 105-day duration ranged from 4.5 to 5.5 t/ha in light alluvial soils under rainfed upland condition. The first fortnight of June was the optimum period of sowing. The dibble seeding behind plough at a spacing of 20 cm (row to row) x 15 cm (hill to hill) was superior to drilling or broadcasting. The aforesaid grain yield could be achieved resorting to use of N at 60 kg, P_2O_5 and K_2O each at 30 kg/ha. Preemergence application of butachlor at 1.25 kg a.i./ha to moist soil following rain was most effective in weed control.

The newly introduced pulse crop Rajmash (PDR 14) was promising with a seed yield ranging from 1.5 to 2.0 t/ha when grown in sequence with rice under rainfed uplands and shallow submerged lowlands (medium lands). The ideal period for growing Rajmash ranged from October to first week of December. Important package of practices included deep seeding behind plough, a spacing of 40 x 15 cm and fertilizer use at 40 kg N/ha and 30 kg each of P_2O_5 and K_2O/ha.

Shallow submerged lowlands. Among the rice varieties, CR 1002 and Moti were the most promising with grain yields of 6.0 to 6.5 t/ha and 5.5 to 6.0 t/ha, respectively. Use of seed drill for stand establishment and controlling weeds through cone weeder (in direct-seeded crop) gave almost a similar yield as that of transplanted crop. The drill-sown crop involved less expenditure and partially solved the problem of labour shortage during peak period of transplantation.

Rice variety Padmini continued to give a yield of 4.0 to 4.5 t/ha, in late planted (August end to first week of September) condition in sequence with jute. This has already spread in the villages of Purbakash, Paschimkash, Khentalo, Haripur and Ranipara.

Rainfed lowlands (intermediate deep water depth of 50-70 cm with flash flood, early seeding by May 20-25 with a moderate dose of 40-20-20 N., P and K kg/ha, rice varieties, Panidhan, Tulasi and CR 260-77 continued to give a yield of 4.5 to 5.0 t/ha as compared to 1.5 to 1.85 t/ha with local checks. These varieties were adopted on a large scale in villages, Khentalo, Sirlo, Ishani, Berhampur, Ranipar, Bhairipur, and Gopalpur. CR.260-77 yielded about 6.0 t/ha in Jagatsinghpur area in shallow lowlands.

SOIL SCIENCE AND MICROBIOLOGY

AC. 02. Effect of Intensive Rice Cropping on the Changes in Soil Properties and Productivity

This long-term compost experiment was initiated during the *kharif* season of 1969 with treatment combinations N, NP, NK, NPK with a no fertilizer control added to each crop and superimposed with or without compost annually in May/June every year. Only a single wet season crop was grown and there was no crop during the *rabi* season as the irrigation water was suspended. Grain yields indicated that there was significant response to application of nitrogen and phosphorus, but not to potassium. Significant response to compost was also noticed.

(A. Bhadrachalam, R.N. Samantaray and S. Patnaik)

AC. 10. 12. Contribution of Nitrogen from Soil, Fertilizer and Green Manures towards the Production of Rainfed Lowland Rice

The experiment was continued for the third year with rice cv. Savitri under rainfed lowland conditions. Fresh green matter and total dry matter (shoot + root) production of *S. aculeata* were in the ranges of 12.7-13.6 t/ha and 4.0-4.1 t/ha, respectively. Total nitrogen contribution from a pure or mixed crop of green manure was 74-88 kg N/ha, of which 32-40% was recovered by rice crop as against 14-32% recovery of chemical-N. In a separate field experiment on N_2-fixation by *S. aculeata* and *S. rostrata*, *S. aculeata* and *S. rostrata* fixed 55 and 42 kg N/ha, respectively in 45 days . This estimation was based on the difference between the N accumulations in the leguminous green manure crop and a non-legume such as jute. The amount of N fixed during the first month of plant growth was very small (6-8 kg N/ha). In 60 and 75 days, however, the nitrogen fixation was high, the values being 61-117 and 155-163 kg N/ha, respectively.

(D. Panda, R.N. Samantaray and S. Patnaik)

AC.11.07. Measures for Increasing the Efficiency of Indian Phosphate Rocks for Growing Rice

This field experiment has been continued from 1984 to study the long-term effect of phosphate rocks on the yield of dhaincha (*S. aculeata*) crop and subsequent supply of N and P from dhaincha crop to the following rice crop. For this purpose, dhaincha was grown at 25 kg seed/ha in plots receiving no-P and 20 kg P/ha as four Indian phosphate rocks (Mussoorie, Jhamarkotra, Purulia, Kasipatnam), Jordan phosphate rock, dicalcium phosphate (DCP) or triple superphosphate (TSP). There was an additional control plot without dhaincha crop. Neither N nor K was applied to any plot . Dhaincha was incorporated to the respective plots at six weeks growth for growing rice. Continuous application of P-carriers effected higher dry matter production of dhaincha than control (no-P) at six weeks growth. The effect of the treatments receiving phosphate rocks was intermediate. The nitrogen uptake by dhaincha crop was 46-48 kg/ha in the treatment receiving DCP and TSP and 38-41 kg/ha in the treatment receiving phosphate rocks.

The grain yield of rice (cv. 1009) without previous dhaincha crop and without P-application was 3.5 t/ha as against 4.0 t/ha with previous dhaincha crop grown without P application indicating the beneficial effect of green manure for rice. The treatments receiving DCP and TSP gave higher grain yield (4.6-4.9 t/ha) of rice than other treatments. The effect of phosphate rocks

on grain yield was intermediate (4.2-4.4 t/ha). The straw yield also showed similar trend.

(R.N. Dash, S.K. Mohanty and S. Patnaik)

AC. 16. 03. Screening of Rice Varieties for Tolerance to Excess of Iron

Thirty cultures developed by the institute were screened for resistance to iron toxicity in a field trial conducted at the Research Farm of the O.U.A.T., Bhubaneswar. The cultures were screened at a nutrient level of 100-50-50 kg/ha, N, P_2O_5 and K_2O, respectively. N was applied in three splits and P and K were applied as basal dose at transplanting. The plants were scored in 1-9 scale at different growth stages of the crop. CR 672-3, CR 617-16-D-10-2, CR 622-21-D-1, CR 626-26-D-2-3, CR 671-30, CR 670-8, CR 675-658, CR 605-3-1-1 and CR 676-641-2 were resistant to Fe toxicity.

(S.K. Mohanty)

AC. 17. 02 Evaluation of Varieties for Nutrient Extractability under Nutrient Stress Conditions

Nutrient extracting ability of rice varieties viz. CR. 1014, CR 1009, CR 1018, Samalei, Tulasi, Jagannath, Pankaj and Mahsuri (145-160 day duration) for nitrogen stress situations was studied in a solution culture experiment. Addition of 50 ppm N to the nutrient solution significantly increased root, grain and straw yields in all the varieties (Table 18) over stress situation (25 ppm nitrogen). Under stress situation CR 1009 gave the highest grain yield and was comparable with CR 1018, Tulasi, CR 1014 and Mah-

Table 18. *Effect of nitrogen stress on grain, straw and root yields of selected varieties in solution culture*

Varieties	Grain (g/pot)			Straw (g/pot)			Root (g/pot)		
	Low N (25 ppm)	Optimum N (50 ppm)	Mean	Low N (25 ppm)	Optimum N (50 ppm)	Mean	Low N (25 ppm)	Optimum N (50 ppm)	Mean
CR 1014	42.0	70.0	56.4	61.8	112.2	87.0	19.3	20.5	19.9
CR 1009	52.8	79.6	66.2	48.1	86.0	67.1	19.1	22.4	20.8
CR 1018	49.7	70.6	60.2	43.2	80.4	61.8	18.2	20.8	19.5
Samalei	35.9	57.5	46.7	39.8	66.2	53.0	14.5	20.9	17.7
Tulasi	45.0	77.6	61.3	55.5	101.7	78.6	19.5	20.5	20.0
Jagannath	40.9	67.7	54.3	36.8	56.6	46.7	17.0	19.8	18.4
Pankaj	32.0	65.2	48.6	58.5	85.5	72.0	18.4	28.1	23.2
Mahsuri	41.9	58.9	50.4	47.6	72.5	60.1	17.8	19.3	18.6
Mean	42.5	68.5	55.5	48.9	82.6	65.7	18.0	21.8	19.9
	CD at 5%								
	Varieties (V)		11.6			17.1			NS
	Nitrogen (N)		5.8			8.6			1.8
	V x N		NS			NS			NS

NS. Not significant.

suri, but was significantly better than Pankaj, Jagannath and Samalei. The straw yield was the highest with CR 1014 which was comparable with Pankaj, Tulasi, CR 1009 and Mahsuri.

(R.N. Dash, M.V.R. Murty and S.K. Mohanty)

AC.19.10. Studies on Movement of Nitrogen in Rice Soil

Efficiencies of various methods of subsurface placement of urea were evaluated with variety Savitri for the second year in field. Vertical mobility of ammonium- and nitrate-N from the site of urea placement was also studied in this experiment. Results showed that at six weeks after basal application of urea, ammonium-N content of soil in 10-15 cm layer right below the band or point of urea placement was slightly higher than that in no-N control indicating limited mobility of applied N to this depth. In 0-5 cm vertical depth, on the other hand, the ammonium-N content of soil was significantly higher with point placement of urea supergranules (40 ppm) than with band placement (19 ppm) or broadcast application of urea (12 ppm). Grain yield of rice varied from 2.3 t/ha with no-N control to 3.5 t/ha with the reduced zone placement of soil-treated urea i.e., freshly prepared mudball urea. While surface broadcasting of prilled urea at the time of sowing or tillering was on par with control, placement of urea on bands or points at sowing or reduced zone placement at tillering was significantly superior. Nitrogen placement at tillering was better than placement at sowing. These two treatments increased grain yield by 25-26% over basal broadcast of urea and by 20-21% over broadcast application of urea at tillering stage. Basal band placement of urea and placement of USG behind the plough gave an average response of 14-15 kg grain/kg N added. Nitrogen uptake by rice ranged from 44 to 91 kg N/ha. Apparent recovery of N was minimum (25-32%) with basal broadcast or behind the plough placement of urea and maximum (61-77%) with basal band placement or reduced zone placement of urea.

(D. Panda)

AC. 19.12. Mineralogy and its Influence on Physical and Physico-Chemical Properties of Rice Soils

Bulk density and moisture retention characteristics were determined on undisturbed core samples excavated from visually identified depths of two soil profiles situated at different locations in the CRRI Farm. Minimum and maximum bulk density was observed at plough and plough sole depth, respectively. Fractions of total volume of soil occupied by transmission ($>50\mu$), storage (0.5-50 μ), and residual (<0.5 μ) pores respectively were computed from the moisture retention curves. Soil compaction at plough sole depth was identified by the smallest volume fraction occupied by the transmission of pores. The fractions of volume contributed by transmission and storage pores were greater in N block soil than in G block soil at equivalent depths. Available water storage capacity (volume of water retained within 0.1 to 10.0 bar tension range) was 13.06 cm and 11.01 cm per meter depth of soil for N and G blocks, respectively.

(M.V.R. Murty, K.R. Mahata and S.K. Pradhan)

AC. 19. 13 Management of Residual Soil Moisture for Dry Season Crops in Rice-Based Cropping System

Effect of straw mulch (applied at 5.5 t/ha) on the groundnut (var. AK. 12-24) yield was studied during *rabi* on a sloping water table. The seeds were sown on 24th December in lines, 30 cm apart. The replications (R) were arranged across the water table slope. Depth to water table gradually increased from 50 cm in R_1 to 105 cm in R_5. The slope (2.5%) of the water table was established by continuous seepage of water from

an adjoining rice field. The wide variation in soil moisture data indicated the anisotropic nature of the soil. However, repeated measurements of soil moisture revealed the following trends of soil moisture distribution in the profile. Based on the similarity in moisture profile among the replications, R_1 and R_2 were combined into one group and the rest (R_3, R_4 and R_5) into another. Moisture content data showed that presence of sandy layers below the subsurface depths restricted the capillary rise of water up to an approximate height of 60 cm. Mulching increased the moisture content at the surface depth of the second group of replications. The soil moisture content of the first group at any depth was not influenced by mulching. When the rice crops attained maturity the supply of water was stopped. It was followed by a quick recession of the water table by a depth of about 1/2 m. The soil moisture contents particularly at lower depths declined sharply. Effect of mulching then becomes more pronounced throughout the depths in response to a higher evapotranspiration rate prevailing at the onset of summer. Pod yield in general was inversely related to haulm yield (Table 19). At greater depth to water table haulm yield/ha decreased by 0.88 t whereas the pod yield increased by 0.15 t which may be attributed to the effects of a drier soil moisture profile. Mulching, however, tended to lower the haulm yield and increase the pod yield at both depths of water table. Effect of mulching on yield therefore cannot be attributed to the moisture conserved by it.

(K.R. Mahata, S.K. Pradhan and M.V.R. Murty)

AC. 23.02. Amelioration of Cd Toxicity in Soil for Rice

The effect of graded levels of Cd (0, 5, 10, 20, 40, 80, 100 mg/kg soil) without and with amendments viz. compost (10 t/ha), lime (1 t/ha) and P (150 kg/ha) was evaluated in pots using alluvial (Haplaquept) soil and variety IR 36 under flooded condition. The grain and straw yields decreased with increasing levels of Cd with a significant reduction in grain yield at 10 mg/kg soil, irrespective of the amendments. Cadmium content in plant increased with Cd supply. The grain Cd content was above the permissible level of 1 ppm at 10 mg Cd/kg soil in the unamended treatment, while in amended soil, this level of accumulation occurred only at 20 mg/kg soil addition, irrespective of the nature of amendments. Among the amendments, lime had a depressing effect on Cd content in straw while P enhanced Cd uptake, particularly at higher levels of Cd addition, which was also reflected in DTPA extractable Cd in post-harvest soil.

(P.K. Nayar, V. Sarkunan and A.K. Misra)

Table 19. *Effect of mulching and depth to water table on pod and haulm yield*

Treatment	Pod yield (t/ha) Depth to water table			Haulm yield (t/ha) Depth to water table		
	58 cm Average of R_1+R_2	85 cm Average of $R_1+R_2+R_3$	Mean	58 cm Average of R_1+R_2	85 cm Average of $R_1+R_2+R_3$	Mean
Mulch	0.76	0.92	0.84	2.13	1.38	1.75
No mulch	0.67	0.81	0.74	2.39	1.38	1.88
Mean	0.71	0.87		2.26	1.38	

AC. 23.04. Evaluation of Ferro-Chrome Waste in Soils for Rice

The vast stretch of chromite deposits in Orissa State is one of the richest in Asia. Open cast mining and ore prospecting resulted in the accumulation of large quantity of waste around paddy fields for want of proper commercial utilisation. Chromium in trivalent and hexavalent form is considered toxic depending upon the soil environment. The waste from one of the typical ferro-chrome plants located at Jajpur-Keonjhar road was taken up for case study. This plant has a production capacity of ferro-chrome at 40 t/day with an equal amount of waste. Of the two major wastes viz. high carbon and low carbon, only the latter is considered because of the hardness and difficulty in handling of the former. The low carbon waste contained about 2.9% total chromium of which 60 ppm is water soluble in the form of Cr (vi). The lime content in this waste is as high as 78% as $CaCO_3$.

(P.K. Nayar. V. Sarkunan and A.K. Mishra)

AC. 24. 01. Direct Field Measurement of Denitrification Loss (Indo-US Project)

A field experiment was conducted using 85% atom excess ^{15}N urea applied at 100 kg/ha to the microplots guarded with GI structure, with and without the application of CaC_2. The flux of denitrified gases showed that denitrification ($^{15}N_2 + {}^{15}N_2O$) increased slowly up to the 9th day following the fertilizer application and decreased thereafter up to the 12th day. After the 19th day onwards there was not much denitrification. Treatment receiving CaC_2 did not show much denitrification loss and the flux varied between 10-20 mg N/day/ha. The grain and straw yields from the plot receiving urea + CaC_2 were 608 g and 662 g respectively as against 585 g and 650 g for the treatment receiving urea alone. The percentage recovery of ^{15}N in the grain and straw were 26.7 and 14.6 for urea + CaC_2 treatment while it was 22.1 and 14.2% for the treatment receiving urea alone. Soil retention of applied ^{15}N decreased with depth. When ^{15}N urea was applied, the per cent retention in the soil was 5.6, 3.6 and 1.9 at 0-5 cm, 5-15 cm and 15-23 cm of soil depth, respectively. The per cent retention of applied ^{15}N, when CaC_2 was admixed with urea was 6.5, 4.0 and 3.4 at 0-5 cm, 5-15 cm and 15-23 cm soil depth, respectively.

(S.K. Mohanty, A. Bhadrachalam and S.P. Chakravorti)

AC. 24. 02. Nitrogen Balance Studies in Cropping System in Rice-Greengram Cropping Sequence

A field experiment was conducted during the wet season of 1987 with four levels (0, 40, 80 and 120 kg N/ha) of N application with and without application of *Sesbania aculeata* (40 kg N/ha) as green manure. ^{15}N tagged urea was applied to microplots well guarded by G.I. structure in N_{80} treatments. All the treatments received a uniform dose of 40 kg each of P_2O_5 and K_2O/ha as single superphosphate and muriate of potash respectively at the time of planting. These treatments were replicated four times in a split-plot design with green manure levels in main plot and N levels in sub-plots. During the *rabi* season of 1988 a moong crop (cv. PDM-54) was taken in the same layout as a residual crop which received a uniform dose of 20 kg each of P_2O_5 and K_2O/ha as triple superphosphate and muriate of potash respectively. The mean grain yield of moong ranged from 0.17 t/ha with 80 kg N/ha to 0.3 t/ha with green manuring treatments. Moong yield was significantly higher under no nitrogen treatment as compared to the other N levels. A similar trend was observed in haulm yield also. However, there was no significant difference in the total N uptake by moong crop for different green manure and N levels.

Table 20. *Effect of different nitrogen management practices on grain and straw yields, N uptake, apparent N recovery and N-use efficiency by rice variety CR 1009*

Treatment	Grain (t/ha)	Straw (t/ha)	N uptake (kg N/ha)	Apparent N recovery (%)	N-use efficiency (%)
T_1	4.0	4.92	56.9		
T_2	5.10	7.01	75.7	23.5	13.8
T_3	5.31	7.45	86.7	37.2	16.3
T_4	5.30	7.47	82.1	31.5	16.2
T_5	5.09	7.97	86.6	37.1	13.6
T_6	5.69	7.55	91.9	43.8	21.1
T_7	5.57	7.48	91.8	43.6	19.6
T_8	5.83	7.32	97.3	50.1	22.9
Mean	5.23	7.15	83.6		
C.D. at 5%	0.38	1.29	8.0		

The third crop of the rotation was rice (cv. Sarasa), direct-seeded in the same layout in the *kharif* season of 1988. A uniform dose of 20 kg each of P_2O_5 and K_2O was applied. Grain yield of rice ranged between 2.0 and 2.3 t/ha and there was no significant residual effect of the treatments applied to first rice crop. Data on N uptake by rice indicated significant residual effect at 120 kg N/ha and interaction of green manure and 120 kg N/ha was significant. Total N uptake by the whole sequence ranged from 112 and 174 kg N/ha and followed the same trend as that of the crop of rice.

(S.K. Mohanty, M.M. Panda and M.D. Reddy)

N management practices for maximum rice yields and N-use efficiency. A field experiment was conducted during wet season using rice variety Savitri with different N management practices (seven treatments) for maximizing rice yields and N-use efficiency at 80 kg N/ha level. Treatments included : (1) no nitrogen control, (2) entire N as basal, (3) entire N applied at 15 days after transplating (DAT), (4) three splits 50 : 25 : 25, (5) three splits 50 : 25 : 25 where the basal dose was applied at 15 DAT, (6) entire N through green manure grown *in situ*, (7) 1/2 N through green manure and the rest as urea in two equal splits at MT and panicle initiation (PI). Forty kg each of P_2O_5 and K_2O/ha was applied at planting. The mean grain yield varied from 4.0 t/ha with control to 5.8 t/ha with the treament receiving 50% of N as green manure and the rest in two equal splits at MT and PI (Table 20). The total N uptake was significantly higher in all the treatments receiving nitrogen than in control. The highest N uptake, apparent N recovery and N-use efficiency were recorded with the treatment receiving half of the nitrogen as green manure and half as urea in two equal splits and it was on par with the treatment receiving entire N as only green manure. N-uptake was sig-

nificantly more in all treatments except in treatment receiving entire nitrogen as basal.

(S.K. Mohanty, A. Bhadrachalam, S.P. Chakravorti and M.D. Reddy)

Recovery of applied ^{15}N by rice in relation to growth. An experiment was conducted using 10% atom excess ^{15}N urea applied at 100 kg N/ha to small microplots (G.I. structure of 9" dia and 18" height which were inserted in the field). Soil and plant samples were collected at weekly intervals up to 10 weeks after transplanting and analysed to estimate the per cent ^{15}N recovery of the applied fertilizer by rice plant (Ratna) and the per cent ^{15}N retained in the soil. It was observed that 100% of ^{15}N was recovered from the soil at 0 day after transplanting . After the first week, 31.64 mg of the applied ^{15}N was recovered from the plant and 30.62 mg was retained in the soil. The per cent recovery of applied ^{15}N fertilizer by both soil and plant was 5.6 at that stage. After the second week 33.5 mg was recovered by the crop and 26.9 mg was retained in the soil . Thus, 60 per ent of the applied ^{15}N was recovered by both the plant and soil. From third week onwards, the per cent ^{15}N recovery of applied fertilizer both from plant and soil was 66.6 to 67.3 up to the 10th week of crop growth.

(S.K. Mohanty, A. Bhadrachalam, S.P. Chakravorti and M.M. Panda)

AC. 25.01. Assessment of Crop Stress Detection and Crop Yield Modelling for Rice through Remote Sensing Techniques

Yield data of all the 70 blocks of Cuttack and Puri districts for three *kharif* seasons (1984-1986) were obtained during this year from Bureau of Economics and Statistics, Orissa. The Land Sat MSS data for three *kharif* seasons were also collected. The IR/Red ratio was calculated using two band data (MSS7/MSS5). Simultaneously few tentative test sites were selected in this area based on their vicinity to a permanent land mark for easy identification on satellite data. The ground truth data collection was carried out for the test sites. The IR/Red ratio of all these test sites were worked out. Based on this, the threshold values to identify rice pixels from other blocks could be determined. A linear regression analysis was worked out between grain yield (y) and area weighted average ratio (x) of blocks. The relationships were derived using data of three years separately as well as combined. The relationship, derived from three–year data excluding 24 data points, was used to test the model to estimate yield for these 24 blocks. Results indicated that the slopes and intercepts of the relationship ($y = a + bx$) for rice crop in the districts of Cuttack and Puri were not much different for 1985 and 1986 while it deviated for 1984. Only 50 per cent of the variation in yield could be explained by the combined equation.

$$\text{Yield (q/ha)} = 33.21 + 31.31 \text{ (MSS 7/MSS5)}$$

The above equation was used to predict yield of 24 blocks which were excluded for deriving this equation for pooled data. The predicted yield was compared with the observed yield. The magnitude of error was ± 22%.

(R.N. Dash, S.K. Nayak, M.V.R. Murty and S. Patnaik)

BGA. 1. Biological (Algal) N_2-Fixation

Effect of Azolla caroliniana *inocula on its growth, N_2-fixation and rice yield. Azolla caroliniana* was grown at the rates of 0.2 , 0.4 , 0.6, 0.8 and 1.0 t/ha after 14 days of planting of IR 36 and Jaya rice varieties during the *rabi* season. Urea at 30 kg N/ha was applied in 3 split doses (15.0 + 7.5 + 7.5) in all the treatments. *Azolla* fresh weight and fixed N at 10 and 20 days after inoculation (DAI) linearly increased with the increasing levels of inoculum up to 1.0 t/ha. These parameters at 30 DAI also increased up to 0.6

t/ha inoculum beyond which inoculum levels showed similar effects. Azolla fresh weight, and N fixed at all the dates with two varieties were comparable. The fresh weight and fixed weight of *Azolla* at 30 DAI ranged from 9.0–15.5 t/ha and 16.8–27.6 kg N/ha for inoculum levels and two rice varieties, respectively.*Azolla* dual cropping significantly improved the grain yields of IR 36 by 8.4–109.% and of Jaya by 9.5–18.09%. The straw yield, number of panicles and grains for both rice varieties were also increased by *Azolla*. The inoculum levels showed similar effects on above traits.

(D.P .Singh and P.K. Singh)

Effect of 2,4-D application on the Azolla *decomposition and rice yield. A. caroliniana* and *A. pinnata* (Bangladesh) were grown (inoculum 1.0 t/ha) after 15 days of planting of rice crop during the *rabi* season . Rice variety IR 36 was used as test crop and 30 kg N/ha as urea was applied in 3 split doses (15 + 7.5 + 7.5). 2,4-D-Na, applied at 0.25 and 0.50 kg a.i./ha on the *Azolla* mat 21 DAI, recorded 18.4 and 37.7% decomposition for *A. caroliniana* and 53.8 and 71.3% for *A. pinnata* at 10 days after 2,4-D application as against 15.4 and 35.5% decomposition for the two species in untreated plots, respectively. However, for both species decomposition was faster when incorporated into the soil as compared to 2,4-D treatment. *Azolla* species increased the grain yield by 13.6-26.0%, but soil incorporation or 2,4-D treatment showed no further improvement in the grain yield.

(D.P. Singh and P.K. Singh)

Effects of phosphorus, molybdenum and iron application on growth and N_2-fixation by Azolla *and rice yield.* This experiment was conducted during *kharif* and *rabi* seasons with 3 levels of phosphorus (0, 8 and 16 kg P_2O_5/ha), 2 levels of molybdenum (0, and 0.15 kg Mo/ha) and 2 levels of iron (0 and 1.0 kg Fe/ha). *A. caroliniana* was inoculated at 1.0 t/ha after 15 days of planting of rice variety IR 36 and 30 kg N/ha as urea was applied in 3 splits (15 + 7.5 + 7.5). Phosphorus application at 0, 8 and 16 kg P_2O_5/ha recorded the *Azolla* fresh weight of 4.0-7.1, 10.0-14.9 and 13.0-15.1 t/ha and the fixed N of 6.3-11.7, 18.1-28.3 and 22.9-29.2 kg N/ha in different molybdenum and iron treatments and two seasons. Molybdenum or iron application significantly increased the fresh weight and fixed N during the *rabi* season .During the *kharif* season, molybdenum application showed no significant effect on the fresh weight, but increased the fixed N whereas effect of iron was not significant on both fresh weight and fixed N. The interactions among phosphorus, molybdenum and iron were not significant. However, responses of *Azolla* to molybdenum and iron application were lower with 16 kg P_2O_5/ha. The grain yield of rice in the control without phosphorus, molybdenum and iron application was 2.8 and 3.6 t/ha in *kharif* and *rabi* seasons, respectively. In both seasons, phosphorus application significantly increased the grain yield (12.0-14.4% in wet season and 8.6-9.5% in dry season) and straw yield whereas effects of molybdenum and iron were not significant. Phosphorus application at 8 and 16 kg P_2O_5/ha produced similar grain and straw yields.

(D.P. Singh and P.K. Singh)

Effects of varying nitrogen and phosphorus levels on the growth and N_2-fixation by Azolla *and rice yield.* This study was performend during *kharif* and *rabi* seasons with 4 levels of nitrogen (0, 40, 80 and 120 kg N/ha) and phosphorus (5, 10, 15 and 20 kg P_2O_5/ha) .Nitrogen was applied as urea in 3 splits, half before planting and a quarter each at maximum tillering and panicle initiation. *A. caroliniana* was grown (1.0 t/ha inoculum) after 15 days of planting of rice crop IR 36 and phosphorus was applied in 3 equal splits

at 0, 7 and 15 days after *Azolla* inoculation. *Azolla* grown without application of N fertilizer recorded the highest fresh weight of 10.0-13.8 and 10.6-17.1 t/ha and the fixed N of 16.3-24.9 and 18.2-32.5 kg N/ha with different levels of P during *kharif* and *rabi* seasons, respectively. The fresh weight and fixed N were not significantly decreased at 40 and 80 kg N/ha during the *kharif* season and at 40 kg N/ha during the *rabi* season. The fresh weight and fixed N were significantly higher with 10 kg P_2O_5/ha than that with 5 kg P_2O_5/ha in both seasons. During the *rabi* season fresh weight and fixed N were higher with 20 kg P_2O_5/ha than that with 10 kg P_2O_5/ha and response to increasing P levels was evident at 0 and 40 kg N/ha levels. The interactions among N and P levels were not significant in both seasons. *Azolla* dual cropping without application of N fertilizer produced the grain yield of 2.4–2.7 t/ha among different P levels and two seasons. The grain yield increased with *Azolla* dual cropping along with increasing N levels up to 120 kg N/ha in the *rabi* season and up to 40 kg N/ha in the *kharif* season. Phosphorus levels showed similar effects on the grain yield in both seasons.

Another experiment was conducted during the *kharif* season with 3 levels of nitrogen (0, 60 and 120 kg N/ha) and 2 levels of phosphorus (10 and 40 kg P_2O_5/ha). Rice variety CR 1018 was used in this experiment. In different N treatments fresh weight of *A. caroliniana* and *A. pinnata* was 32.5-46.2 and 22.1-66.6% higher with 40 kg P_2O_5/ha than that with 10 kg P_2O_5/ha, respectively. Increasing N levels significantly decreased the fresh weight and fixed N of both *Azolla* species. The growth of *A. caroliniana* was better than that of *A. pinnata*, irrespective of N and P levels. *Azolla* species along with 0, 60 and 120 kg N/ha urea recorded the grain yields of 3.2–3.4, 3.9–4.1 and 4.5–.0 t/ha in two phosphorus treatments. The two *Azolla* species and phosphorus levels were at par with regard to the grain yield.

(D.P .Singh and P.K. .Singh)

Growth and N₂-fixation of Azolla caroliniana *and rice yield at varying levels of urea.* This experiment was conducted during the *rabi* season using rice variety IR 36. Urea at 20, 40, 60, 80 and 100 kg N/ha was applied in splits, half before planting and a quarter each at maximum tillering and panicle initiation stages. *Azolla* was grown (inoculum 1.0 t/ha) after 10 days of planting. Increasing levels of urea decreased the fresh weight and fixed N, but effect of urea was not significant up to 60 kg N/ha. Urea levels of 0-100 kg N/ha recorded the grain yields of 4.3–6.0 t/ha . *Azolla* application increased the grain yield by 2.8–16.9% at varying levels of urea and response to *Azolla* decreased with increasing levels of urea.

(P.K. Singh)

Effect of Azolla *species on rice yield.* The performance of four *Azolla* species namely *A. caroliniana, A. nubra, A. filiculoides* and *A. pinnata* was tested during the *kharif* season with application of 0, 40 and 80 kg N/ha as urea in split doses . *Azolla* species were grown at the rate of 1.0 t/ha after 10 days of planting of rice variety CR 1018. The fresh weight and fixed N for all the species were highest in the absence of applied urea, being 14.1, 12.3, 9.6 and 8.3 t/ha and 32.4, 26.4, 18.5 and 16.7 kg N/ha for *A. caroliniana, A. nubra, A. pinnata* and *A. filiculoides*, respectively. Ure.a at 40 kg and 80 kg N/ha decreased the fresh weight of different species. The interactions of *Azolla* species and urea levels were not significant. Among *Azolla* species tested, the inhibitory effect of urea was relatively higher on *A. pinnata* whereas *A. caroliniana* performed better at all levels of urea application. The grain yields were highest with *A. caroliniana* treatment and lowest with *A. pinnata* treatment.

(P.K. Singh)

Effects of levels and methods of phosphorus application on growth and N_2-fixation of A. caroliniana *and rice yield. Azolla* was grown at 1.0 t/ha after 7 days of planting of rice variety IR 36 during the *rabi* season and phosphorus at 8, 16 and 24 kg P_2O_5/ha was applied once during inoculation or in 2 and 4 split doses. Urea at 30 kg N/ha was applied before planting in all treatments. Increasing levels of phosphorus application significantly increased the fresh weight and fixed N of *Azolla* and the grain yield of rice.

(P.K. Singh)

Response of two Azolla *species to application of pesticides Furadan and Thimate. A . caroliniana* and *A. rubra* were grown in unplanted fields and Furadan (3% a.i. as carbofuran) or Thimate (10% a.i. as phorate) were applied at 1, 2 and 3 kg/ha. Fresh weight and fixed N of both *Azolla* species significantly increased with increasing doses of Furadan. Both parameters for both species increased gradually with increasing doses of Thimate. The growth of *A. caroliniana* was better than that of *A. rubra*, irrespective of pesticide treatment.

(P.K. Singh)

Studies on sporocarp germination in Azolla caroliniana. The sporocarp bearing fresh *Azolla* plants were dried, powdered and shaken in a container so that the micro and megasporocarps got attached. The sporocarps were then separated with the help of a 40-mesh sieve and used for germination studies. Light was essential for sporocarp germination. The percentage germination was higher in solid medium than in liquid medium. The appearance of *Anabaena azollae* was noticed in 3rd leaf of the sporophyte, whereas heterocysts were formed at 4th leaf stage and mature heterocysts were noticed in 5th leaf. The sporocarps germinated in the pH range of 6.5 to 8.0, with highest frequency of germination at pH 7.0. Addition of 2.5-5.0 mM nitrate, 0.10-0.75 mM ammonium, 1.0-2.5 mM nitrate or 0.30-0.50 mM urea to the medium increased germination by 17.6-24.9, 21.3-32.6, 14.2-22.1 and 19.0-31.1%, respectively. Higher concentrations of these salts were inhibitory. The highest germination frequency was observed with 5.0 mM nitrate, 0.5 mM ammonium, 1.0 mM nitrite and 0.5 mM urea. Phosphorus (0.25-1.5 mM phosphate) also increased germination especially at 1.0 mM phosphate level. Addition of 100 ppm kinetin and gibberellic acid recorded 67 and 55% germination, respectively against 40% in control. Use of both kinetin and gibberellic acid together gave 84% germination.

(P.K. Singh)

SM. 01. Pesticide Metabolism in Rice Soils

In continuation of the work reported in the previous year, a carbofuran-degrading bacterium was isolated from the enrichment culture which was taken from a flooded soil incubated at 35^0C and repeatedly treated with carbofuran. The bacterium was a strict aerobe, motile, Gram-positive, non-acid fast and non-spore-forming. Based on the morphological and other biochemical characteristics, the bacterium was tentatively identified as an *Arthrobacter* sp. The ability of the bacterium to degrade carbofuran as a sole source of carbon and nitrogen was more pronounced at 35^0C than at 20^0C. After 48 hr, the insecticide concentration in inoculated medium decreased to less than 10% of the original level at 35^0C while no appreciable decrease in its concentration was noticed at 20^0C during the same incubation period. Assay of $^{14}CO_2$ showed that almost all the ring-labelled-^{14}C in carbofuran that decreased was accounted for as $^{14}CO_2$. Thus, about 80% of the ring labelled-^{14}C in carbofurn was evolved as $^{14}CO_2$ in 72 hr. after inoculation at 35^0C. 7-Phenol was detected as a metabolite, but it never accumu-

lated in stoichiometric amounts, probably because of its rapid metabolism. The bacterium readily degraded carbafuran, carbaryl, 3-hydroxycarbofuran and 7-phenol. 3-Hydroxycarbofuran and 7-phenol almost completely disappeared in 72 and 288 hr respectively. Carbaryl, a related carbamate insecticide, which was degraded almost at the same rate as carbafuran also reached undetectable levels within 72 hr. HPLC analysis of the samples showed that hydrolysis was the principal route of degradation of carbaryl by the bacterium. At 8 days, no carbaryl was detected in the inoculated medium while 9.4 mg of 1-naphthol per ml accumulated in the medium indicating that the bacterium hydrolysed carbaryl with the concomitant accumulation of 1-naphthol in large amounts. From these evidences it appears that the bacterium, isolated by soil enrichment at 35^0C possesses a greater capacity to mineralize carbofuran at this temperature.

(N. Sethunathan, T.K. Adhya and V.R.Rao)

SM. 02. Biological N_2-Fixation by Free-Living Bacteria in Rice Soil

Soil salinity is an important factor affecting microbial activity and crop production. Few studies indicate that considerable nitrogen fixation occurs in saline and acid saline soils. In a laboratory incubation study, the effect of natural and artificial soil salinity on soil N_2-fixation, nitrogenase (C_2H_2 reduction) and N_2-fixing populations was evaluated in rice soils under two water regimes. Nitrogen fixation was more pronounced under flooded conditions and was further enhanced by the addition of rice straw to flooded nonsaline soils. Nitrogen fixation significantly decreased with an increase in soil salinity (beyond 4 dS/m). Addition of a salt mixture to a nonsaline soil (0.6 dS/m) to a salinity level of 4 dS/m also produced a significant inhibition of N_2-fixation. Upon leaching the saline soil N_2-fixation improved. When a highly saline soil ((30 dS/m) was leached, salinity level declined to almost 10 dS/m with an improvement in N_2-fixation. However this improvement in N_2-fixation in leached soil was never as high as in a normal nonsaline soil. Under nonflooded conditions, the N_2-fixation in a nonsaline soil was low and addition of salt mixture further lowered it. Addition of rice straw enhanced N_2-fixation in normal nonsaline, saline and highly saline soils especially under flooded conditions. Leaching the saline soil improved the populations of anaerobic N_2-fixers and *Azospirillum*. *Azotobacter* populations, however, were not affected by the soil salinity. Under submerged conditions, the populations of *Azospirillum* were higher. Thus, soil amelioration practices like organic matter application and leaching are likely to improve the general fertility status of the soil, N_2-fixation and select groups of N_2-fixing microorganisms in soils under rice cultivation. The data further indicate that water regime also plays an important role in determining the extent and effect of soil salinity on N_2-fixation in rice soils.

(V.R. Rao, T.K. Adhya and N. Sethunathan)

PLANT PATHOLOGY

PATH. 01. Assessment of Germplasm Collections, Released Improved Varieties and Breeding Materials Against Different Diseases

Blast

Breeding material. Of the 34 entries tested, CR 572, CR 574 and CR 289-1046-16 were tolerant to blast. Entries, Carreon, Tapoo 20, Rasi, Zenith, Te-tep, IR 34, IET 8892, IET 2508, CR 10R-157, CR 113-4741, CR 115-6, CR 571, CR 572 and Taichung Shih 183 showed better tolerance to blast than Jaya, Cauvery, IR 56 and CR 82-146.

Promising lines from IRRI. Of the 78 entries tested, IR 32307-1073-2-2, IR 3615-4-2-3, IR 1364-375-1-2, IR 1476-125-5-3 and IR 36 were tolerant while IR 64 was resistant.

Varieties from Mizoram . Of the 800 collections evaluated, 25 entries were resistant and 36 entries showed tolerant reaction.

Varieties from genetic stock. Of the 589 varieties received from Genetic Resources, 113 were resistant, 41 moderately resistant, 77 susceptible and 358 highly susceptible.

Mutant population of IR 50. Of the 90 lines earlier selected as resistant to blast from M-4 and IR 50 treated with EMS, 11 lines were resistant/tolerant with leaf area damage ranging from 0 to 4%. The yield of these IR 50 mutants was better than that of original IR 50 (Table 21).

(K.V.S.R. Kameswar Row. B. Padhi. U. Dhua and N.P. Sharma)

Table 21. *Field performance of blast tolerant mutants of IR 50*

Mutant line	% of leaf area damaged	Yield (t/ha)
1-3-1	8	5.9
7-3-1	0.2	4.2
8-2-1	0.2	5.3
8-8-1	0.2	4.9
9-6-1	0	3.5
11-5-1	0	4.6
13-6-1	0.5	5.3
21-2-1	4	4.5
KR 70-1	0	5.7
IR 50 (resistant mixture)	32	5.3
IR 50 (susceptible mixture)	8	4.4
Normal IR 50	32	4.2

The plants of the rice accessions of the World Genetic Stock series obtained from I. R. R. I. viz., WGS-426, 555, 563, 564, 740, 801, 827 and 862 were resistant to both foliar infection and infection of the basal node of the panicle by two cultures of *P. oryzae* one each from leaf and neck [*P. oryzae* IC. 17 (L&O)].

The plants of the rice accessions of the World Genetic stock obtained from I. R. R. I. viz., 560, 562, 847 and 849 were susceptible to both foliar infection and infection of basal node of the panicle to the two cultures of *P. oryzae* utilised in this study.

(J. Veeraraghavan)

Sheath blight

Breeding material. CR 666-75 and CR 666-23-2 from the 22 early cultures and B-15, SR 95-

1 and SR 145 from the 24 dwarf rice varieties were tolerant under artificial inoculation tests.

Lemon grass - highly tolerant to sheath blight organism. Lemon grass (*Cymbopogon flexuosus*), a fast growing and sturdy grass when inoculated with *Rhizoctonia solani* on plants/detached leaves, produced only restricted reddish discolouration without clear-cut lesions with no sclerotial production.

(A.P. Dath)

Bacterial blight

Reaction of released varieties. Of the 130 rice varieties screened, none was resistant to bacterial blight both under natural and artificial tests. Some of the varieties viz., Jayashree, Annada, Sowbhagya, Sannidhi, Kusuma, Vikas, Gobind, TPS 1, IR 20, Sona, Panidhan 1, Surekha and Lakshmi have shown only 5 to 10 per cent of the leaf area damaged due to this disease as against 20-75 per cent in the remaining varieties.

Germplasm. Of 1307 entries tested by artificial inoculation in the field, 33 entries were resistant.

Incidence of bacterial blight and bacterial leaf streak diseases in some scented rice varieties. All the six scented rice varieties (Basmati 370, Pakistan Basmati 370, T 412, Badsha Bhog, IET 8580 and IET 8579) , grown under four levels of nitrogen fertilization (0, 30, 60 and 90 kg/ha). were susceptible to both bacterial blight and bacterial leaf streak diseases with a score ranging from 5-9 (as per SES) especially at higher levels.

Breeding for disease resistance involving a wild rice Oryza barthii. In *kharif* 1988, 254 cultures of F6 generation from crosses involving *Oryza barthii* were grown and artificially inoculated for identifying uniformity in resistance as well as in plant type. Though the uniformity for resistance was achieved in a number of cultures, segregation for morphological characters like plant height, panicle type, grain size and others continued in most of the cultures. The 16 cultures derived from CR 289-1008 x *Oryza barthii* were uniformly susceptible while several single plants were collected with resistance and good plant type from the crosses of Jaya x *O. barthii* for testing in the next generation.

(P.R. Reddy)

Rice tungro virus complex

Performance of CRRI cultures for lowland situation against rice tungro. Fifty five F_4 progenies were tested in the *kharif* season by

Table 22. *Reaction of CRRI rice cultures to tungro*

Culture	Cross	Tungro incidence (%)	Tolerance score
CR 617-16-11-7	HTAER 770-22-14157-16-1/Tox 896-R-R-R-102	21.0	3
CR 624-24-39	Champa x Savitri	19.0	3
CR 626-26-6-3-1	Champa x Savitri	15.0	3
CR 626-26-8-1-1	Champa x Savitri	18.0	3
CR 626-26-14-1	Champa x Savitri	17.0	3
CR 626-26-14-4	Champa x Savitri	25.0	3

field screening technique. Reaction of some promising rice cultures to tungro is given in Table 22.

Yield trial of tungro resistant cultures. Ten CRRI cultures, selected as tolerant to tungro in *kharif* 1987, were assessed in *kharif*, 1988 in desease-free plots for their yield potential. Four cultures viz. CR 30-26-1 , CR 404-14-1, CR 380-26-39 and CRM 25 yielded 4 t/ha. These cultures possessing both tungro tolerance and high yielding ability can be recommended for growing in farmers' fields.

(S.K. Mohanty, A. Anjaneyulu, G. Bhaktavatsalam and S.K. Singh)

Multiple resistant cultures. One hundred and one cultures/breeding materials were screened against blast, helminthosporiose, sheath blight, sheath rot, *Cercospora*, bacterial blight and bacterial leaf streak diseases of rice. Several multiple resistant cultures to different diseases were isolated.

(B. Padhi)

PATH. 02. Durable Resistance for Major Diseases

Rice tungro virus. A total of 99 popularly grown high yielding varieties were evaluated for durable resistance to rice tungro virus under severe disease pressure. Durable resistance was evaluated through various parameters like disease (ICP), relative area under disease progress curve (RAUDPC), the apparent infection rates estimated by logistic method (r) and gomperts (k) method. Among all the parameters, RAUDPC was the best and most convenient parameter for the evaluation of durable resistance, since it exhibits distinct differences among host genotypes, takes all the data into consideration, does not involve any transformation of the data and is least influenced by minor differences in disease severity early in the season. Accordingly, the varieties Swarnaprabha, Kahitish, Biraj, Vanaprabha, Jaladhi-1, CR 575, ADT 36 and Vikash were identified to possess durable resistance to tungro. Durable resistance was associated with delay in onset of the disease as depicted in the disease progress curves from a few representative varieties.

(S. K. Singh, A. Anjaneyulu, P. Nayak, S. K. Mohanty and G. Bhaktavatsalam)

PATH. 03. Disease Management Strategies

Pathogenic variability of blast fungus. Eleven cultures of *Pyricularia oryzae* Cav. (10 isolates from blast specimens at CRRI campus and one from Maruteru, Andhra Pradesh) were tested for their pathogenicity on international blast differentials of rice varieties obtained from USDA, U. S. A. and IRRI, Philippines.

The differentials from USDA yielded the reaction pattern IC 17 (L&O) while those from IRRI yielded the reaction pattern IC 9 (L&O). The differentials Usen (fourth) and Dular (fifth) from IRRI were susceptible and resistant, respectively. The reaction pattern obtained by utilizing plants raised from seeds from USDA, U. S. A. only is valid since Atkins *et al.* (1967) utilized that source only.

Five cultures of *P. oryzae* which were identified earlier as belonging to reaction pattern IC 17 (L&O), USDA-GP and maintained by subculturing on oatmeal agar medium regularly proved to be stable in their pathogenicity. These cultures also yielded IC 9 (L&O) when they were tested concurrently on international blast differentials from IRRI seeds and proved to be stable in their pathogenicity after host-passage *in vivo* three times during the period under report.

Two varieties of the international blast differentials (USDA), one each from the resistant and susceptible genotype of *Oryza sativa* L., as evidenced by literature is sufficient to construct

a set of differentials instead of 8 varieties since both the sets gave similar results.

(J. Veeraraghavan)

Pathogenic variability of blast fungus in nature. The seeds of 8 international blast differentials viz., Raminad-str.3, Zenith, NP 125, Usen, Dular, Kanto 51, CT 8970 (S) and Caloro were sown in the nursery trays and exposed to natural conditions. Race groups IC and IE were dominant in *rabi* and race IF was dominant in *kharif*.

(B. Padhi)

Investigations on sheath blight

Viability of Rhizoctonia solani *sclerotia in different sources of irrigation water.* Viability of sclerotia of *R. solani* in six sources of irrigation water : 1) pond with lot of water hyacinth growing in it, ii) pond having abundant algal growth, iii) plot in which *Azolla* is being grown, iv) a waterlogged rice field, v) river water in the irrigation canal and vi) tube well was examined. Sclerotia of *R. solani* were added to these water sources and incubated at 28 ± 1°C. The viability of sclerotia was tested at monthly intervals by plating on PDA also by detached leaf technique. Sclerotia were viable for as long as 150 days in pond water with water hyacinth as compared to 60 days in water from other sources. Evidently, pond water harbouring water hyacinth favoured the multiplication and survival of the sheath blight pathogen.

Influence of rice tungro virus (RTV) on sheath blight development. Plants of Taichung Native-1 were inoculated first with RTV and when the symptoms of tungro started appearing, the same plants were inoculated with *R. solani*. The development of sheath blight symptoms was faster and more severe in RTV-infected plants than in RTV-free plants. However, the incidence of RTV was not affected by sheath blight infection. Even on detached RTV-infected leaves, severe symptoms of sheath blight developed on inoculation with *R. solani*. The altered host physiology by RTV infection seems to play some role in increasing the severity of sheath blight.

(A.P. Dath)

Epidemiology of rice tungro

Spatial distribution of rice tungro virus. Spatial distribution patterns of tungro incidence were studied in a naturally infected field plot (40 m x 40 m). Periodic observations were recorded on the number and position of tungro-infected plants at 5-day intervals. Observations were spread over 0-100% infection of the plant population. Based on the total number of runs and doublets as well as on the negative binomial distribution, the disease spread was observed to be aggregation pattern, the infection starting from a single plant spreading to nearby plants, thus forming an infection focus. Several foci distributed all over the field merge together to form a uniform epidemic of tungro disease.

(G. Bhaktavatsalam, A. Anjaneyulu, S.K. Singh, S.K. Mohanty and P. Nayak)

Botanical pesticides to control different diseases. Fractions from *Aegle marmelos* and *Ocimum sanctum*, obtained through hydrodistillation, showed strong inhibition against *Pyricularia oryzae*, and varying degrees of inhibition against *Cochliobolus miyabeanus, Rhizoctonia solani, Fusarium moniliforme, Curvularia lunata, Aspergillus niger* and *A. flavus*.

Groundnut, an important cash crop in a rice-based cropping pattern, is attacked by tikka leaf spot (*Cercospora arachidicola*) and collar rot (*Aspergillus niger*) leading to decreased yield and deterioration in grain quality.

Seed dressing of groundnut seed (var. AK 12-24) with the hydrodistillates obtained from *O. sanctum* at 1% aqueous suspension caused phytotoxicity, but the fractions from *A. marmelos*

at the same concentration triggered better germination and growth. Seed treatments at 0.1% with one of the hydrodistillate fractions from either of the botanicals increased mean germination percentage of seed and the radicle growth over control. *O. sanctum* treated seeds (0. 1% and above) of groundnut did not exhibit bacterial (unidentified) contamination.

(S.N. Tewari)

Chemical control of fungal diseases

Blast

Performance of systemic fungicides as spray vs. granular applications under upland conditions. Amongst granular fungicides, Coratop 5G (Pyroquilon) reduced foliar blast (25 per cent) as against 64 per cent in control, of a highly blast susceptible variety IR 50. Carbendazim as spray at 0.5 kg a.i./ ha reduced foliar blast by 36 per cent.

Efficacy of new fungicidal formulations (WEC/WP) on blast. Fungicides, Beam 75 WP, Befran 25 AS, Rabicide 500 WP, Edifenphos 50 EC, Kasumin 3 l and Bavistin 50 WP controlled blast when sprayed on IR 50 with significant increase in yield. Highest yield (3.27 t/ha) was recorded in Beam 75 followed by Bavistin WP (3.1 t/ha) as against 2.07 t/ha in control.

Evaluation of seed dressing with fungicides in seedling blast control. The trial was conducted in field and greenhouse with two replications under severe disease pressure. In the field, tricyclazole (Beam 75 WP) and Pyroquilon (Fongorene 50 WP) at 3 g/kg of seeds were equally effective and significantly superior to other treatments up to 30 DAS and were on par with carbendazim at 56 DAS. In greenhouse, Pyroquilon (Fongorene) totally prevented leaf blast appearance up to 27 DAS and was on par with carbendazim (Bavistin 50 WP) or tricyclazole (Beam 75 WP) applied at 1 g/kg.

(U.D. Singh and K.V.S.R. Kameswar Row)

Chemical control of sheath blight

Laboratory studies. None of the insecticides or herbicides, tested under artificial conditions, was superior to the commonly used fungicide, Bavistin in arresting the growth of sheath blight fungus, *Rhizoctania solani.* Among the various new fungicides tested, Roveral (iprodione) was highly effective in inthibiting the mycelial growth and sclerotial germination.

Field studies. Of the commonly used systemic and nonsystemic pesticides (fungicide-Bavistin, Rhizolex, Topsin, Dithane M-45, antibiotic-Validacin, herbicide-Saturn and pesticide mixture - Saturn + Dithane M-45) evaluated for the control of sheath blight disease under artificial epiphytotic conditions, Topsin was the most effective, followed by Validacin and Rhizolex. Efficacy of Bavistin against sheath blight disease declined appreciably as compared to earlier field tests. Yield was highest in Validacin-treated plot.

(U.D. Singh)

Etiology of blast. Offspring lesion producing ability of various types of parent lesions viz., purple lesions with thin or thick orange or orange-brown margins was examined. The quantity and quality of parent lesion influence the quantity and quality of offspring lesions.

Purple lesions with yellow or dark margins were produced on *O. meriodinelis, O. alta, O. glaberrima, O. nivara, O. punctata, O. mijuta, O. australensis* and *O. barthii.* No lesions developed on *O. merdiana* and *O. eichengeri.*

(U. Dhua)

Modelling on yield loss assessment due to diseases

Effect of bacterial blight, bacterial leaf streak and sheath blight diseases on the cultivar Kanima.

In a field experiment on the cumulative effect of the three diseases on yield, rice plants (Karuna) were artificially inoculated with sheath blight pathogen at tillering and flowering stages of crop while natural infection was used for bacterial blight and bacterial leaf streak diseases.

Inoculation of rice plants with sheath blight pathogen at flowering stage coupled with natural incidence of bacterial blight and bacterial leaf streak caused greater yield reductions than did the inoculation at tillering stage. Simulated yields through the computer model also showed a similar trend in the grain yields despite some differences between actual and simulation yields.

Influence of bacterial blight on grain yield in MW 10. The cultivar MW 10 was inoculated with bacterial blight pathogen at early tillering, maximum tillering and flowering stages. The observations on the disease incidence in terms of leaf area damage was recorded at weekly intervals until maturity.

The actual grain yields following inoculation at tillering and maximum tillering almost coincided with simulation yields. But, a great difference was noticed between simulated yield (6.1 t/ha) and actual yield (3.3 t/ha) at flowering stage inoculation and in the check plots.

(P.R. Reddy and U.D. Singh)

Physiology of disease resistance

Phytoalexin in disease resistance. Phytoalexins, antimicrobial substances produced by plants in response to infection or chemical and physical stimuli, govern the induced form of resistance in plants. To assess the role and importance of phytoalexin in disease resistance, a dependable qualitative and quantitative method to determine the level of phytoalexin formed under different situations is a basic need.

The phytoalexin produced in blast resistant cultivar IR 8 was separated on paper chromatograms. This compound reacted positively with vanillin (3%)–sulphuric acid (0.5%) in methanol and saturated antimony trichloride in chloroform. These reactions suggest that the phytoalexin detected by us in rice is a terpenoid compound. Based on its mobility on paper chromatograms in different solvent systems coupled with bioassay involving *Pyricularia oryzae, Helminthosporium oryzae* and *Curvularia lunata*, the phytoalexin detected by us appear to be different from the previously reported phytoalexins in rice. A qualitative and quantitative assay method has also been developed using the sensitive high performance liquid chromatography.

Employing paper and high performance liquid chromatographic methods and bioassay techniques, phytoalexin formed in three different situations involving (1) a blast resistant cultivar IR 8, (2) a susceptible cultivar Karuna raised from seeds treated with copper sulphate and (3) leaf blades of Karuna pre-inoculated with a non-pathogen of the foliage (*Curvularia lunata*) was extracted and compared. In all these three situations, similar phytoalexin was formed in rice. Understandably, the terpenoid phytoalexin detected by us may be one of the important factors of resistance in rice to the blast fungus.

To examine the significance of the terpenoid phytoalexin in diseases other than blast such as brown spot caused by *Helminthosporium oryzae*, sheath blight caused by *Rhizoctonia solani* and bacterial blight caused by *Xanthomonas campestris* pv *oryzae*, the effect of seed treatment with 14 chemicals belonging to heavy metals, amino acids and growth regulators which are known to induce phytoalexin synthesis in plants on the reaction of plants to these three pathogens was examined in a nethouse experiment. Treatments like copper sulphate, cadmium chloride,

mercuric chloride and leucine, which were capable of reducing blast severity, also decreased the severity of brown spot. Bioassay of the exudates containing the phytoalexin with *H. oryzae* revealed that the terpenoid phytoalexin detected by us may induce resistance of rice to brown spot in addition to blast although *H. oryzae* was less sensitive to the compound than *P. oryzae*. However, none of these test chemicals influenced the tissue resistance to either *R. solani* or *X. campestris* pv. *oryzae*. This would suggest that the induced resistance operating through the formation of phytoalexin against blast and brown spot pathogens may not govern resistance to sheath blight and bacterial blight.

(R. Sridhar)

Residues of carbendazim in plant tissues. Residues of carbendazim present in the radicles and coleoptiles and in shoot portions of seedlings (cv. Karuna) grown from seeds treated with the fungicide and in adult plants sprayed with the fungicide at boot leaf stage were quantified in a high performance liquid chromatograph at different periods after the fungicide application.

Levels of carbendazim residues detected in the radicles and coleoptiles four days after seed germination and in seedlings and adult plants were proportional to the concentrations used for treating the plants. The fungicide was detected up to three weeks after germination in seedlings raised from seeds treated with the fungicide and up to five weeks after spraying on the adult plants. The tissue levels of carbendazim, however, decreased with the age of plant. Presence of carbendazim residues in the radicles demonstrates the movement of the fungicide to the root tissues where it may offer protection against the root infecting pathogens initially when the fungicide was applied as seed treatment. The levels of carbendazim residues detected in seedlings and adult plants at three and five weeks after treatment was lower than the levels required to kill the pathogen by its direct toxic effect.

(R. Sridhar)

PATH. 04. Seed Pathology and Grain Discolouration

Studies on the biology, ecology and pathology of Sarocladium oryzae. The pathogen, *Sarocladium oryzae* was present on discoloured and non-discoloured seeds of varieties CR 1009 and CR 333-6-1 and it was detected in the hulls and kernels. Growth of the fungus was better on the kernels as compared to unhulled seeds.

The disease was transmitted from seed to seedlings in blotter tests and seed to mature plants in the pots. Symptoms of the disease appeared only at ear emergence stage on the flag leaf sheath. Healthy looking leaf sheaths harboured the pathogen without showing any symptoms. Evidently, the seeds can be a potent source of infection in the field.

False smut of rice, its biology, ecology and pathology. The fungus, *Ustilaginoidea virens* was present on the kernels, lemma and palea in culture CR 333-6-1 naturally infected with false smut disease. The associated fungi were *Trichoconis padwickii, Fusarium* sp., *Drechslera oryzae, Sarocladium oryzae* and *Curvularia* sp.

In a rice seed sample obtained from plants severely infected by false smut disease, *Ustilaginoidea virens* was detected in kernels (40%), lemma (80%) and palea (71%).

(L.P. Kauraw)

Coordinated Trials

Blast

Slow blasting. Of the 30 varieties evaluated, 2 entries viz., RP 2334-336-99-47 and IR 64 showed intermediate infection.

(K.V.S.R. Kameswar Row)

Tungro. Of 250 entries of National Screening Nursery 1988 (NSN), only 2 entries IET No. 9681 (IR 50/IET 7916) and IET No. 10436 (Lalnakanda/IR 30) scored a tolerance score of 1 against tungro disease, 9 entries scored a tolerance score of 2 and 33 entries scored a tolerance score of 3.

Of 203 entries of National Screening Nursery (special) (NSN(S), only 1 entry IET 11372 (Pankaj/CR 1014) scored a tolerance score of 2 and 12 entries scored a tolerance score of 3.

Of 94 entries of multiple resistance screening trial (MRST), only 1 entry (Bhavani/ARC 10550) scored a tolerance score of 2 and 8 entries scored a tolerance score of 3.

Disease management trials

Blast.. Of 7 fungicides evaluated under reasonably severe leaf blast infection, Beam 75, Befran 25, Ediphenphos, Fugione, Kasumin and Bavistin were superior to Rabicide in reducing infection and increasing yields.

(K.V.S.R. Kameswar Row)

Sheath blight. The disease pressure was high in Annapurna. Only thiophanate-methyl effected a significant reduction in disease incidence. Disease intensity in other treatments was on par with that in untreated control.

(U.D. Singh)

Brown spot. Observations were recorded on seedlings of culture CR 650-11 and the susceptible check Benibhog infected with brown spot pathogen. Dithane M-45 75 WP (2.5 g/l) was sprayed just on the day of first appearance of the disease. The disease intensity was 2.4 and 5.5 on CR 650-11 and Benibhog, respectively under protected condition as compared to a corresponding score of 3.5 and 7.5 under unprotected condition.

(B. Padhi)

Sheath rot. Seven varieties viz., IET 7592, IET 7895, IET 8611, IET 8616, IET 7304, IET 8613, and IET 7302 were used in the trial with split-plot design in 5.1 x 2.1 m plots with 15 x 1 cm spacings having four replications.

In general, when all the varieties were pooled together, the average infection of sheath rot was 55.5% with 3.1 kg/plot yield under protected (Bavistin 50 WP) condition and 80.7 % infection with 1.8 kg/plot yield under unprotected condition.

(B. Padhi)

ENTOMOLOGY

ENT. 01.01. Evaluation of Rice Germplasm and Elite Breeding Materials against Major Insect Pests

Gall midge and stem borer. Fifteen cultures from the crosses of Phalguna x TKM 6, IR 13427-6-1 x RNR 1446, Ratna x ARC 10654, Ratna x ARC 10660, Nagarjuna x ARC 5984 and Ratna x ARC 5984 were promising against gall midge and stem borer from among 94 cultures received through DRR as MRST.

(B.C. Misra)

The set of 85 entries, screened for leaf folder in *kharif*, was also tested against gall midge under heavy natural infestation (up to 100% infested hills and 69% silver shoots in the susceptible entries). Entries viz., ARC 1128, Choorapundy, CR 157-39-9, RP 2235-85-62-8, RP 2199-102-14-19-10, RP 2199-41-25-30-55, RP 1579-43 and CR 410-3225-2 and IR 38 were free from infestation.

(P.S. Prakasa Rao and G. Padhi)

A set of 80 entries assembled from CRRI as gall midge resistant donors was tested by Andhra Pradesh Agricultural University at Panukuvalasa of Srikakulam district in *kharif* under high natural infestation.. Besides the three Orumundakan sources viz., Orumundakan, Orumundakan Mutant tall and Orumundakan mutant semi-tall, the other entries identified as resistant to the north coastal A.P. biotype of gall midge were ARC 6650, MNP 762, Tellagarika, Sannavari, PTB 10, AC 1224, AC 1630, AC 3283, AC 404, AC 355 and AC 169.

(P.S. Prakasa Rao)

In *rabi*, a set of 115 entries including 25 entries from coordinated SBS entries was screened in field with the standard egg mass implantation technique on growing plants at 2 egg masses per hill. The borer infestation (dead hearts + white ear heads against total non-flowered and flowered tillers) ranged from 3.8 to 44.7%. Varieties which recorded less than 10% borer infested tillers are : CR 410-3225-2, CR 292-8049, H 16, HB 368, HB 349, CR 157-39-9, RP 1579-1354-6, RP 1579-1369-71, RP 2199-3-154-7, RP 2235-179-16-10, RP 2430-338-41. RP 2430-342-45, RP 2430-372-75, Tnaulfer 831324, IR 36 and IR 38.

(P.S. Prakasa Rao and G. Padhi)

A set of five scented and one superfine rice varieties grown in *rabi* under 4 nitrogen levels was assessed for borer infestation. The relative susceptibility was in the order : Basumati 370 (28.9%) > IET 8580 (25.8%) > IET 7590 (25.2%) > CRM 25 (24.3%) > IET 8579, (22.9%)

(P.S. Prakasa Rao)

Brown planthopper. Three cultures *viz.*, RR 50-5, RR 2-6 and RR 49-3 of 75-90-day duration under direct-seeded condition were moderately resistant to BPH under manual infestation. Four varieties *viz.*, AC 24029, AC 24825, AC 24187 and AC 24950 were resistant and 6 varieties *viz.*, AC 24974, AC 24641, AC 24070, AC 24140, AC 24578 and AC 24384 were moderately resistant among 210 varieties from genetic stock when screened against BPH under normal infestation.

(B.C. Misra)

Leaf folder. A set of 44 entries was direct-seeded in *rabi* in the pattern of modified uniform blast nursery with dhaincha as border alround to allow high relative humidity build-up. Within one month, a high level of blast followed by severe leaf folder damage was observed in many entries.

Based on the per cent leaf damage scored in the 0–6 scale as per S. E. S., entries viz., HB 349 (1), Raminad st. 3 (1), Dular (2), IBN 115 (2), Tappoz (2), IR 6646-4569 (2), Rasi (3), Tetep (3) and CR 571 (3) were relatively less susceptible recording a score of 3 or less.

(P. S. Prakasa Rao)

In *kharif*, a set of 85 entries including 40 entries of the coordinated leaf folder screening set was screened in the field by supplementing 3rd instar leaf folder larvae at 3 per plant on 4 plants per entry between 25 and 40 days after planting in addition to natural infestation. Observations on the extent of damage leaf-wise transformed to folder damage index showed that with damage index ranging from 7.2 to 41.4 in different varieites, the entries viz., IR 36 (7.2), RP 1579-1360-62 (10.0) T 2005 (8.2), CR 645-1 (10.2), CR 645-54 (10.0), CR 645-60 (12.8) CR 645-127 (11.2), RP 2199-34-37-55-3 (10.8), Balam (11.8), CR 260-30 (11.6), Mahsuri (10.5) CR 292–5739 (10.3), CR 292-8049 (12.8), Choorapundy (13.4), CR 260-171 (12.8) and CR 260-136-321 (13.7) were relatively less susceptible with less than 15.0 damage index as against 41.4 in the susceptible TN 1.

(P.S. Prakasa Rao and G. Padhi)

Case worm. A severe infestation of case worm was noticed in *kharif* following heavy rains and flooding during 25 to 30 September in an experimental plot grown to 15 varieties. The leaf damage by case worm ranged from 5 to 80%. Observations indicated that only one entry viz., CR 689-4 suffered as low as 5% leaf damage compared to 50 to 80% in remaining entries.

(P.S. Prakasa Rao)

Gundhi bug. Fortytwo cultures received from CURRS, Hazaribagh were screened against gundhi bug under manual infestation. Of these, only one culture RR 50-3 was least susceptible.

(B.C. Misra)

ENT. 01.02. Isolation of Nematode Resistant Rice Varieties and Studies on the Nature of Inheritance of Resistance against Nematode Parasites of Rice

Screening of rice varieties against white-tip nematode. The 27 rice varieties from Mizoram which were earlier found to be free from this nematode were further examined. Virtually, no nematode was detected in the grains of 18 varieties (Maubun, Bialte, Sawite, Burhbandum, Phylbunkawnglawng, Farel, Fazai, Maipuam, Lianran, Rangabiny, Rangkawi, Damser, Local Manipur, Kylypamei, Kylysai, Zachan, Biruchuk and Burma Kawnglwng); but, in remaining entries, the nematode number ranged from 10 to 50.

Screening of rice varieties against the root-knot nematode. All the 57 Mizoram cultures screened against the root-knot nematode, *Meloidogyne graminicola* were moderately resistant to susceptible. The range of egg mass index ranged from 1.8 to 4.4 among varieties.

(Y.S. Rao, J.S. Prasad and M.S. Panwar)

ENT. 02. Evaluation of Pesticides against Pests Infesting Lowland Rice

Insecticidal treatments, comprising of seed treatment with chlorpyrifos at 0.5 kg a.i./ha at the heading, furrow treatments with carbofuran (1.0 kg a.i./ha) and neem cake (100 kg/ha) or with carbofuran alone; foliar spray of chlorpyrifos at 0.5 kg a.i./ha either two rounds at the vegetative stage or one round at the heading stage and combined treatments (2 sprays at vegetative and one round at the heading stage) were evaluated with the test varieties CR 1018 and CR 260-30, under direct–seeded condition. Protection given at the vegetative stage as furrow treatment with neem (6.9%), without neem (9.2%), seed treatment (8.7%) and foliar sprays (6.8%) brought down

the infestation level from 13.9% dead heart recorded in the control in CR 1018. Furrow treatment with neem continued to record lower infestation of 8.9% as against 20.9% dead heart in the control, subsequently. Similar trend was also seen in CR 260-30 with dead heart incidence of more than 25% initially and 18.6% later in the control, while furrow treatment with neem recorded dead heart incidence of 11.7% initially and 11.2% later. This treatment gave highest grain yield of 3.8 t/ha in CR 1018 and 3.1 t/ha in CR 260-30 as against 3.2 t/ha in CR 1018 and 2.7 t/ha in CR 260-30 in the control. The yield of CR 260-30 was affected by moisture stress at the heading stage.

Under transplanted condition, foliar spray only at the heading stage was tested in the above varieties. CR 1018 sprayed with monocrotophos and oxydemeton methyl recorded lower stem borer incidence (2.2 and 3.7% white ear head) and yielded 5.6 and 4.0 t/ha grain yield, respectively when compared to 8.8% stem borer incidence and 3.7 t/ha yield in control. In the case of CR 260-30, methyl parathion (1.9%) followed by monocrotophos (2.2%) were superior in respect of control of stem borer over others and untreated control (6.7%). However, the highest grain yield of 3.2 t/ha was recorded in monocrotophos treatment followed by 3 t/ha with oxydemeton methyl as against 2.2 to 2.6 t/ha in other treatments including control.

(S. Rajamani)

ENT. 03. Development of Varieties with Built-in Resistance to Major Pests of Rainfed Lowland

Varietial trials with advanced cultures. A set of 20 advanced cultures from different cross combinations was re-evaluated during *rabi* for their resistance to stem borer and leaf folder as well as yield potential in replicated field trials under natural insect infestations which occurred in fairly high levels (up to 28% dead heart and 18% white ear head and 32% leaf folder damaged leaves). Based on relatively lesser susceptibility and high grain yields, three cultures *viz.*, CR 694-1, CR 694-2 and CR 695-1 were selected and nominated into All India Coordiated Multiple Resistant Variety Trials for *kharif*. These three cultures also possessed resistance to gall midge as well as brown planthopper.

A set of 40 advanced cultures developed from many cross combinations with high yield potential as well as multiple resistance to insects suitable to rainfed lowlands was also re-evaluated in field during *kharif* for their field resistance against gall midge, stem borer and leaf folder under natural field infestation. Based on yield potential and multiple resistance, cultures *viz.* CR 410-3225-2, CR 308-38, CR 308-408, CR 309-254, CR 309-262. CR 309-266, CR 309-268, CR 309-274, CR 309-275, CR 309-277 and CR 311-34 were identified as promising and some of these are included in the All India Coordinated Multiple Resistant Variety Trials.

(P.S. Prakasa Rao)

Breeding for multiple resistance to major pests of rainfed lowlands. A set of 58 cultures carried forward from *kharif* was re-evaluated in the field under high gall midge pressure and again single plants from 12 most promising lines with gall midge resistance, good plant type, good grain quality and high yield potential were carried forward. Another set of 71 advanced single plant progenies from other cross combinations received earlier from DRR was re-evaluated and single plants from 16 lines with different durations, but with resistance to gall midge and brown planthopper together with good plant height and grain quality were again carried forward.

(P.S., Prakasa Rao and K. Srinivasulu)

Breeding and development of high yielding, long duration varieties for rainfed lowlands with

special reference to resistance against north coastal Andhra Pradesh gall midge biotype. Based on earlier years' results, a set of six cultures originating from Orumundakan (CR 308, CR 309 and CR 311) was tested along with 17 other cultures in replicated field trials at five endemic blocks of N.C.A.P. viz. Ragolu, Panukuvalasa, Venkarmapeta, Peddapeta and Narayanapuram by the A.P.A.U. (Rogolu centre). High gall midge pressure occurred in all centres and all the six cultures originating from Orumundakan viz., CR 308-408, CR 308-38, CR 309-262, CR 309-262, CR 309-277-74 (IET 10743), CR 309-268-54 (IET 10742) and CR 311-34 proved to be most outstanding in respect of resistance to the local biotype of gall midge. Similar field trial was conducted at Panukulvalasa by A.P.A.U with 36 entries which included 32 released or promising CRRI cultures resistant to gall midge. Cultures CR 157-303, CR 157-212, CR 157-1900 and CR 403-2-2 were promising against gall midge.

(P.S Prakasa Rao)

ENT. 04. Systems Analysis and Simulation Models for Pests and Diseases in Rice

In a field experiment on the estimation of yield losses due to yellow stem borer, complete protection, early and late protection treatments recorded lower number of dead hearts but higher number of ear bearing tillers in comparison to untreated control. The simulation results showed high number of ear bearing tillers in complete protection treatment. However, both the observed and simulated yields were recorded to be higher in complete protection treatment. In another experiment conducted to simulate the damage by the yellow stem borer, 0, 5, 15, 30 and 60% tillers were removed by clipping at the base at vegetative, panicle initiation and grain filling stages. The detillering at 5, 15, 30 and 60% resulted in a yield loss of 0.3, 2.1, 12.2 and 16.3%, respectively at vegetative stage and 3.9, 12.7, 23.8 and 40.5%, respectively at panicle initiation stage. The observed and simulated yield losses were comparable in detillerings at grain filling stage. In a Separatefield experiment, the gall midge incidence (silver shoot) ranged from 5 to 18%. The total number of tillers was 54.7% more in control plots in comparison to protected plots. Of the total number of tillers, 63.3% in protected plots and 13.5% in control plots contributed towards yields.

To incorporate as a driving variable in the model in the estimations of yield losses due to yellow stem borer and gall midge, the maintenance respiration in the damaged tillers was estimated at regular intervals after infestation. The maintenance respiration in the tillers increased by 3.5% by 2nd day after larval invasion in yellow stem borer attack. By the 5th day it shot up to 8.4% in comparison to healthy tillers. With regard to gall midge, the maintenance respiration increased to an extent of 19.9% by the 2nd day after invasion by the maggot. On the 5th day, it was 16.1% more than the infested tillers and on the 21st day it was 3.2%.

(J.S. Prasad, P.R. Reddy, S.K .Nayak and K.S. Rao)

ENT. 08. Studies on Genetics of Gall Midge Resistance in Rice

Six hundred single F_2 plants from each of 17 crosses involving gall midge resistant donors were grown in field under high gall midge pressure and were scored in F_2 for their reaction. Suitable numbers of susceptible and resistant single plants were carried forward for confirmatory tests in F_3. The resistant donors involved in the crosses were ARC 10666, Banglei, ARC 5984, IR 36, ARC 10660, ARC 6632, ARC 10659 and PTB 12.

(P.S. Prakasa Rao and K Srinivasulu)

ENT. 09.01. Basic and Applied Field Ecological Studies on Population Dynamics, Bionomics and Biotypes of Major Rice Pests and Their Role In Pest Management

Incidence of stem borer at heading in relation to nitrogen levels in scented varieties. In studies with 4 scented varieties grown under 4 levels of N in *rabi*, the mean stem borer infested tillers were 18.0, 21.3, 28.0 and 33.3%, respectively under 0, 30, 60 and 90 kg N/ha. Thus, stem borer incidence was positively correlated with added nitrogen levels.

(P.S. Prakasa Rao)

Role of ratoon crop raised from stubbles after-harvest of kharif *on insect pest dynamics.* The stubbles left in field after harvesting of 200 entries in *kharif*, 1987 were fertilised and irrigated and other routine crop management practices were introduced to allow profuse ratooning. Alongside, a field planted to varieties Ratna and Neela as usual in *rabi* was also taken for study of insect pests and their infestations. Weekly sweep-net observations on insects from both ratoon and *rabi* transplanted crop were also made. Incidence as well as sweep-net counts of insects showed that crops raised from ratoons after harvest of *kharif* crop recorded 5 to 6 times more populations of stem borer moths, leaf folder and green leafhopper. Also, the incidence of stem borer manifesting as dead hearts as well as white heads was very high (40–60%) in ratoon crops as compared to 5–10% in the corresponding transplanted field. While the transplanted field crop did not record any gall midge incidence (up to 15% in different varieties) indicating that ratoon crop provided ideal microenvironment for the uninterrupted activity and carry over of rice gall midge during the *rabi* season.

(P.S. Prakasa Rao)

Relationship of number of eggmasses of yellow stem borer to build-up of incidence. The central plant in one square meter plot planted with variety Jaya at 20 x 20 cm spacing was implanted with 4-day-old healthy laboratory-laid egg masses at the rate of 0, 1, 2, 4, 6, 8 and 10 egg masses at 60 DAT. The incidence estimated at 25 days after egg mass implantation ranged from 2.3 to 27.4%, Though the treatments did not show clear-cut increase in infestation with increasing number of egg masses, the larvae that hatched out from the central plant could migrate and cause damage up to the 3rd plant in its vicinity.

(P.S. Prakasa Rao and G. Padhi)

Coordianted gall midge biotype monitoring trials (GMBT). A set of seven entries representing different varieties from 4 groups was tested at Cuttack in *kharif* under high gall midge pressure (100% infested hills in susceptible entries) in field. Phalguna from group II and Banglei from group III were highly resistant while other entries *viz.*, Eswarakora and W 1263 of group I were susceptible.

(P.S. Prakasa Rao)

Secondary selections from BAM 3/TN 1 as possible resistant source against north coastal A.P. gall midge biotype. Mahendra, Vamsi (RGL 1746/BAM 3/TN 1) and Pushkala, released as promising high yielding varieties for the north coastal Andhra Pradesh by A.P.A.U., were screened against gall midge at CRRI in *kharif* under high (100% infested hills) gall midge pressure. Vamsi was highly resistant. Single plant selections free from gall midge were made at Cuttack (40) and Ragolu (29).

(P.S. Prakasa Rao)

Optimum pest control trial (coordinated). Seven pre-released cultivars along with Jaya were evaluated for their reaction to insect pests and yield potential both under unprotected and

optimum protected conditions. Plant protection, i.e., phorate granules at the rate of 1.0 kg a.i./ha at 20 DAT against gall midge and chlorpyrifos spray at 0.5 kg a.i./ha at the heading stage against stem borer was provided. Gall midge was the major insect pest causing 30.6% silver shoots in Jaya. Three cultivars (WGL 47969, IET 9710 and IET 9996) recorded less than 1% silver shoots. CR 294-548 and CR 317-166 recorded 13% incidence while IET 9762 and IET 9757 recorded 26.7 and 30.7% silver shoot, respectively. Protection reduced the incidence moderately. Stem borer incidence in these varieties was low, the maximum being 3.5% under unprotected condition. Highest grain yield of 5.5 t/ha was obtained in WGL 47969, followed by IET 9710 and IET 9996 each yielding 4.6 t/ha. Jaya yielded only 2.6 t/ha. However, protection increased the yield by 5 to 49%. The increase in the yield of resistant cultures through protection ranged between 0.4% to 7%. The highest grain yield of 6.0 t/ha was obtained in the susceptible cultivar IET 9762 under protected condition and this amounted to be a 36% increase over its unprotected treatment.

(S.Rajamani)

ENT. 09.02. Interrelationships and Bioecology of the Host Plant, Rice Pest and their Natural Enemies

Stem borer

Effect of popularly used pesticides on the parasitic populations and extent of parasitism caused on stem borers. Extent of parasitism and parasitic population generally declined after spray treatment with chlorpyrifos at 0.5 kg a.i./ha. Parasitism levels recorded on the resistant variety IR 36 were higher than in susceptible Jaya; likewise IR 36 supported more *Trichogramma japonicum* and *Telenomus dignoides* than Jaya. Adverse effect of spraying on parasitism and parasite population was noticed for 3 to 4 days immediately after the treatment; but the population build-up thereafter restored the parasitism level.

(Y.R.V.J. Rao)

Estimation of egg parasitism and hyperparasitism. Of 450 egg masses collected from rice fields during November/December, 3.9% of the egg masses were not parasitised, 8.7% were partially parasitised and 62.3% were completely parasitised; the hyperparasite *Eupteromalus pamarae* destroyed 20.2% of the parasitised eggs. *Telenomus dignoides* and *Tetrastichus schoenobii* were the important parasites.

(V.N. Rao)

Succession of egg parasites. Trichogramma japonicum, Telenomus dignoides and *Tetrastichus schoenobii* were the important egg parasites from *Scirpophaga incertulas* while *T. japonicum and Telenomus sp.*, were from *Chilo auricilius.* As in the previous three years, the succession trend of egg parasites changed with *T. dignoides* emerging out as the dominant parasite in both *rabi* and *kharif* seasons followed by *T. japonicum* and *T. schoenobii.*

(Y.R.V.J. Rao)

Population of parasites in fields. Parasite populations were estimated on the basis of emerged parasites per 100 egg masses of *S. incertulas* collected from rice fields. In both *rabi* and *kharif* seasons, *T. dignoides* occurred in more numbers followed by *T. schoenobii* and *T. japonicum.* More number of egg parasites occur in *rabi* than in *kharif* season.The total output of egg parasites was more in both seasons during this year than in the past two years. Larval parasites *viz., Temulucha philippinesis, Bracon chinesis* and *Cotesia flavipes* were seldom collected. Pupal parasite *Tetrastichus ayyari* was not found during this year.

(Y.R.VJ. Rao)

Natural parasitism of S incertulas. Stem borer moths started appearing during third week of January and reached peak during last week of February. Moths were not available from 4th week of April to 4th week of October. In *kharif* season, moths appeared from 5th week of October and reached the peak during 2nd week of November; thereafter population declined and moths became scarce during December. The egg masses, larvae and pupae of stem borers were low in numbers and their distribution was uneven and irregular. Egg masses were not available in the rice fields during certain periods coinciding with the scarcity of moths. During *rabi* season, parasitism by *T. japonicum, T. dignoides* and *T. schoenobii* ranged from 71.4 to 100% egg mass-wise and from 16.6 to 67.7% egg-wise in different weeks, the peak reaching during 3rd week of April. During *kharif*, the egg mass-wise parasitism ranged from 84.6 to 100% and egg-wise parasitism ranged from 29.8 to 100%. Complete parasitism of egg masses occurred from 2nd week till the end of November. Larvae and pupae were collected from infested rice tillers; but no parasitism was observed.

(Y.R.V.J. Rao)

Studies on the egg parasites of S. incertulas. *T. japonicum, T. dignoides,* and *T. schoenobii* are being maintained on egg masses of *S. incertulas*. In addition, *T. japonicum*, is also being maintained on the eggs of stored grain pest *Corcyra cephalonica* in the laboratory whenever the original host eggs are not available.

When egg parasites were released, larval emergence gradually reduced with increase in dosages of *T. japonicum* and minimum pest hatch occurred at rates from 30 to 100 parasites per 10 egg masses.

Preliminary studies have shown that parasitism of *S. incertulas* could be increased when host eggs were constantly supplied and preserved in the fields during the periods of scarcity and in the beginning of the season when the egg masses are not available in the field.

(Y.R.V.J. Rao)

Laboratory rearing of stem borers S. incertulas *and* C. auricilus *on artificial diets and natural diets. S. incertulas* which could not survive on any of the artificial diets tested so far was reared on cut stems of rice in the laboratory. For *Chilo auricilus*, besides rearing on cut stems of rice, Rajma diet containing Rajma seed powder, wheat powder, yeast, ascorbic acid, sorbic acid, methyl parahydroxybenzoate, vitoelin capsule, formaldehyde and distilled water was used in the laboratory.

(Y.R.V.J. Rao)

Gall midge

Preference of parasitoids for hosts in rice environment. The preference of the egg larval parasitoid, *Platygaster oryzae* and the larval and pupal parasitoids, *Neanastatus grallarious, Eurytoma* spp. and *Obtusiclava oryzae* for rice gall midge and other midge species present in the rice environment in the grasses was studied. *P. oryzae* for rice gall midge and other midge species present in the rice environment in the grasses was studied. *P. oryzae* preferred the rice gall midge over all other midge species present in the grasses; but *O. paspali* midge was at par with the rice gall midge. The other midges in decreasing order of preference were *O. sp.* nr oryzae, *O. mnesitheae, O.* sp. nr *andropogonis* and *O. difficilis*. The preference of the larval and pupal parasitoids was different. This group preferred *O. mnesitheae* followed by *O.* sp. nr *andrapagonis, O. paspali, O. difficilis, O. oryzae* and *O.* sp. nr *oryzae*. The larval and pupal parasitoids are negligible in rice gall midge when its activity is maximum. Normally their activity in

rice increases when the fields are dry and the gall midge is active in the activated stubbles.

(K.C. Mathur and P.K. Das)

Distinction between silver shoots with parasitised and unparasitised midges. The silver shoots were collected from rice varieties like (MW 10, Ratna and Udaya), wild rice (*O. perinnis*) and grasses (*Panicum, Paspalum* and *Echinocloa*). The circumference of silver shoots containing unparasitised midges ranged from 0.3 to 0.7 mm whereas that of silver shoots having mummies of *Platygaster oryzae* ranged from 0.4 to 0.9 mm in all cases. The silver shoots containing parasite mummies had larger circumference than silver shoots containing unparasitised gall midges.

Hidden and expressed incidence of gall midges. During examination of rice crop, many of the attacked tillers were hidden without giving any outward symptom of the presence of gall midge in it. As such the estimation of incidence gave erroneous results. The hidden and expressed incidence of gall midge was estimated in rice variety during September and October when the crop suffers maximum damage. The results indicated that expressed and hidden incidence of gall midge was 23.6 to 17.4 and 0.2 to 1.2%, respectively. The expressed and hidden parasitism by *P. oryzae* during the same period was 40.0 to 42.0 and 0 to 1%, respectively.

Effect of insecticidal application on survival of gall midge parasite. Chlorpyrifos was applied on rice crop in emulsified and granular formulation in October when parasitisation was maximum. The suvival of parasite of gall midge was better in treatments with granular formulation than in treatment receiving emulsified formulation.

Extent of adult emergence from P. oryzae *cocoons.* The emergence of the parasitoid of rice gall midge, *Platygaster oryzae* was 0 to 90 numbers from individual mummies in different seasons. The emergence of P. Oryzae was always less from the grass gall midge than from the rice gall midge.

(P.K. Das)

Leaf folder

Factors affecting mortality of leaf folders. Cnaphalocrocis medinalis occurred in large numbers during *rabi* season. *Apanteles cypris* accounted for maximum larval mortality in the third instar stage (50.0%) and disease was an important mortality factor in the fifth larval instar. Population of *Marasmia exigua* was very low in *rabi* and mortality due to parasitism was maximum (18.6%) in the fourth instar stage. In the first generation population of *C. medinalis* during *kharif* season, highest mortality due to parasitism (22.2%) was observed in the third instar stage. Disease was the next important factor. In the second generation population, maximum mortality due to parasitism (50.0%) was observed in the fourth instar stage. Maximum mortality due to parasitism in the third gerneration populations was 48.5%. *Brachmia arotraea* and *M. exigua* accurred in low numbers during this period.

Effect of varieties on parasitism of leaf folder. Effect of varieties influencing parasitism of leaf folder larvae was studied in field. CR 260-131-225-46 supported a larval population of 22.5/plot and registered a larval parasitism of 33.3% while CR 260-131-225-40 supported a larval population of 34.8 plot and showed 19.4% larval parasitism.

Alternate hosts supporting leaf folder population and its larval parasitoids. C. medinalis and *B. arotraea* were found feeding on *Echinocloa* sp. during rabi season. *Macrocentrus* sp. parasitised larvae of *C. medinalis* to the extent of 6.5%. Larvae of *C. medinalis* and *B. arotraea* were col-

lected from *Echinocloa sp., Cardiochiles nigriclis* parasitised larvae of *C. medinalis* to the extent of 12.5%. During this period, as the three species of leaf folders were present on rice and parasitism due to *C. nigricollis* was 30.0%.

(K.S. Behera)

Leafhopper and planthopper. Studies on egg parasites. Egg parasitism in brown planthopper was studied from January to March. *Anagrus* sp. and *Oligosita* sp. parasitised the eggs partially or completely. Maximum parasitism of 20.6% was recorded and an unidentified hyperparasite was dominant. During *rabi*, egg parasitism in green leafhopper was 18% and *Anagrus* sp. was the dominant parasite. Egg parasitism in *Tettigella* sp. was studied during *rabi* and *kharif* seasons. The eggs were parasitised by *Anagrus* sp., *Oligosita* sp. besides another unidentified parasite. A maximum of 46.8% parasitism was recorded in *rabi*. During *kharif*, partial parsitism gradually decreased from 32.6 to 9.1% with a corresponding increase in complete parasitism, An unidentified hyperparasite was doninant. Its activity was comparatively less in *rabi* (2.4%) than in *kharif* (63.7%). *Dryinid* cocoons were available in reasonable numbers for study towards the end of *kharif* season. One hundred cocoons were collected for study. *Pseudogonatopus hospes, Hallogonatopus orientalis* and *Donisthorpina* sp. were recorded during the period. Sex ratio was highly in fovour of females. The hyperparasites *Ceraphron* sp. and *Eupteromalus pamarae* parasitised the cocoons (28.9%) in nature.

(V.N. Rao)

Minor pests

Studies on non-insect parasites/predators in rice environment. Cocoons containing pupae of an unidentified neuropteran were collected from a weed plant in rice fields in both *rabi* and *kharif* seasons. *Eupteromalus pamarae* and the neuropteran emerged from the cocoons. Of 450 egg masses of spiders from rice fields collected and studied during *kharif*, 6.2% was parasitised, *Clistopyga* sp. being the important parasite. In a study with 380 egg masses of spiders collected from rice fields and studied during *kharif*, *Clistopyga* sp. (4.5%) was the dominant parasite followed by *Idris* sp. (2.6%), an unidentified parasite (0.8%), *Ceratobius* sp. (0.5%) and *Baeus* sp. (0.3%). Egg in 3.4 % of the egg masses dried and *E. pamarae* accounted for 5.0% hyperparasitism.

(V.N. Rao)

ENT. 09.03 Persistence and Residues of Pesticides and their Effect on the Behaviour of Major Insect Pests and Rice

Evaluation of ovicidal action of insecticides on the egg mass of rice yellow borer Scirpophaga incertulas. Twelve insecticides on the egg masses of rice yellow borer were tested at 0.04% concentration. Chlorpyrifos, BPMC, quinalphos, ethofenprox and methyl parathion were effective ovicides with 99, 87, 79, 75 and 76% kill of the eggs; other insecticides, phosalone, oxydemeton methyl, malathion, diazinon and phosphamidon showed less than 50% kill.

Evaluation of insecticides for the control of stem borer. Four insecticides as granules and three insecticides as sprays were evaluated against stem borer during *rabi*. Application of all the granular insecticides, carbofuran, chlorpyrifos, ethioprop and cartap caused less dead heart incidence (0.3, 0.4, 1.2 and 2.3% respecticely) than did the spray formulations of chlorpyrifos, phosalone and decamethin + buprofezin (10.6, 14.0 and 15.1% dead hearts, respectively) whereas 26.8% dead hearts were recorded in untreated control.

Evaluation of granular insecticides for the control of stem borer after flowering stage of the crop. Six granular insecticides (carbofuran, ethioprop,

quinalphos, chlorpyrifos, cartap and phorate) were applied at 1 kg a.i /ha to the paddy water after the flowering stage for their effectiveness against stem borer which affects the crop after the flowering stage. All the granular insecticides checked the white ear head damage with 3-7% white earheads in all treated plants as compared to 22.5% in untreated control.

Persistence of chlorpyrifos as influenced by the mode of application. Chlorpyrifos at 0.02 and 0.05% concentrations, when administered as seedling root dip for 12 hours, persisted for 30 days as demonstrated by 100% kill of the released freshly hatched larvae of *Scirpophaga incertulas* ; when given as whole seedling dip for one minute, the insecticide applied at 0.02 and 0.05% persisted for 15 and 18 days, respectively.

Economics of pest control. The effectiveness of seedling root dip with chlorpyrifos followed by a foliar spray of the same insecticide at the rate of 0.5 kg a.i./ha was compared with foliar spray of chlorpyrifos at 10 days after transplanting (DAT) and phorate granules at the rate of 1 kg a.i/ha at 60 DAT with the test varieties IR 36 and Jaya against stem borer in the *rabi* season. Insect damage was maximum at the vegetative stage of the crop with 46.4 and 31.2% dead hearts in Jaya and IR 36, respectively. Seedling root dip treatment recorded 9.7 and 8.8% dead heart in Jaya and IR 36, respectively as compared to 23.5 and 19.0% dead heart with foliar spray. Phorate applied after the vegetative stage of the crop controlled the white ear head damage with 6.1 and 7.5% in Jaya and IR 36 respectively while other treatments were on par with untreated control (7.7 and 10.5% respectively). However, late prevention did not increase the grain yield and was on par with untreated control which yielded 2.9 t/ha (Jaya) and 2.6 t/ha (IR 36) . Early protection with seedling root dip gave the highest grain yield of 4.6 t/ha and 3.9 t/ha with Jaya and IR 36, respectively as compared to corresponding yields of 3.5 and 3.4 t/ha with foliar spray.

Evaluation of insecticides against rice gall midge, Orseolia oryzae. Granular insecticides (quinalphos, phorate, ethioprop, cartap, chlorpyrifos and Oncol) at 1 kg a.i./ha ha at 15 and 60 days after transplanting and chlorpyrifos spray at 0.5 kg a.i. /ha at 15 at 15, 30 and 60 days after transplanting were evaluated against gall midge during *kharif* season Granules of chlorpyrifos, phorate, quinalphos and ethioprop and chlorpyrifos spray moderately controlled the gall midge (22.9 to 30.8% silver shoot as against 46.1% in untreated control and 51.1% in Oncol treatment). These effective treatments recorded higher grain yield (3.2 to 3.83 t/ha) than untreated control (1.98 t/ha).

In a separate experiment, six granular insecticides (ethioprop, carbofuran, cartap, chlorpyrifos, quinalphos and phorate) and emulsifiable concentrations (chlorpyrifos, phosalone and ethofenprox) were evaluated for their effectiveness against gall midge. In general, granular insecticides were better than spray formulations. Among the granular insecticides, chlorpyrifos and quinalphos performed better than other insecticides with less than 10% silver shoots as compared to 38.6% silver shoots in untreated control at 50 days after transplanting.

Evaluation of insecticides against rice gundhi bug (Leptocorisa oratorius). Four dust formulations (quinalphos, methyl parathion, fenvalerate and BHC) were applied at 25 kg/ha on variety RR 194-177. All the insecticides reduced the gundhi bug number to nil from 30–40 adult and nymphs per square meter area when observed at 24 and 48 hours after application; the untreated control plot continued to harbour a population of 10–15 number per square meter. In a green-

house experiment, 12 insecticides were evaluated as spray formulations against the adults of rice gundhi bug. All the insecticides at 0.04% and neem oil at 5% concentration were sprayed on the panicles at milk stage. Ten adult gundhi bugs were kept confined to the panicles by putting them inside perforated paper bags in each replication. Mortality of the insect was observed after 24 hours. Immediate knock-down effect was observed with methyl parathion, malathion, oxydemeton methyl, BPMC, monocrotophos, ethofenprox, quinalphos, and chlorpyrifos; neem oil, phosphamidon, diazinon and phosalone did not show promising knock–down effect, the mortality rate remaining below 50%. Three insecticides (monocrotophos, oxydemeton methyl and ethofenprox) were the most promising which remained effective for 10 days while all other insecticides lost their effectivenss after 8 days.

(S. Rajamani, R.C. Dani and M. Jena)

ENT. 09.04 Storage Pests of Rice and their Management using Botanical Pesticides

Indigenously available 20 plant materials were evaluated for their bio-efficacy against *Angomois* grain moth *Sitotroga cerealella*, a serious pest of stored paddy. Population build–up of adults, female ratio and per cent weight loss of grains were the test parameters for evaluation of bio-efficacy of the plant materials. Thirteen products viz., oil of neem *(Azardirachta indica)* > oil of polang (*Callophyllum inophyllum*) > seed extact of black pepper (*Piper nigrum*) > leaf extract of begunia (*Vitex negundo*) > leaf extact of wild sage (*Lippia geminate*) > oil from the fruit peels of orange (*Citrus reticulata*) > rhyzome extract of turmeric (*Curcuma linga*) > leaf extract of *Tithonia diversifolia* > leaf extract of *Andrographis paniculata* > leaf extract of *Toona cilliata* > seed extract of *Chenopodium abrosioides* > leaf extract of *Euphorbia pulcherrima*, showed significant biocidal activity in that order. None of the test materials adversely affected the grain viability.

Under natural conditions of insect infestation, a synthetic pyrethroid K-othrine (Deltamethrin) 2.5% WP was evaluated as grain protectant against strorage insect pests for a period of 12 months. The product was tested by direct grain treatment, by admixing the treated paddy husk grains and also by treating storage containers. Absolute grain protection was achieved at 8 mg K-othrine/kg grain in grain treatments and at 20 mg K-othrine/2 g husk/kg grains in grains admixed with treated husk for a period of 48 weeks. However, protection, though promising, was less pronounced with lower doses used.

(A. Prakash and J. Rao)

Basal application of neem cake at 150–250 kg/ha had no effect on the incidence of stem borer and gall midge. However, basal application of neem cake followed by ULV spray of neem oil (50%) effectively controlled brown planthopper population by 83% and white-backed planthopper population by 75%.

(S. Sasmal and K.C. Mathur)

ENT. 09.05. Chemical Control of Parasitic Nematodes of Rice

FMC 67825, nemacur and ethioprop followed by quinalphos were effective as seed soaking treatment in 0.2% solution against the root-knot nematode. The treatment with cartap was on par with the control. Five chemicals viz., carbofuran, cartap, quinalphos, ethioprop and FMC 67825 were tested at 1 kg a.i./ha as soil application against the rice root nematode. Sampling at one month after application of chemical at flowering and at harvest of the crop showed that carbofuran, FMC 67825 and ethioprop

effectively controlled the root nematode. The highest grain yield was recorded in carbofuran followed by FMC 67825 and ethioprop.

Population dynamics of parasitic nematodes of rice and rice soils. Sesbania aculeata, S. rostrata, water hyacinth compost, FYM compost + prilled urea (PU), prilled urea and urea supergranules (USG) were applied to soil during the *kharif* and their effect on the population of rice root nematode was observed during *rabi.* Results revealed that the organic amendments with PU recorded less number of root nematodes at flowering and harvest in comparison to inorganic amendments (PU and USG) and control.

Biochemical changes in rice inoculated with Helicotylenchus multicinctus. The total chlorophyll content of uninoculated rice plants (variety Satia) was 2.62 mg/g fresh tissue at 15 days and increased to 4.35 mg/g fresh tissue at 35 days. Inoculation of 10-day-old seedlings with the nematode decreased the total chlorophyll content with the advent of nematode damage by 1.06, 49.26 and 28.73% at 15, 25 and 35 days respectively in comparison to the uninoculated plants. Photosynthetic rate in uninoculated plants at 15 days was 27.3 mg CO_2 dm^2 hr and then increased to 31.3 mg CO_2 dm^2 hr at 35 days. Photosynthetic rate in infected plants was 26.8 at 25 days and 28.2 at 35 days . The per cent reduction was 1.1 at 15 days which increased to 10.2 at 35 days. The root activity in uninoculated plants decreased from 0.352 r/fresh wt/hr at 15 days to 0.178 at 35 days. The root activity was reduced by 26.1, 16.4 and 2.0% in the inoculated plants at 15, 25 and 35 days, respectively.

(Y.S. Rao, J.S. Prasad and M.S. Panwar)

ENT. 09. 06. Nature and Mechanism of Brown Planthopper Resistance in Rice

Developmental period from first instar nymphs to adult brown planthopper was more in resistant varieties like Gangla, Mudgo and ARC 14529 (15, 17 and 19 days respectively) than in susceptible Jaya and TN 1 (11 and 13 days, respectively). Fifteen amino acids (aspartic acid, threonine, serine, glutamine, proline, glycine, alanine, valinine, isoleucine, leucine, tyrosine, phenylalanine, histidine, cystine and organine) were detected in two susceptible varieties (Jaya and TN 1) and four resistant varieties (Ptb 33, Ptb 21, CR 57-11-2 and MR 1523) by paper chromatography.

(P. Samal)

ENT. 09. 07. Effect of Behaviour-Controlling Chemicals on Insect Pests of Rice

Applaud, commonly known as buprofezin (Nihon Nohyaku Co. Ltd., Tokyo, Japan) was tested against brown planthopper, yellow stem borer, leaf folder and gundhi bug in the laboratory. It showed strong killing effect against nymphs of brown planthopper. The LC-90 of Applaud was 1, 8 and 18 ppm against 2nd, 3rd and 4th instar nymphs of brown planthopper, respectively on 4th day of application. It did not show quick knock–down action and took 3 to 7 days to cause visible effect on the nymphs. Thus, most of the nymphs died at the moulting stage. The death pattern of 4th instar brown planthopper nymphs with 100 ppm Applaud was 10% at 4 days after treatment and increased to 75% at 5 days, 80% at 6 days and to 85% from 7 to 35 days. The death pattern of 4th instar brown planthopper nymph was 100% with a standard insecticide, chlorpyrifos at 200 ppm concentration as compared to zero with Applaud 24 hr after treatment. The death percentage dropped to zero at 7 days after treatment with chlorpyrifos, whereas Applaud caused 90% mortality of nymphs from 7 days of treatment to 38 days. Evidently, Applaud is effective for a longer period than chlorpyrifos. Adult brown planthopper was not killed

by Applaud. Freshly hatched yellow stem borer larvae, when released on plants treated with 200 and 400 ppm Applaud caused dead hearts as in untreated control plants, but when the treated plants were teased after 7 days, 100% mortality of the larvae was observed. Applaud was not effective on the larvae of leaf folder and nymphs of gundhi bug.

(R.C. Dani and M. Jena)

ENT. 12. Biodeterioration of Paddy Seed Quality due to Insects and Mites and its Control

Five species of bugs (*Esariocoiis ventratis, Mendia histrio, Nezara viridula, Gerris nitida and Morridipanura nieiurei* – identified by the Zoological Survey of India) and two species of mites have been found infesting developed grains leading to a deterioration in seed/grain quality during survey of paddy fields at CRRI farm and also in rural areas of Dhenkanal, Puri, Balasore and Cuttack districts.

(J. Rao and A. Prakash)

ORP. 01. Integrated Control of Rice Pests

The project was shifted during *kharif*, 1987 from Salipur Block in Bahugram area of Cuttack district to the new site in eight villages *viz.*, Banguary, Himpur, Pahal, Rudrapur, Nakhara, Janmejaypur, Johal of Balianta block of Puri district and village Kacheramal of Sadar Block (II) of Cuttack district. The area is highly endemic to brown planthopper, white-backed planthopper, green leafhopper, gall midge, stem borer and leaf folder and to diseases like bacterial blight, sheath rot, etc. A total of 107 family holdings was taken up to implement various programmes under integrated control of rice pests.

The varieties/cultures, popular among farmers during *rabi* and *kharif*, are Annada, Heera, Vanaprabha, Tulasi, Udaya, CR 333-6-1, Gayatri, Moti, CR 333-1-1-3, CR 333-1-15-2 and Panidhan. Most of the varieties did not require insecticidal application. One or two need-based application of insecticides were given to Gayatri, CR 629-246, Annada and CR 401-7 when the pest populations exceeded economic threshold level.

Cultural methods and minimum use of pesticides. Destruction of rice stubbles soon after the harvest of paddy to minimise carry over of yellow borers to the next crop as well as early sowing were practised to evade the attack of white-backed planthopper, brown planthopper and gall midge. Seedling root dip in 0.02% chlorpyrifos emulsion before transplanting to control stem borer and gall midge was widely adopted by the farmers.

Conservation of natural enemies. Insect-resistant varieties/cultures such as Udaya, CR 333-6-1, CR 333-1-1-3, CR 333-5-2-3 and Panidhan did not require any insecticidal application. This helped in successful conservation of natural enemies such as spiders, coccinellid beetles, bugs, dragon and damsel flies. One or two need-based sprays of quinalphos, monocrotophos or chlorpyrifos on other cultures disrupted natural enemies, but temporarily. The parasitism level was restored in a fortnight after insecticide application.

Surveillance. Yellow borer was noticed in CR 629-246, T 1242 and Balabhadrapakhia in low populations in the villages Johal, Bhimpur and Nakhara during October-November. In one or two places in Janmejoypur and Rudrapur incidence of yellow borer exceeded economic threshold level; hence, chlorpyrifos at 0.5 kg a.i./ha was sprayed to control the pest. Gall midge was observed in the tillering stage in the variety Gayatri in the villages Johal and Rudrapur. Leaf folder incidence was noticed in almost all the varieties; especially in Annada,

CR 1018 and CR 333-6-1. Gandhi bug appeared in a severe form in all the upland and medium land varieties necessitating large scale dusting of insecticide gammaxene.

Popularisation of improved management practices in rice. Stale seed bed-line sowing with placement of fertilizer behind the plough in the plough furrow and dibbling the seed behind the plough were advocated. The cultivators were also trained with economics of seed-cum-fertilizer drill and use of cone weeder for the control of weeds under upland situations.

(B.C. Misra)

AGRICULTURAL ENGINEERING

AE. 21. Water Management in Rainfed Upland Rice-Based Cropping System

Water stress during flowering of upland rice. Area selected for this project comprised of four villages around Kuakhia Bazar of Rasulpur block in Cuttack district. From the study on aquifer system of the area, it was found that the sandy loam soil combined with deep phreatic surface of the drainable, unconfined aquifer and rapid natural drainage net-work involving two giant river systems of Brahmani in north and Kharashrota in south, do not allow any standing water in rice

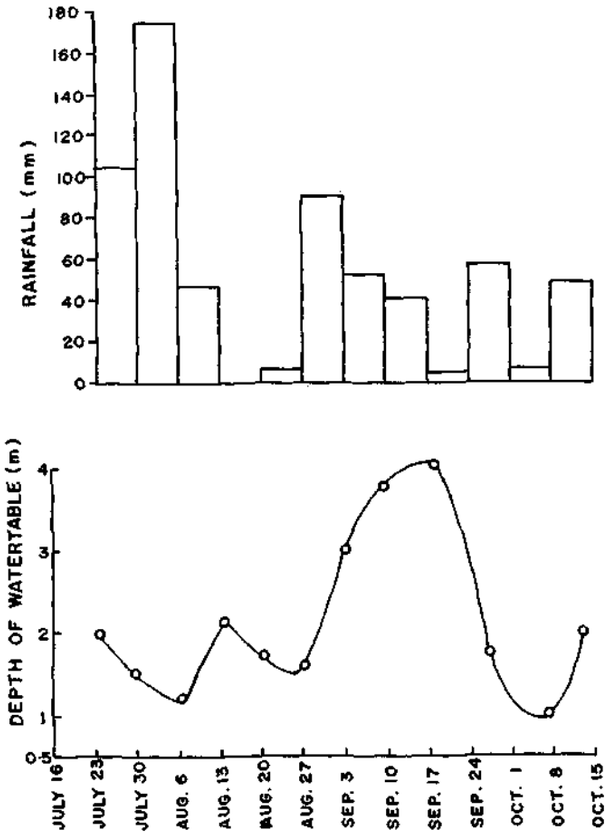

Fig. 2. WEEKLY RAINFALL AND SHALLOW WATERTABLE DEPTH IN KUAKHIA FROM MID-JULY TO MID-OCTOBER

fields even during intense rainfalls. During 1988, this caused moisture stress when rain stopped for a fortnight after 12th August (Fig. 2) causing a reduction in rice yield of around 50 per cent due to sterility.

Inventory of water resources. A survey was conducted for harnessing surface water resources. A contour survey was conducted in the cultivable area of the project site for storage and recycling of drainage water from Dudhei nala by providing small dams and sluice gates at two places. For determination of aquifer recharge, daily rainfall and weekly fluctuation in phreatic surface were recorded from mid-July to mid-October. The time lag between rainfall and aquifer recharge was 40 days.

Winter crops in rotation to upland rice. Vegetables, pulses and oil seeds (Table 23) were grown in the project area with the help of 2 open wells and 4 pits dug on the bed of Dudhei nala. Among these crops, profit from tomato was the highest. The hybrid tomatoes required less water and were tolerant to wilting at fruiting stage. But these varieties were susceptible to early blight. An application of Dithane M-45 in nursery, at 10-day intervals after transplanting for 1 month and at 15-day intervals up to first harvesting controlled early blight of hybrid tomato.

(P.C. Mohapatra)

AE. 03. Design and Development of Seed Drill for Dry Sowing of Paddy

A three-row bullock drawn seed-cum-fertilizer drill and one 10-row tractor mounted seed -cum-fertilizer drill for dry sowing were designed, fabricated and tested. The seed metering device in both bullock drawn and tractor drawn seed drill was similar to 2-row manual seed drill. It had six rectangulsr cells on each, cylindrical metering roller. The fertilizer metering device in both bullock drawn and tractor drawn seed drill was fluted roller type. Both the seed and fertilizer rate could be changed as per requirement. The power to the seed and fertilizer metering devices were transmitted by chain and sprocket drive from ground wheel. The draft requirement of the bullock drawn seed drill was about 40–45 kg. The output of the bullock drawn seed drill was 0.1 ha/hr and of tractor drawn seed drill was 0.6 ha/hr. The cost of fabrication of the bullock drawn and tractor drawn seed drills were about Rs. 800/- and Rs.4,000/- respectively.

(F.C. Das and S.P. Patel)

AE. 07. Development of Low Cost and Low Capacity Expeller

Presently in tribal and rural areas the people extract oil from non-conventional oil seeds in a small batch with the help of crude wooden press mounted on the tree trunk. The KVIC power ghani or commercial expellers are not within the reach of these farmers, hence an equipment is

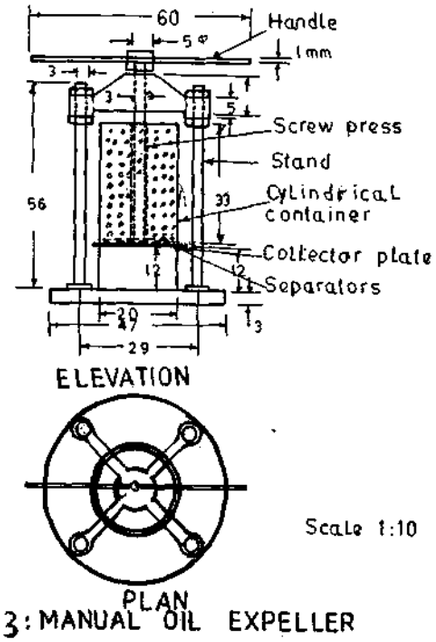

Fig: 3 : MANUAL OIL EXPELLER

Table 23. *Details of the vegetables grown under water management project during winter of 1988-89*

Crop	Variety	Date of sowing	First harvest (days after sowing)	Area under coverage (ha)	Average yield (t/ha)	Total expen-diture (Rs./ha)	Net return (Rs./ha)	Remarks
Tomato	Pusa early crop	4.9.88	70	0.4	25	15,000	22,000	
	Pusa Rubi	4.9.88	75	0.4	25	15,000	22,000	
	Punjab Kesari	26.9.88	70	0.2	60	20,000	70,000	
	Century-12 (hybrid)	4.9.88	85	0.2	80	20,000	120,000	
	Amrut (hybrid)	4.9.88	70	0.2	85	20,000	150.000	
	BT-1	26.9.88	85	0.2	40	15,000	45,000	
	BT-10	26.9.88	105	0.2	45	15,000	52,000	
	PKM-1	17.9.88	90	0.4	20	15,000	15,000	
	Maruthan	17.9.88	90	0.4	35	15,000	37,000	
	Selection-22	17.9.88	95	0.4	40	15,000	45,000	
Brinjal	MHB-1(hybrid)	17.9.88	90	0.1	-	-	-	Harvest is continuing
	MHB-3(hybrid)	17.9.88	100	0.1	-	-	-	-do-
	MEBH (hybrid)	17.9.88	110	0.1	-	-	-	-do-
	BB-11	17.9.88	110	0.1	-	-	-	-do-
Cabbage	Pride of India	17.9.88	85	0.1	6.0	6,000	10,000	
	Nidhi (hybrid)	17.9.88	100	0.1	12.5	8,000	15,000	
Bindhi	Parveen Kranti	17.9.88	85	0.1	2.8	3,000	4,000	
Cauli-flower	S-16(hybrid)	17.9.88	110	0.1	-	8,000	15,000	
Raddish	Pusa Chetki	4.9.88	55	0.1	-	6,000	10,000	
	Hill queen	4.9.88	70	0.2	-	6,000	10,000	
French bean	contender	4.10.88	60	0.01	2.5	3,000	7,000	
Arhar	Upasi-120	28.10.88	120	0.01	-	-	-	Not harvested
Rajmah	VL-63	28.10.88	85	0.01	-	-	-	-do-
	PGR-14	28.10.88	90	0.01	-	-	-	-do-

*Data presented above are collected from few farmers' plots. Yield, price and expenditure vary widely from time.

designed and developed (Fig. 3). Its fabrication is also complete. Mini manual oil expeller consists mainly of a cylinder and a screw mechanism for press. In order to get maximum recovery four separators with perforations have been provided in the cylinder. Mahua seeds were taken for trial.

Its seeds were ground, made to powder and then steamed (open steamed) for one hour. This material then was put inside the cylinder and the upper handle was screwed to press the material in the cylinder. Perforations were made on the side wall of the cylinder as an outlet of oil. Three batches each of 5 kg seeds were expelled. The moisture content in the de-oiled cake was high because of open steaming (Table 24). Total time taken for extraction was 30 min per batch after steaming.

(A.K. Behera)

AE. 08. Development of a Paddy Dryer Suitable for Small and Medium Farmers

A batch type paddy dryer having 0.3 t holding capacity designed and is under fabrication. The unit comprises of a drying chamber, waste fired furnace coupled with heat exchanger, and a blower. The unique feature in the present unit is the use of heat exchanger which helps in getting clean hot air without being contaminated with flue gas or smoke. Therefore, this dryer can be most suitably used to dry parboiled paddy.

(P. Mishra)

AE. 09. Development of a Rice Puffing Machine

A small puffing machine has been developed to puff parboiled rice (muri), paddy (khai) and flaked rice (chura). This unit comprises of a furnace, coupled with heat exchanger, puffing chamber, cyclone separator, frying pan and a small blower. Puffing of rice/paddy takes place by hot air at around 260^{0}C in the puffing zone . The puffed material is carried by the cyclone separator. The air thus escaping from the top of the cyclone still possesses enough heat potential. Therefore, it is allowed to pass through a double walled frying pan in which the soaked rice is roasted before puffing. The unit costs around Rs. 700/- and its operation is easy.

(P. Mishra)

AE. 15. Study of Wind Profile of Orissa and Assessment of the Potential of Using Wind Energy for Various Agricultural Operations

The hourly wind speed data at 10 metres height at village Balipadia and village Ramachandi of district Puri in the year 1988 were collected from Orissa Renewable Energy Development Agency, Bhubaneswar. At Balipadia wind speed exceeded 8 km/h throughout the year except December, January and February and throughout the year in Ramachandi. Wind speed at Ramachandi was about 20 km/h at most of the time which is most suitable for electricity generation, Wind speeds were uniformly distributed at Ramachandi throughout the year. The wind speed was high during 7.00-19.00 hr. It

Table 24. *Performance of manual oil expeller*

Name of seed	Treatment	Quatity per batch (kg)	Before expelling		After expelling	
			Oil content (%)	Moisture content (%)	Oil content (%)	Moisture content (%)
Mahua	Open steaming	5	38.5	12.0	10.0	26.7
Mahua	-do-	5	39.0	12.0	10.5	26.5
Mahua	-do-	5	37.5	11.7	9.5	26.0

is concluded that due to uniform distribution of wind speed a low and medium power generation system at these locations will be suitable.

(D.K. Jaiswal)

AE. 17. Field Studies for Determining the Command Area of a Wind Mill

Some of the wind mills installed in the farmers' fields in Cuttack and Balasore districts were visited. These are used for irrigation of crops like paddy, wheat, blackgram, mustard, vegetables, greengram, banana and coconut at different locations. Farmers could irrigate up to 3.5 acres of paddy crop with the help of a wind mill during *rabi* season.

(D. K. Jaiswal and P. C. Mahapatra)

AE. 18. Energy Requirements in Agricultural Sector

Energy census. A survey was conducted in the village Barabati in Cuttack district from June, 1987 to May, 1988. The village has 73 ha land under cultivation. The major crops in the village were paddy and groundnut covering about 95 and 70% cultivated area, respectively. Groundnut was grown in *rabi* under rainfed condition. Other crops of the village are greengram and sugarcane. The cropping intensity in the village was 192%. On the basis of survey, draft power availability was 0.82 DAP/ha of cropped land. Local varieties of paddy were grown in about 40% of the cultivated area and weeding consumed lot of energy. Therefore, there is a need to raise the crop in row by seed drill and use mechanical weeder for weed control. Energy for crop production was provided by human (26.1%), bullock (27.3%), F. Y. M. (3.1%), fertilizer (12.8%), seed (29.4%), chemical (0.2%) and machinery (1.0%). High yielding varieties of rice consumed higher energy on weeding in comparison to local rice. Specific energy which is the ratio of the operational energy in MJ to yield in quintal was the highest for greengram and blackgram and lowest for sugarcane. Total input energy utilisation was the highest for sugarcane and lowest for greengram and blackgram (Table 25). Pod picking and shelling of groundnut was done manually and, therefore, there is a need to introduce groundnut thresher and groundnut decorticator to save the human energy. Operation-wise, field preparation consumed highest energy in the cultivation of dif-

Table 25. *Energy utilization (MJ/ha) for the cultivation of different crops.* (Village-Barabati, Cuttack –1987-88)

Energy crop	Total input energy	Operational energy	Human energy	Specific energy (MJ/q)	Output-input energy ratio	
					Main product	By-product
HYC rice	11,675	6,163	3,502	195.8	3.98	7.39
Local rice	7,957	5,073	2,436	261.0	3.59	7.41
Sugarcane	58,382	11,294	8,455	19.5	5.21	7.05
Groundnut	8,639	4,799	1,982	377.4	3.70	5.18
Greengram	3,167	2,561	782	539.1	2.19	3.49
Blackgram	3,059	2,333	969	373.0	3.00	4.83

Table 26. *Energy (MJ/ha) required for puddling under different puddling treatments* (kharif, 1988)

Treatment	Human	Bullock	Diesel	Machinery	Total
T_1	18.5	42.9	1,259.3	94.2	1,414.9
T_2	148.9	1,067.5		33.1	1,249.5
T_3	75.3	540.4		26.8	642.5
T_4	96.8	694.1		74.6	865.5

ferent crops. There is a need to make this operation energy efficient by introducing energy efficient implements. Out of the total energy consumed in the village, about 76.4% was used for domestic activities. About 83.3% of energy in the village ecosystem comes from non-commercial (renewable) source of energy, 8.2% from commercial energy and 8.5% from animate energy source (human and animal).

Energy requirements for field preparation. Energy requirements for the field preparation in rice cultivation under wetland condition were studied during *kharif* (Table 26). Four implement combinations were taken for puddling : T_1, three passes of tractor drawn disc puddler + planking (tractor); T_2, one pass of M. B. plough + two passes of deshi plough + planking (bullock); T_3, one pass of M. B. plough + three passes of bullock drawn puddler (implement factory, BBSR) + planking (bullock) and T_4, one pass of M. B. plough + four passes of harrow puddler + planking (bullock). In implement treatments, one M.B. ploughing followed by three passes of bullock drawn puddler required the least energy for puddling. It was mainly because of the higher area coverage and better churning of soil by bullock drawn puddler. Tractor drawn disc puddler required highest energy for puddling, but least human energy. Use of bullock drawn puddler after one M. B. ploughing saved about 73.6 MJ/ha human energy and 527 MJ/ha bullock energy in comparison to two deshi ploughing after one M.B. ploughing.

(S.P. Patel and F.C. Das)

STATISTICS

ST. 07. Statistical Evaluation of Agricultural Field Experiments

Grain yield and straw yield data for the period from 1969 to 1988 from the long-term field experiment to study the soil properties in the presence and absence of compost were utilised in this study. The experiment was conducted in RBD with treatments, control, N, NP, NPK in the presence and absence of compost. The variety used in all the years was not the same. This study revealed that the indices of 65.6% and 67.4% for grain yield and straw yield respectively were satisfactory for the design adopted.

(A.V.S. Rao and K.M. Sahu)

AGRICULTURAL ECONOMICS

ECON. 01. Economics of Seed Production Programme

The cost of cultivation and the return from each breeder rice variety grown under seed production programme were determined in *kharif* at C. R. R. I. farm. The relevant data were collected separately for IR 36, Ratna, Savitri and Annada grown under seed production programme. The study indicated variable cost of cultivation as Rs. 5582/ha. The yield per hectare was highest with Annada (5.1 t) which was followed by Savitri (5.0 t), Ratna (4.7 t) and IR 36 (3.0 t). The same trend was observed for gross return and net return. The net return per rupee spent was 3.43 for Annada, 3.32 for Savitri, 3.09 for Ratna and 1.67 for IR 36. The cost of rice production per quintal based on variable cost was higher with IR 36 (Rs.174) which was followed by Ratna (Rs. 109), Savitri (Rs.103) and Annada (Rs.101). Evidently, cultivation of breeder seed is more profitable than cultivation for consumption.

(Salik Ram)

ECON. 02. Economic Analysis of Experimental Data

The data of this experiment were collected from the nitrogen varietal trials conducted by Agronomy Division in *kharif*. Varieties grown were MW 10, IR 36, IET 7590 and CR 260-77, of which MW 10 and IET 7590 are of coarse type and IR 36 and CR 260-77 are of fine quality. A functional relationship between quantity of nitrogen applied and the treatment mean yield obtained was worked out by using quadratic form of production function given below :

$$Y = a + bN + cN^2$$

where Y is the mean yield, a , b and c are constants and N is the nitrogen applied. The nitrogen price was Rs. 4.94 per kilogram. The paddy price used for an individual variety was based on its grain type. The price for coarse paddy and fine paddy per kilogram was Rs. 1.50 and Rs. 1.54, respectively. The quadratic equation fitted to the data explained over 87 per cent of the variation in yield. From the ' a ' values of the four varieties, all the four varieties appeared to yield well even without nitrogen application at the management level of the experimenter. At zero N, yields were 3.2 t/ha for MW 10, 3.3 t/ha for IR 36, 4.3 t/ha for IET 7590 and 4 : 5 t/ha for CR 260-77. Duration of the cultivar was positively correlated with the yield. Comparing the 'b' and 'c' values, it is evident that all varieties except IET 7590 responded to more than 96 kg N/ha. The range of optimum nitrogen rate varied from 71 to 116 kg/ha at the current nitrogen-paddy price ratio- IET 7590 gave highest average response per kg of nitrogen at optimum N as compared to lowest response with MW 10. Maximum and minimum return to nitrogen was obtained from IET 7590 (Rs.1821) and MW 10 (Rs.379/ha), respectively. Variety CR 260-77, a fine quality rice, occupied the second position with regard to return. The yield at optimum level of N was lowest with MW 10 (3.6 t/ha) and highest with IET 7590 (5.9 t/ha).

(Salik Ram and M.M. Dash)

COMMUNICATION AND TRAINING

Communication. Rice production technology was disseminated through extension literature, advisory service, extension folders, booklets and bulletins to extension personnel, rice farmers, students and other visitors. During this year a total of 2539 visitors comprising VAWs (384), students (152) and farmers (2003) visited this Insititute and got information about latest technology adopted for rice production in different land situations. These visitors were from nine states of India viz. Assam, Andhra Pradesh, Bihar, M. P., Orissa, West Bengal, Tripura and Tamil Nadu.

Exhibits in the museum were updated.

Research highlights for 1987 was brought out in 1988.

(S.K. Mohanty, J.K. Roy and S. Veerasamy)

Training. A training course on Rice Production Technology was organised for 20 Subject Matter Specialists representing six states of India viz. Gujarat, Haryana, Jammu & Kashmir, Maharashtra, Orissa and West Bengal from September 5-17. This training course was sponsored by the Directorate of Extension, New Delhi.

(J.K. Roy, S. Veerasamy and S.K. Mohanty)

OPERATIONAL RESEARCH PROJECTS

ORP. 01. Operational Research Project on Rice (Rasulpur Block, Cuttack District)

The project continued for third year in succession involving 175 farm families and about 190 ha of rainfed rice area in a cluster of three villages (Barabati, Chitrakul and Durgapur) under Rasulpur block of Cuttack district. The programme included introduction, intensification and popularization of improved early, medium and lowland elite rice cultures and cultivars, besides improving the productivity of oilseed, pulse and vegetable crops in rice fallows. Fresh water aquaculture was further popularised in the project area.

Stabilization of rice yield

Rainfed upland. As a follow-up of about 40% substitution of the traditional varieties by Annada over the last two years of introduction, line sowing technology (seed dibbled behind plough) was introduced this year to replace the conventional broadcast seeding. This practice facilitated weed management and reduced the cost of weeding by about 25%. Among the high yielding varieties, Annada substituted traditional cultivars by more than 40% besides coverage with Annapurna and Parijat by about 24%. Annada (4.7 t/ha) continued to outyield Annapurna (4.2 t/ha) and Parijat (2.6 t/ha) under a fertility level of 20-50 kg N and 10-20 kg each of P_2O_5 and K_2O/ha. The traditonal varieties like Bakuri and Sathia yielded only 2.7 t/ha.

Rainfed.medium land. Feasibility of growing a multiple resistant cultivar (Udaya) of about 130-day duration to substitute long duration varieties was attempted, so that the productivity of the pulses/oil seeds grown in sequence could be increased. But, the variety was badly infested with gundhi bug and grasshopper and yielded only 1 t/ha despite plant protection measures indicating unsuitability of varieties of such duration.

Rainfed lowland. The coverage of improved lowland rice was stepped up by around 110% over the last year through introduction and intensification of submergence-tolerant semi-dwarf, intermediate and tall promising cultivars developed by the Institute.

A. Intermediate lowlands (20-50 cm water depth),Direct seeded rice. Five improved cultivars namely Gayatri, Utkalprabha, Tulasi, Panidhan and CR 260-77 of about 150-180 day duration were further popularised in the project villages. Improved management practices like early sowing (May end to first week of June) in rows behind plough coupled with application of fertilizer at 15-30 kg N and 10-20 kg each of P_2O_5 and K_2O/ha were followed to ensure optimum crop stand and to induce submergence tolerance of crop. Based on the crop cuttings, highest mean grain yield of 4.3 t/ha was recorded with Gayatri followed by Utkalprabha (4.1 t), Tulasi (3.9 t) and CR 260-77 (3.4 t). The average yield of Panidhan of still longer duration (170-180 days) was 3.7 t/ha, whereas yields of traditional varieties like Champeisiali, Mugudi, Hatimahula, Koila and Betanasia were low (2.9 t/ha). The improved varieties suffered from low to moderate moisture stress due to cessation of rain in the reproductive phase of crop (from mid-October) resulting in a marginal reduction of productivity over the last year. However,

Utkalprabha was not affected. Wild rice posed a serious problem this year in some plots competing with the cultivated rice, Panidhan, in particular productivity of which was reduced by 50-60% in some patches.

Late planted rice. Effort was made to improve the productivity of late planted traditional rice after the harvest of early *kharif* (June to first fortnight of August) vegetables, especially okra. The programme included the use of improved varieties namely Utkalprabha, Tulasi and CR 260-77, line planting with aged seelings, fertilizer at 50 kg N in split doses and 40 kg P_2O_5/ha and seedling root dip treatment with chlorpyrifos (0.02%). Maximum grain yield was observed with Tulasi (4.7 t/ha) followed by Utkalprabha (3.5 t) and CR 260-77 (3.1 t).

B. Semi-deep lowland (50-90 cm water depth). Performance of the late maturing (160-180 days) flood-tolerant tall cultures namely CR 383-10, CR 301-3066 and Panidhan was evaluated against a local check (Champeisali). The crop survived two cycles of complete submergence for 24 to 48 hr in the first week of August and October and the average water depth in field was 62 cm in August, 58 cm in September and 77 cm in first week of October. The local variety (Champeisali) escaped stem borer incidence (1.3%) by virtue of its earliness as compared to improved test cultivars (7.3 to10.2%) the flowering of which coincided with the brood emergence. This reduced the grain yield of high yielding varieties (2.3 to 2.9 t/ha),on par with the local cultivar (2.9 t).

Rice based cropping system

*Oil seed (*rabi *groundnut).* Improved cultivation practices like early sowing (October to mid-November) in row behind plough with optimum seed rate (120 kg/ha) and basal dressing of fertilizers at 10-20 kg N and 20-40 kg each of P_2O_5 and K_2O/ha were extended to groundnut variety, AK 12-24 of around 120-day duration in upland rice fallows. Total coverage of winter groundnut in project villages was about 80 ha. In view of complete cessation of winter rain this year, one irrigation at late vegetative stage (70 days after sowing) followed by fertilizer application at 11 kg N and 28 kg P_2O_5/ha was tried in one area in village Barabati. However, the result presented in Table 27 indicated reduction of yield by about 21% with irrigation over that of crop fully dependent on ground water contribution. Early sown crop grown in residual moisture of upland rice gave a mean yield of 3.2 t of pod/ha with a range of 2.4 to 4.4 t of pod/ha (Table 27).

Table 27. *Performance of* rabi *groundnut (AK 12-24) with and without irrigation*

Replication (farmer)	Irrigated		Unirrigated	
	Yield (t/ha dry weight)	No. of pods/plant	Yield (t/ha dry weight)	No. of pods/plant
1	2.34	19	2..80	23
2	2.24	20	3.48	31
3	2.80	30	3.20	28
4	2.32	28	3.00	40
5	2.40	25	2.80	24
Mean	2.42	24.4	3.06	29.2

Rajmash. An improved variety of Rajmash viz. PDR 14 of 90-day duration was introduced in upland rice fallows in five locations. The mean grain yield was as high as 1.74 t/ha realised from average 20 pods/plant grown with 100 kg N and 80 kg P_2O_5/ha and one to two irrigations at vegetative stage. The crop was acceptable to the farmers.

Greengram. Fertiliser management with 7 kg N and 16 kg P_2O_5/ha at sowing was extended to a local mung cultivar of about 90-day duration grown in residual moisture of lowland rice over an area of around 2.8 ha. Use of fertilisers improved the productivity by 61% (0.6 to 0.8 t/ha).

Tomato. Substitution of local tomato by improved/hybrid cultivars namely Century 12, BT 1 Selection 22 and Pusha Alidrop was examined in five locations in the project villages. The improved tomato started fruiting after about 100 days of sowing and the mean yield was 64 t/ha as compared to 23 t of traditional varieties. This was attributed to almost three-fold increase in the yield of fruits (133) per plant and fresh weight (8 kg). This programme made a considerable impact on the farmers since tomato has been a popular cash crop in the area.

Monitoring of pests and diseases

Upland rice. Rice varieties namely Annada and Annapurna remained unaffected by pests and diseases. However, in the shady patches under high fertility level, bacterial leaf streak of low to moderate intensity was noticed. At heading stage, grasshopper and gundhi bug caused damage in patches. No plant protection measure was used.

Lowland rice. Seedling root dip treatment with chlorpyrifos at 0.02% as an effective method for controlling insect pests in late planted crop was demonstrated for the first time in one of the project villages. This operation protected the crop for a month against incidence of early stem borer, leaf folder and case worm.

Heavy moth population (one moth/m^2) was noticed at boot leaf stage, but was checked by chlorpyrifos spraying at 0.5 kg a.i/ha over an extended area. Wild rice (*Oryza sativa spontaneous*) adjacent to lowland rice harboured stem borer and panicle midge.

Groundnut. Seed treatment with carbosulfan at 0.5 kg/100 kg of seed, used in one village to control termite incidence in winter groundnut, provided better crop stand.

Tomato. A prophylactic spraying 20 DAP with Dithan M-45 and fenvalarate, on improved/hybrid tomato, introduced in the project villages was effective against the commonly encountered wilt disease in the area. The villagers were advised to apply monocrotophos or fenvalarate whenever fruit borer damage was noticed.

Fishery development programme

Rice-cum-fish culture. Technology of rearing fast growing fishes (catla, rohu, mrigal and common carp at 9,000 no/ha) in association with direct-seeded lowland rice (Utkalprabha) followed by rearing in the adjacent ditch/small pond was popularised this year. Rice yield was 1.9 t/ha. Fish yield of 330 kg/ha was obtained within five months giving an additional income of Rs. 6,600.00/ha to the farmer.

Composite fish culture. Fresh water fish culture technology was extended to three ponds of the project village covering a total water area of 0.9 ha involving farmers in scientific rearing of Indian major carp and common carp fry at 5,000 to 10,000 no/ha.

The ponds recorded a production ranging from 340 to 1400 kg of fish/ha within a short spell of 5 to 8 months and gave an income of Rs. 6,800 to 27,800/ha of water area.

(D.P. Sinhababu and S. Rajamani)

CENTRAL RAINFED UPLAND RICE RESEARCH STATION, HAZARIBAGH

PG. 01. Collection, Evaluation and Preservation of Rice Germplasm

Collection. Forty upland rice varieties from Bihar, Orissa, Madhya Pradesh , Gujarat, Maharashtra, Tamil Nadu and Himachal Pradesh were added to make the germplasm collection up to 696.

Evaluation. Seventeen traditional lowland cultivars along with two checks, Khairasal and Rajshree were evaluated. HRC 590 (4.1 t/ha), a weekly photosensitive, non-scented pure line selection from local Bherakakar with 145-day growth duration and HRC 595 (3.8 t/ha), a scented culture appeared most promising. Thirtysix gora rices were studied for 13 panicle and seed characters. Maximum variation was observed for number of secondary branches (CV 27.3%) while grain length showed the least variation (CV 5%). Moderate variation was observed in 1000-grain weight among the HRC collections. Twentynine traditional varieties were evaluated for eight physico-chemical and four cooking quality components of grains. All varieties except HRC 426 had short, bold grains and 50 per cent of these varieties had red kernel. Chalkiness (abdominal white) was observed in HRC 14 and HRC 20 and aroma in HRC 29 and 30. Majority of the cultivars had low amylose content (< 20%). Variation was maximum with water uptake (CV 14.6%) and minimum with volume expansion (CV 9.4%).

Preservation. Six hundred and eleven upland rice varieties were maintained in 3-row plots and 25 traditional varieties were selected for further evaluation.

(P. K. Sinha. J. S. Chauhan. K. Prasad and V. S. Chauhan)

PG. 02. Varietal Improvement for Rainfed Upland Condition

Observation nursery. Two hundred and sixty one advanced generation bulks were compared with four checks (Brown gora, Kalinga III, Annada and Birsadhan 101) grown in four rows each and 83 bulks were selected for further evaluation. Twenty bulks derived from 15 crosses involving China 4, Milang, Tetep, L 62. 2A VRS 242-1-2, K 39, Kalakeri, C 22, MW 10, CR 289-1208, CR 143-2-2, RP 1442, Rasi, IR 3273-3-3-95, Bala and DR 92 were found to be uniform and superior to checks.

Off-season nursery. Of 133 single plant progenies grown in off-season nursery at Cuttack, 201 single plants of desired plant type were selected from the most promising crosses viz. DR 92 x L 62-2A, DR 92 x VRS 242-1-2, K 32 x IR 3273-3-3-9-5 and K 39 x RP 1442-2-2-3-2.

Advanced field testing. Of 14 cultures tested, RR 165-1160 of intermediate height (110cm) and moderate vigour yielded highest (3.1 t/ha) with superior grain characteristics. Cultures RR 149-177 and RR 167-982 yielded higher than Kalinga III. Early maturing (80 days) cultures RR 145-22 and RR 160-10 yielded significantly higher than Cauvery.

Outstation trial. Cultures RR 149-177 and RR 145-22 performed well in unbunded uplands while CR 314-5-10 was promising in bunded uplands in outstation trials.

Performance of cultures in national trial. Culture CR 314-5-3 (IET 8787) was recommended for minikit trials in Maharashtra and RR 52-1

(IET 9315) for West Bengal, eastern Uttar Pradesh, Tamil Nadu and north-eastern States. In preliminary variety trial I with 36 cultures, RR 165-1160 (IET 10921) with 2.7 t/ha yield ranked third in zone-V (eastern Madhya Pradesh and south Bihar).

(V.S. Chauhan, P.K. Sinha, J.S. Chauhan and K .Prasad)

PG. 02. 02. Evaluation for Disease Resistance

Blast. Screening of 200 indigenous and exotic germplasm resulted in the identification of 42 genotypes with consistent and stable field resistance to leaf and neck blast for the fourth year in succession. Exotic germplasm collections IAC 25, IAC 1131, M 148, DAO, PAO, Salumpikit, Tres Mareas and Lai Lwang were resistant to blast with a score of less than 4 in the nursery. Fifteen elite lines obtained from different sources and 14 fixed cultures derived from progenies of eight crosses exhibited moderate to high levels of resistance to leaf and neck blast (Tables 28 and 29). Thirtyeight selections (F_6) from crosses VRS 242-1-2 x Milyang 46, DR 92 x L 62.2A, DR 92 x VRS 242-1-2 (P 33-C-33 x Tetep) x P 33-C-33 and (China 4 x Secondo Brazil) x VL 502 appeared promising for resistance to blast. Four lines (selections 158, 168, 172 and 173) among the 85 IR 50 mutants had low leaf blast infection and moderate resistance to neck blast consistently for the last two years. Two hundred and fortynine NSN and 94 MRSN lines were also screened against blast of which 46 and 54 NSN lines and 20 and 24 MRSN lines recorded scores of less than 3 and 5, respectively. Of the 28 cultures tested for horizontal resistance to rice blast, eight exhibited resistance to blast with lesion types of 1, 2 or 3. Fifteen cultures had slow blasting ability with lesion type 4 and less than 5 per cent leaf infection.

(M. Variar, P.K. Sinha, J.S. Chauhan and V.S. Chauhan)

Brown spot. Of 335 local genotypes and 232 advanced breeding lines tested for field resistance to brown spot, 92 cultures were resistant.

Table 28. *Elite cultures resistant to blast at Hazaribag* (kharif, 1988)

Entry	Source	Blast reaction
HPU 800	UVT (H) 1983	1
IET 7613	NSN (1985)	3
IET 7616	SIPU (1986)	3
IET 7635	SIPU 1986	2
BG 380-2	IRBN (1987)	2
BG 3623G TB 49	" "	2
IR 32843-92-2-2-3	" "	3
B 30-16-260-3	" "	3
B 2992-8-TB-73-2	" "	2
RP 2217-71-73	SIPU (1986)	2
RAU 4045-10	BAU, Kanke	0
Rohini	KAU, Pattambi, Kerala	0
At 77-1	IURON	0
IET 10972	CRRI, Cuttack	3
IET 10973	" "	2

Table 29. *Fixed cultures resistant to blast at Hazaribagh*

Designation	Cross	Blast reaction	
		Leaf	Neck
RR 145-573 (892)	CR 289-1208 x IR 3880-13-7	5	MR
RR 145-574 (895)	-do-	5	MR
RR 146-52 (959)	(Brown gora x CR 143-2 10) x CR 143-2-2	3	MR
RR 146-54 (958)	-do-	3	MR
RR 159-90 (845)	CR 143-2-2 x C 22	5	MS
RR 161-915 (915)	CR 143-2-2 x Kalakeri	2	MR
RR 165-1187-2 (827)	MW 10 x C 22	4	MR
RR 166-645 (938)	C 22 x CR 289 - 1208	1	R
RR 166-645 (938)	-do-	0	R
RR 167-976 (885)	C 22 x Kalakeri	4	MR
RR 167-976 (884)	-do-	4	MR
RR 167-982 (863)	-do-	6	MR
RR 174-908 (908)	RR 51-1 x RR 161-915	2	MR
RR 174-909 (909)	-do-	2	MR

Ch 13, IAC 47, Damodar, Khamu, Novalato, H 71, IR 64 and CICA 6 were most promising among the germplasm and RR 35-2, RR 35-33, RR 18-41, RR 153-65, and RR 151-3-91 among the advanced breeding lines.

Bacterial leaf blight. Advanced breeding lines derived from T 1242 x IR 1820-52-2-4-1, B 2025, C-MR 33-2 x BG90-2, CR 199-1 x Mahsuri and CR 129-118 x CR 43-76 were evaluated for field resistance to bacterial leaf blight. Among 110 cultures, 21 cultures were resistant. RR 122-1-2057, RR 122-1-2061, RR 56-2067, RR 98-2073 and RR 63-2089 were the most promising.

(V.D. Shukla and K. Prasad)

PG.04. Assessment of Breeding Materials Received from Different Sources

Station trial. Eighteen promising breeding lines in the 90-95 day duration group were evaluated with four check varieties in a randomised complete block design with two replications. Four entries (RR 167-982, IET 10975, RR 19-2 IET 10973) were significantly superior to Brown gora in their yielding ability (Table 30). Elite breeding cultures of 95-110 day duration for favourable uplands were evaluated under transplanted and direct-seeded conditions. In the direct-seeded trial, RR 165-1153 (2.6 t/ha) and CR 406-1045 (2.49 t/ha) produced significantly higher yield than the checks (1.31 t/ha). BG 731-2 (3.91 t/ha) and IR 31787-16-1 (3.5 t/ha) yielded highest among the 18 selections evaluated under transplanted situation. IR 39357-133, IR 31785-58-1 and IR 28239-94 were superior to the checks Rasi, Ratna and Birsadhan 201.

DRR trial. Ninetytwo entries were evaluated in three coordinated trials (PVEVT, PVT 1 UVT 1). The local check Brown gora was the top yielder in UVT 1. In PVEVT and PVT 1, IET 11402, IET 114143, IET 11414, IET 11429, IET

Table 30. *Salient characteristics of the selected genotypes in station trial*

Entry	Height (cm)	Days to 50% flowering	Grain yield (t/ha)
RR 167-982	114	65	3.00
IET 10976	85	64	2.98
RR 19-2	72	54	2.80
IET 7613	94	64	2.64
IET 10973	75	51	2.51
Brown gora (check)	112	61	2.00
Kalinga III (check)	109	58	2.28
Bala (check)	84	60	2.50
Birsadhani 101 (check)	78	58	2.25
CD at 5%			0.64

11432, IET 11438, IET 11441, IET 11442 and IET 11448 were promising with a duration of less than 90 days and *IET 10898, IET 11701, IET 11703,* !!707, IET 11729 and IET 11734 in the 95-110 day duration group.

Collaborative programme. Fiftyone advanced cultures developed at Cuttack and Hazaribagh were grown in an observation nursery. Only 14 entries yielded grain (1.3 t/ha to 3.8 t/ha). CR 636-19 (3.8 t/ha), CR 666-100 (2.7 t/ha) and CR 693-575 were promising.

(J.S. Chauhan. V.S. Chauhan and D. Maiti)

BG. 03. Inheritance Studies on Physiological and Morphological Characters

Genetics of blast resistance. The F_1 plants of the crosses RR 20-2-10 x RR 158-327, RR 49-2 x RR 17-1, RR 18-3 x RR 20-2-10, RR 50-2 x RR 13-1, CR 143-2-2 x Co13, IRAT 112 x Co 13, CR 143-2-2 x IRAT 112 and RR 19-2 x Brown gora indicated dominance of the gene(s) controlling blast resistance.

(K. Prasad and P.K. Sinha)

Yield components. Fortysix early maturing genotypes were studied for genetic variation, heritability and genetic advance. The differences were highly significant among the genotypes for plant height, days to 50% flowering, panicle length, 1000-grain weight and grain yield except for panicle weight. This suggested that in early and very early maturing genotypes panicle weight rather than panicle number is important in improving grain yield. The higher genetic variability was recorded for spikelet/panicle (GCV 22.2%) and the lowest for panicle weight (GCV 4.8%). Grain weight, spikelet number, spikelet fertility, panicle weight, spikelets/ panicle, spikelet fertility, and panicle weight were highly heritable with higher estimates for heritability and genetic advance in 1987 than in 1988.

(J.S. Chauhan. V.S. Chauhan and D. Maiti)

PP. 01. Epidemiology of Major Upland Rice Diseases

Disease surveillance. Crop survey in the district during *kharif* indicated predominance of brown spot on gora rices, incidence varying between 5 and 40 per cent under unbunded situations. Leaf blast was moderate at tillering under direct-seeded conditions on traditional cultivars in the bunded (favourable) uplands. Transplanted rice was free from infection. Incidence

of bacterial blight, sheath rot and sheath blight was low.

Disease-yield loss relationship. A linear model to predict yield loss in upland rice due to sheath rot was developed. An increase in 1 per cent disease intensity resulted in 1.3 and 1.7 per cent loss in grain yield on moderately susceptible (IET B 611) and susceptible (IET 7804) cultures, respectively. A prediction equation Y - 4.644-0.67 was prepared for estimating loss in grain yield under known conditions of sheath rot incidence for this region.

Ecology and perpetuation. Acrocylindrium oryzae survived for two months (September-November) on left-over stubbles in the field, up to 10 months after harvest on infected stored seed and 8 months on rice straw. The pathogen survived on inflofescence of *Echinochloa colona* for 7 months and on dried leaves in storage up to 6 months. Infected rice seeds and plant parts of *E. colona* in seed mixtures appeared to be the source of primary inoculum under mono-cropped conditions in rainfed uplands.

Pre-disposing factors. Influence of nitrogen and spacing on bacterial blight development under favourable uplands was evaluated on varieties TN (1) and RR 75-2. Lesion length was significantly higher at 90 kg N/ha and 120 kg N/ha than at 60 kg N/ha ; 15 x 15 cm spacing caused higher disease incidence on both the varieties than with 15 x 20 cm and 20 x 20 cm spacings. Effect of the disease was accentuated by drought at flowering.

Pathogen variability. Studies on the use of bait plants for blast by periodical sowing and disease assessment of several probable candidates among upland rice germplasm led to the identification of three sets of varieties differing in their susceptibility at different stress levels. The first set (White gora-GRC 315, Brown gora-HRC 397) comprised of susceptible varieties showing infection earliest in the season (July); the second set (Kalinga III, Prasanna) shows no infection in July but with scores of 8-9 in late nurseries (September) and the third set (Rasi, RAU 4045-3) is resistant with scores of 3-5 in October. Although measurement of pathogen propagules by spore traps for blast is complicated by sequential development of the disease on grasses, ragi and upland rice in that order coupled with the occurrence of races with seasonal fluctuations, such trap nurseries would be useful in monitoring diseases and races.

International bacterial blight differentials were tested for their reaction with local isolates of Hazaribagh. DV 85 was resistant and other differentials exhibited varying degrees of susceptibility.

(V.D. Shukla, D. Maiti and M. Variar)

PP. 02. Disease Management in Upland Rice

Blast. Resistance to blast in upland rice cultures RR 145-22, IET 10972, CR 289-1008 and CR 143-2-2 was stable. Rate of disease progress, measured by sequential ratings of diseased leaf area, was used for identifying slow blasting lines among upland rice germplasm and breeding lines. Beam 75 WP and Fongoren 50 WP reduced spread of leaf blast in the nursery for 45 and 30 days respectively at 4 g /kg seed. Seed treatment alone was, however, not sufficient for blast management in field plots on extra-early cultures (IET 10970, IET 10971) under direct-seeded conditions, but seed treatment with Beam 75 WP followed by granular application of Kitazin at 15 DAT was the most effective for blast management with significant yield increases in HR 12 and IR 50 under favourable uplands.

Bacterial blight. Streptomycin and streptopenicillin at 1000 ppm sprayed once at 35 days

after transplanting arrested lesion development significantly over control. These antibiotics at lower concentrations were not effective.

Sheath rot. Mechanical separation of healthy seed in 20 per cent brine solution reduced sheath rot intensity and increased grain yield on extra-early cultures under direct-seeding. Seed treatment (Bavistin 25 SD at 4 g/kg seed) followed by one spray of Bavistin WP (0.2%) was the most effective for sheath rot management under unbunded uplands.

(M. Variar. D. Maiti and V.D. Shukla)

SS. 01. Effect of Soil Amendments on Physico-Chemical Properties, Moisture Conservation and Productivity of Upland Rice

Comparative performance of various mulches. A significant increase in grain yield was recorded in all the mulch treatments over control. Maximum grain yield (2.2 t/ha) was obtained with the application of 5 t/ha rice straw as mulch which was significantly superior to other mulch treatments consisting of farmyard manure (2.4 t/ha) + rice straw (6 t/ha).

(R.K. Tomar, R.K. Singh and C.V. Singh)

SS. 02. Input Management in Rice and Rice-Based Cropping System under Rainfed Upland Condition

Effect of methods of phosphorus application. Three doses of phosphorus (20, 40, and 60 kg P_2O_5/ha) and three methods of application (surface mixing; furrow application; and application after 25 DAS followed by raking) were tested in rice var. Kalinga III. Urea (40 kg N/ha) and muriate of potash (20 kg K_2O/ha) were applied. Grain yield increased with increasing levels of phosphorus irrespective of the method of P application. Maximum yield was recorded at 40 kg P_2O_5/ha except with broadcasting followed by raking which recorded a maximum at 60 kg.

Evaluation of phosphatic fertilizers. Two sources of phosphatic fertilizers viz. single superphosphate (SSP) and Mussorie rock phosphate (MRP) at five levels (0, 20, 40, 60 and 80 kg P_2O_5/ha) of P were evaluated along with 20 kg K_2O as basal application. Forty kg N was applied in 2 splits to rice variety Kalinga III. Phosphorus applied in the form of SSP and MRP increased grain yield. Grain yield increased only up to 40 kg P_2O_5/ha with SSP; but maximum yield was recorded at 80 kg P_2O_5/ha with MRP.

In a study on the effect of fertilizer level of N (0 , 20, and 60 kg N/ha) and P and K (0, 20 and 40 kg /ha), maximum grain yield (2.0 t/ha) was obtained in the treatment N_{60} P_{40} K_{20}.

Phosphorus management in rice-based intercrop. In intercropping trial of rice + pigeonpea, three levels of phosphorus (0, 30 and 60 kg P_2O_5/h) were used with rice variety Kainga III and pigeonpea var UPAS 120. Highest monetary return (Rs. 4771/ha) was obtained with 3 : 1 rice : pigeonpea at 60 kg P_2O_5/ha.

(R.K. Singh. C.V. Singh and R.K. Tomar)

AG. 01. Agronomical Management of Rainfed Upland Rice

A trial with three seeding dates (last week of May, 3rd week of June and 2nd week of July), three nitrogen levels (0, 30 and 60 kg N/ha) and two seed rates (200 and 400 seeds/m^2) was conducted over a period of two years. Sowing in last week of May and 3rd week of June produced higher yields. Seeding in 2nd week of July significantly reduced grain yield in 1987 while May-

sown crop in 1988 outyielded the crop sown on all other dates. Highest grain yield was obtained by drilling 400 seeds/m^2 with application of 60 kg N/ha. The response of five promising upland cultures/varieties to nitrogen at 0, 20, 40 and 60 kg N/ha was studied in 1987 and 1988. Phosphorus and potash were applied at 40 and 20 kg /ha, respectively. Nitrogen was top dressed in three splits. CRH 165-1160 proved superior to Brown gora. Yields of Kalinga III, RR 149-177 and CRH 165-1160 were obtained with 60 kg N/ha in both the years. However, increasing nitrogen levels beyond 40 kg N/ha failed to increase grain yields of Brown gora and CRH 165-1160 in 1987 and of RR 145-22 in 1988. Crop was sown on 4th July and 26th June in 1987 and 1988, respectively.

A trial using three stand establishment techniques (broadcast, drilling the seeds in rows 20 and 30 cm apart) along with four seed rates (200, 300, 400 and 500 seeds/m^2) was conducted under rainfed upland conditions with Kalinga II as test variety. Drilling the seeds in rows 20 cm apart was superior over other methods.

In intercroppijng trial, rice cv. Kalinga III was sown as sole crop in rows 20 cm apart. Blackgram (T 9), greengram (Sunayana), redgram (BR 65), cowpea (Gamati) and ragi (local) were intercropped with rice. Rice and redgram were sown in two ratios viz. 3 : 1 and 4 : 1 rice and ragi in 2 : 2 and rice with blackgram, greengram and cowpea in 2 : 1 row ratios. The yield obtained from sole crop of rice was 2.2 t/ha. The rice yield varied with different intercrops. Highest rice yield (1.6 t/ha) was recorded in rice + redgram (4 : 1). Among the intercrops, gram produced the highest yield of 0.4 t/ha. In terms of rice equivalent yield, highest yield was obtained in rice + redgram (4 : 1) followed by rice + redgram (3 : 1). Maximum monetary return was also obtained with rice + redgram (4 :1).

(C.V. Singh, R.K. Singh and R.K., Tomar)

AG. 02. Weed Management

Identification of critical stage for weeding. For a short duration upland cultivar Kalinga III, plots kept weed-free for the first 40 days produced yields equivalent to completely weed-free plots. Delaying weeding till 40 days resulted in 50 to 55% loss in yield

(C.V. Singh, R.K. Singh and R.K. Tomar)

AE. 01. Integrated System Approach for Watershed Management for Rainfed Drought-Prone Areas

Soil loss rate from cultivated upland fields. The red lateritic upland sloppy lands of Chhotanagpur region (129 mm annual rainfall) have high erosive characteristics. The run-off water from a 0.628 ha plot was collected in a pond with cement plastered bottom and side walls over brick work (up to 1 m) . As calculated by area volume method and the capacity survey of the pond, the average annual silt rate from the monocropped (paddy var. Kalinga III) 1.6% sloped field was 0.82 mm per year (10.24 t/ha/year).

Estimation of evapotranspiration (ET). Reference of potential ET for a short duration paddy (var MW 10) was calculated empirically from the Class A pan evaporation data collected for 16 years (1972-87) from Demotanr, Soil Conservation Research Farm, Hazaribagh. The calculated ET at 20, 50 and 80% probability levels were 895, 675 mm, and 502, respectively for the *kharif* crop between 22nd and 43rd meteorological weeks.

Performance of water harvesting pond in rainfed watershed. In addition to irrigation water for timely land preparation in July, in initial phase drought year, a life saving irrigation in the watershed management increased yield by 774 kg/ha (41.2%) over the yield (1879 kg/ha) of unirrigated paddy (var. MW 10) during 1980-88

period. The benefit-cost ratio was 4 : 13 for a small (400 m^2) water harvesting pond constructed in 1981 at a cost of Rs. 9,000/- giving 10-15 cm life saving irrigation only using critical drought spell.

(D.K. Paul)

AE. 02. Percolation and Seepage Prevention in Water Harvesting Tanks in Rainfed Drought-Prone Areas

Ground water recharge in upland fields. Ground water fluctuation and storage in the heavy clay loam soil and light sandy loam soil areas of the farm was studied (1980-88) at various toposequence, with the help of the ground water budget equation with data for rainfall for 75 years and evaporation for 16 years. Ground water recharging takes place only during June ,July and August and the total recharge in 1988 in the upland areas with red loam soil (Masipiri) and the clay loam soil (Shankarpur) was 224 and 174 mm, respectively, with a net depletion of ground water of 29 and 33 mm, respectively in 1988. The depletion rate is faster in the post rainy season than in the preceding summer months.

(D.K. Paul)

EASTERN INDIA RAINFED RICE PROJECT

To develop ecologically sustainable and economally viable technology for the rainfed ecosystem through technology development and verification in farmers' fields, the Eastern India Rainfed Rice Project (a collaborative project of ICAR-IRRI, financed by IFAD) was started in January, 1988. CRURRS, Hazaribagh was identified as the lead centre for rainfed upland ecosystem. The important findings of Farmer-Researcher managed on-farm trials and researcher-managed trials at the experimental farm are outlined below.

On-farm trials at Meru village. In a varietal evaluation trial, Kalinga III and RR 149-177 produced superior yield with a better grain type than the local variety Brown gora. Split application of nitrogen at 20 or 40 kg/ha together with 40 and 20 kg K_2O/ha produced higher yield in comparison with application of 15 kg N/ha at seeding without any P or K (farmers' method).

For weed management, Pre-emergence application of butachlor at 1.5 kg a.i/ha followed by one hand weeding produced yields at par with two hand weeding. The loss in grain yield due to brown spot was negligible in moderately resistant varieties like Heera and Kalinga III while the reduction in yield was considerable in local variety Brown gora.

Researcher-managed trial in experimental farm. Rice and pigeonpea (4 : 1) intercrop recorded maximum return (Rs. 6812/ha) as compared to sole crop of rice (Rs. 5720/ha). Direct seeding of Kalinga III at 112.5 kg ssed/ha marginally increased grain yield by 0.3 t/ha over 90 kg seed/ha; further increase in seed rate to 135 kg/ha decreased grain yield. In another study on stand establishment techniques, sowing behind the plough 20 cm apart recorded significantly higher grain yields than broadcasting or sowing 30 cm apart.

(V.S. Chauhan. K. Prasad. R.K. Singh. M. Variar and C.V. Singh)

CENTRAL LOWLAND RICE RESEARCH STATION, KHARAGPUR

Evaluation of Rice Germplasm with Special Reference to Submergence Tolerance

One hundred Mizoram rice collections obtained from the main Institute (CRRI) at Cuttack were grown in trays. One-month-old seedlings were subjected to screening by dipping them in a tank at a water depth of about 50 cm for a period of six days. Only entries 51, 55, 95, 103 and 106 tolerated submergence. Similarly, 120 lowland cultures received from CRRI were subjected to submergence tolerance test at panicle initiation stage along with checks, Gajaraj I, Jaladhi I, Jalmagna and Bombay mugai. None could tolerate submergence even for 4 days at panicle initiation stage. Bombay mugai (local popular variety) which had slow growth during vegetative stage showed fast growth at panicle initiation stage at a rate of 40 mm/day as noticed also with Jalmgna, Jaladhi I and Gajaraj I.

Evaluation of Germplasm/Cultures for Tolerance to Bacterial Leaf Blight (BLB)

One hundred entries from Mizoram rice collections were artificially clip-inoculated with a suspension of *Xanthomonas campestris* pv. *oryzae* at maximum tillering stage. Eight entries (51, 55, 58, 64, 103, 106, 112 and 126) were tolerant to bacterial leaf blight (BLB). One hundred and twenty lowland rice cultures obtained from Cuttack were also clip-inoculated at maximum tillering stage for BLB reaction. All the entries except CR 672-12 and 672-13 were highly susceptible (BLB scores 7 to 9). CR 672-12 and CR 672-13 were moderately susceptible with a reaction of 6.

(K. Pande and S. N. Shukla)

Varietal Improvement

As a part of identification of rice varieties for wider adaptibility, 120 lowland cultures along with checks such as Jagannath, Tilokkachari, Savitri, Gayatri, and Hathipanjar received from CRRI, Cuttack were screened for yield and other characters. CR 662-2217, CR 665-141 and CR 303-39 were too early and 17 cultures (late group) flowered after 20th November. A semi-dwarf culture, CR 683-198 had the highest average yield of 750 g/m^2, with average height of 130 cm; CR 686-242, CR 528-3-2-2, CR 626-26-14-1, CR 670-37 and Hathipanjar yielded 650 g/m^2. The third group comprised of Tilokkachari, Jagannath, CR 617-16-D-10-2, B 12C, CR 491-7, CR 260-30-47-18, CR 686-86, CR 682-124, CR 672-21, CR 671-30, CR 626-26-3-3 and CR 622-21-D-1 with a yield of 600 g/m^2. A large number of fixed cultures are available with good phenotypic acceptability, some with tolerance to BLB and gundhi bug. Selection nos. 13 (IET 4141 x CR 98-7126), 15 (IR 8 x Surekha) and 16 (IR 1561 x PTB 33) were least affected by gundhi bug. CR 369-42, CR 367-63, P 2 (a selection from CR 146-5443) and P 12 (a selection from Pankaj x Mahsuri) were also promising. One semi-dwarf selection S-57, with a matching duration of local types, scent and good grain quality recorded yield of 4.2 t/ha. About 3,000 single plants have been selected from 25 segregating populations based on phenotypic acceptability, plant type and tolerance to pests and diseases. About 40 lines were tolerant to BLB at maximum tillering stage.

(S.N. Shukla and K. Pande)

Evaluation of advanced cultures/varieties. Twenty varieties (Pankaj, IET 9188, CR 1016,

IET 9187, CNM 539, Jagannath, IET 9757, IET 5656, IET 8553, IET 7592, C8, Janglijata, IET 7590, CR 1090, Kabirajsal, CR 1018, CR 1006, C 10, C 6 and IET 7251) with local checks such as Janglijata and Kabirajsal were tested at 0, 30 and 60 kg N/ha having one common dose of P_2O_5 (40 kg/ha) and K_2O (30 kg/ha) applied basally. C 10, CR 1006, CR 1018, IET 7590, Jaganath, C 8 and CR 1016 yielded 7.8, 6.0, 6.4, 7.3 ,6.3, 5.4 and 5.8 t/ha, respectively at 60 N level. The yield of a traditional variety, Kabirajsal was 3.2, 4.8 and 5.8 t/ha at 0, 30 and 60 kg N/ha, respectively.

(N.C. Pande and S.N. Shukla)

Rice varieties for late planted situation. Five rice varieties (CR 1016, CR 1018, CNM 539, IET 9757 and IET 7251) were transplanted on 21st July, 10th August, and 31st August. An uniform level of N (60 kg/ha) , P_2O_5 (40 kg/ha) and K_2O (40 kg/ha) was applied as basal dose. In general, early planting of varieties showed highest yield which decreased with delayed planting. However, this trend was not uniform with all the varieties. Yield was highest in IET 9757 (7.0 t/ha) planted in July. CR 1016 (4.8 t/ha) showed similar yield potential in 1st and 2nd dates of planting indicating its suitability for late planting. Among the late planted varieties (31st August) CR 1018 (4.3 t/ha) gave maximum yield.

(N.C. Pande and S.K. Singh)

Cultural Practices

IET 7592 and a local tall variety, Kabirajsal were used in this study. Treatments included : T_1, direct-seeded without fertilizer with normal seed rate; T_2, direct-seeded with normal seed rate with 40:20 kg N, P_2O_5/ha; T_3, direct-seeded with 50% more seed rate than normal and with 60:40:30 kg N, P_2O_5 , K_2O/ha; T_4, transplanting with 6-7 seedling/hill with 40:20 kg N, P_2O_5/ha; T_5, transplanting with shoots removed from T_3 along with 60:40:30 kg N, P_2O_5 and K_2O/ha and T_6, transplanting from the nursery sown at the time of direct-sown crop without any fertilizer. IET 7592 yielded 6.5 t/ha in T_2, 5.6 t/ha in T_3, 5.5 t/ha in T_5 and 4.8 t/ha in T_6. According to this study, a higher seed rate can be used and transplanted as a fresh clonal crop if required. Kabirajsal yielded 6.3, 4.9, 3.3 and 3.5 t/ha in T_3, T_5, T_4 and T_6, respectively.

(N.C. Pande and S.K. Singh)

Integrated Nutrient Management

Three doses of nitrogen *viz.*, 0, 30 and 60 kg/ha were used in 10 combinations of organic and inorganic sources while an uniform application of P_2O_5 and K_2O each at 20 kg/ha was applied at the time of puddling. Dhaincha (45-day-old seedlings) was used as green manure with IET 7590 as the test variety. All 1:1 combinations of green manure + urea produced better yield in comparison to 1 : 1 combinations of farmyard manure + urea. At 60 kg N, green manure alone produced 5.5 t/ha while urea alone at the corresponding level produced 5 t/ha. Highest grain yield of 6.7 t/ha was obtained with 1 : 1 of green manure + urea.

(N.C. Pande)

Performance of Lowland Varieties in Farmers' Fields in Balarampur Village

The 8.5 acres of area belonging to 28 farmers' families were selected at village Balarampur under Kharagpur II Block in southern part of Midnapore district (West Bengal) under this programme. Improved rice varieties were tested under moderate application of fertilizer and need-based application of pesticides. Seven improved rice cultures (CR 1018 and IET nos. 9757, 7251, 8553, 7592, 9187 and 9188) yielded 4.0 to 5.5 t/ha. An additional yield of 1.5 to 2.0 t/ha was realised under this programme with improved varieties from the same land. IET 7251 lodged, but was still preferred because of good panicle, grain, straw and matching duration to local types.

(S.N. Shukla, K. Pande and N.C. Pande)

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3. Misra, N. C. and Misra, B. C. (1988) Screening of rice varieties against white backed planthopper *Sogatella furcifera* (Horv.) Indian J. Plant Prot. 16 : 201-204.

4. Prakasa Rao, P. S. (1988) A gall midge resistant culture CR 294-548 with a duplicate and complementary genes of IR 20. Oryza 25 : 65-67.

5. Prakasa Rao, P. S. and Padhi, G. (1988) Weather factors influencing outbreaks of the yellow rice borer *Scirpophaga incertulas* Walker in rice. Indian J. Agric. Sci. 58 494-495.

6. Prasad, J. S. , Panwar, M. S., Rao, Y. S. and Rajamani, S. (1988) Control of the root-lesion nematode, *Pratylenchus indicus* Das 1960. In Rainfed Upland Rice. Indian J. Nematol. 18 : 117-118.

7. Prasad, J. S. and Rao, Y. S. (1988) The effect of different inoculation levels of *Pratylenchus indicus* on the growth and yield of rice. Nematol. Medit. 16 : 123-124.

8. Rao, J. and Prakash, A. (1988) *Caloglyphus berlesei* Michael, an acarid mite in rice. Oryza 24 : 386-387.

9. Rao, Y. S. , Jayaprakash, A. and Mohanty, J. K. (1988) Nutritional disorders in rice due to infestation of *Heterodera oryzicola* and *Meloidogyne graminicola*. Rev. Nematol. 11 : 375-380.

10. Sahu, S. C. and Chowla, M. L. (1988) Resistance of rice cultivars to root-knot nematode, *Meloidogyne graminicola*. Oryza 25 : 62-64.

11. Sahu, S. C. and Das, S. N. (1988) The rice root nematode (*Hirschmaniella* spp.) Oryza 25 : 333-347.

12. Swain, B. and Prasad, J. S. (1988) On the biotypes of root-knot nematode *Meloidogyne graminicola* in rice. Curr. Sci. 57 : 848-849.

13. Swain, B. and Prasad. J. S. (1988) Chlorophyl content in rice as influenced by the root-knot nematode, *Meloidogyne graminicola* infection. Curr. Sci. 57 : 895-896.

14. Zaheruddin, S. M. and Prakasa Rao, P. S. (1988) Ovipositional host status of some weeds, wild rice and cultivated crop plants for *Nilaparvata lugens* Stal. Indian J. Agric. Sci. 58 : 659-661.

Agricultural Engineering

1. Chakravarty, A. , Mishra, P. and Banerjee, H. D. (1988) Investigation of combustion of raw and acid leached rice husk for production of pure amorphous white silica. J. Mat. Sci. 23 : 21-24.

Agricultural Economics

1. Ram, Salik, Dash, M. M. and Mishra, R. K. (1988) Growth pattern of major commercial crops in the state of Orissa during plan periods. Indian J. Agric. Econ. 43 : 512-513.

Central Lowland Rice Research Station, Kharagpur

1. Shukla, S. N. (1988) Save your rice crop from pest and disease. Indian Farming May issue, 13-16.

LIST OF TRAINING, CONFERENCES, SYMPOSIA AND WORKSHOPS ATTENDED BY SCIENTISTS DURING 1988

1.	Rice Pathologists' group meeting	Jan 16–17	Hyderabad	Dr. R. Sridhar
2.	State level seminar on modernisation of rice mills	Feb 6	Bhubaneswar	Dr. A. K. Behera
3.	International Congress of Plant Physiology	Feb 15–20	New Delhi	Dr. K. S. Murty Dr. V. P. Singh
4.	International Conference on research on plant science and its relevance	Mar 7–11	Delhi	Mr. D. Maiti
5.	Group discussion on drainage of Agricultural lands for field level control of water in coastal saline area	Mar 14–16	Port Canning	Mr. P. C. Mahapatra
6.	Workshop on 'How to sustain green revolution'?	Apr 22–23	Allahabad	Dr. D. Panda
7.	Annual Rice Workshop	Apr 26–29	TNAU, Coimbatore	Dr. J. K. Roy Dr. G, B. Manna Dr. K. S. Murty Dr. K. V. S. R. K. Row Dr.R. Sridhar Dr. V. S. Chauhan Mr. J. S. Chauhan Mr. M. Variar
8.	National Workshop on utilisation of soil survey data for bund and water management in irrigation commands	May 8–14	WALMI Bhubaneswar	Dr. M. D. Reddy Dr. A. R. Sharma
9.	International Workshop on Indo-US -STT Programme on Nitrogen Fertilizer Efficiency	May 16–18	New Delhi	Dr. P. K. Singh Dr. S. K. Mohanty
10.	National Seminar on basic research for crop disease management	May 18–20	Aduthurai	Dr. R. Sridhar
11.	Mini Workshop of All India Coordinated Research Project on Nematode pests of crops and their control	May 27–28	New Delhi	Dr. J. S. Prasad
12.	National Seminar on Changing pest situation in the current agricultural scenario of India	June 14–16	New Delhi	Dr. G. B. Manna Dr. P. S. Prakasa Rao

13.	Indo-US-STI Joint Workshop on Agriculture	July 23–27	Bangalore	Dr. P. K. Singh Dr. S. K. Mohanty Dr. A. Bhadrachalam
14.	Workshop on 'Crop yield modelling'	July 27–28	Ahmedabad	Dr. R. N. Dash
15.	Project design workshop	Sept 14–16	Hyderabad	Dr. R. N. Misra Dr. N. P. Sharma Dr. P. Nayak
16.	National workshop on pest and disease surveillance for integrated pest management	Sept 16–17	Coimbatore	Dr. P. S. Prakasa Rao
17.	Crop project design workshop	Sept 21–22	New Delhi	Dr. S. Patnaik Dr. R. N. Misra Dr. N. P. Sharma Dr. P. Nayak Dr. S. C. Sahu
18.	Orientation Workshop on farming systems research methodology	Sept 26–Oct 6	IRRI, Philippines	Dr. K. P. Jha Dr. V. S. Chauhan
19.	National Symposium on nutritional ecology of insects and environment	Oct 2–4	Muzaffarnagar	Dr. Anand Prakash
20.	UGC National Workshop on Diagnostic and biochemical techniques in plant viruses	Nov 1–14	Tirupati	Dr. Santosh K. Mohanty
21.	Annual Conference and Workshop on All India Coordinated Project on Biological Nitrogen Fixation	Nov 2–4	Parbhani	Dr. V. R. Rao
22.	International Conference on appropriate agriculture technologies for farm women	Nov 30-Dec.6	New Delhi	Dr. K. P. Jha Dr. Gouri Padhi Dr. Jagdiswari Rao Dr. Mayabini Jena
23.	Workshop on methodologies for research on water management in irrigated rice fields	Dec 5–6	Coimbatore	Dr. D. K. Paul
24.	National Seminar on Review and update of thrust areas in life sciences	Dec 6–8	Lucknow	Dr. P. K. Singh
25.	Indo-US Workshop on genes and development	Dec 11–15	New Delhi	Dr. S. C. Sahu Dr. P. Nayak

26.	International Workshop on genes and development	Dec 19–22	Bangalore	Dr. T. K. Adhya
27.	Fortyeight Annual Conference of Indian Society of Agricultural Economics	Dec 27–29	Varanasi	Dr. Salik Ram
28.	Workshop of All India Coordinated Scheme on Micro and secondary nutrients and pollutants in soil and plants	Dec 28–29	Bhubaneswar	Dr. P. K. Nayar Dr. A. K. Misra Dr. V. Sarkunan
29.	International Symposium and Workshop on Biological nitrogen fixation associated with rice production	Dec 28–31	Bhubaneswar	Dr. P. K. Singh Dr. G. B. Manna Dr. Dinesh Chandra Dr. S. K. Mohanty Dr. N. Sethunathan Dr. V. R. Rao Dr. D. P. Singh Dr. D. Panda Dr. R. N. Samantaray

DISTINGUISHED VISITORS

Dr. R. B. Austin, Professor, Institute of Plant Science Research, Cambridge, U. K.

Dr. John C. O' Toole, Senior Scientist, Rockfeller Foundation, U. S. A.

Dr. J. Litsinger, Entomologist, IRRI, Philippines

Dr. Ronnie Coffman, Chairman, Plant Breeding, Cornel University, U. S. A.

Dr. I. Watanabe, IRRI, Philippines

Dr. M. S. Swaminathan, Ex-Director General, IRRI, Philippines

Dr. S. K. Dutta, Professor Dept. of Botany, Howard University, U. S. A.

Dr. R. K. Chaudhury, Professor, Molec. Biol. Lab., Calcutta.

Dr. K. Kanungo, Member, ASRB

Dr. D. R. Bhumla, Chairman. QRT

Dr. S. Chelliah, Tamil Nadu Agric. Univ. and Member, QRT

Dr. S. Biswas, Project Director, Eastern India Rice Project

RETIREMENT OF SCIENTIST/STAFF

Mr. M. V. Rao, Principal Scientist (Agronomy) retired on 28. 2. 1988.

Dr. Y. S. Rao, Principal Scientist (Entomology) retired on 30.11. 1988.

Dr. K. S. Murty, National Fellow (Plant Physiology) retired on 30. 11. 1988.

Mr. N. K. C. Patnaik, Selection Grade Scientist (Plant Breeding) retired on 30. 6. 1988.

Mr. A. R. Khan, S. S. G. IV retired on 31.5. 1988.

Mr. Jadumani Sahu, S. S. G. II, retired on 31. 8. 1988.

Mr. Sarangadhar Roy, S. S. Gr. II retired on 30.9. 1988.

STAFF/ SCHOLARS WHO OBTAINED Ph. D. in 1988

Name	Discipline	Name of the Guide
A. R. Sharma	Agronomy	Dr. B. N. Mittra
N. C. Misra	Entomology	Dr. B. C. Misra
B. Swain	Entomology	Dr. J. S. Prasad
R. K. Tomar	Agronomy	

STAFF

Director	:	S. Patnaik, M. Sc. , Ph. D.
Joint Director	:	P. K. Singh, M. Sc. , Ph. D.

Genetic Resources

Principal Scientists	A. Krishnamurthy, M. Sc. , M. Sc. (U. K.) (Head) S. D. Sharma, M. Sc. , Ph. D.
Selection Grade Scientists	D. P. Ghorai, M. Sc. , Ph. D. S. R. Dhua, M. Sc. (Ag.) A. R. Panda, M. Sc. (Ag.)

Plant Breeding and Genetics

Principal Scientists	K. Srinivasulu, M. Sc. (Head) J. K. Roy, M. Sc. , Ph. D. R. N. Misra, M. Sc. , Ph. D. M. J. Balakrishna Rao, M. Sc. C. Gangadharan, M. Sc. , Ph. D. N. P. Sarma, M. Sc. , Ph. D. P. J. Jachuk, M. Sc. P. N. Sreedharan, M. Sc.
Selection Grade Scientists	N. K. C. Patnaik, M. Sc. ** D. Choudhary, M. Sc., Ph. D. D. P. Srivastava, M. Sc. , Ph. D. S. N. Ratho, M. Sc. (Ag.), Ph. D. R. N. De, M. Sc. (Ag.), Ph. D. G. J. N. Rao, M. Sc. , Ph. D. M. Nagaraju, M. Sc. R. N. Rao, M. Sc, Ph. D.
Scientists	Ashok Kumar, M. Sc. ** J. N. Reddy, M. Sc. (Ag.) , Ph. D.

Plant Physiology

Principal Scientists	G. Sahu, M. Sc. , Ph. D. (Head) T. R. Dutta, M. Sc. , Ph. D. D. P. Bhattacharjee, M. Sc. , D. Phil.

	Ch. N. Rao, M. Sc., Ph. D
	K. S. Murty, M. Sc. (Ag.), Ph. D. **
Selection Grade Scientists	S. K. Nayak, M. Sc.
	G. Ramakrishnayya, M. Sc.
Scientist	V. P. Singh, M. Sc., Ph. D.

Biochemistry

Principal Scientists	S. B. Lodh, M. Sc., D. Phil. (Head)
	M. N. Sahay, M. Sc., Ph. D., A. I. C., F. I. C. (India)
Scientists	B. B. Nanda, M. Sc.
	Bhaskar Das, M. Sc. (Ag.)

Agronomy

Principal Scientists	G. B. Manna, M. Sc. (Ag.), Ph. D.
	M. V. Rao, M. Sc. (Ag.) **
	K. C. Das, M. Sc (Ag.), Ph. D.
	C. R. Padalia, M. Sc. (Ag.)
	V. N. Saraswat, M. Sc. (Ag.), Ph. D.
(Project Coordinator, Weed Control)	
Selection Grade Scientists	K. P. Jha, M. Sc. (Ag.), Ph. D.
	Dinesh Chandra, M. Sc. (Ag.), Ph. D.
	B. T. S. Moorthy, M. Sc (Ag.), Ph. D.
	K. Srinivasa Rao, M. Sc. (Ag.) Ph. D.
Scientists	M. Devender Reddy, M. Sc. (Ag.), Ph. D
	A. R. Sharma, M.Sc. (Ag.), Ph.D.

Soil Science and Microbiology

Principal Scientists	S. K. Mohanty, M. Sc. (Ag.), Ph. D. (Head)
	N. Sethunathan, M. Sc., Ph. D., F. A. Sc.
	P. K. Nayar, M. Sc. (Ag.), Ph. D.
Selection Grade Scientists	A. Bhadrachalam, M. Sc.
	R. N. Dash, M. Sc., Ph. D.
	A. K. Misra, M. Sc., Ph. D.
	S. P. Chakravarty, M. Sc., Ph. D.
	V. R. Rao, M. Sc., Ph. D.
	V. Sarkunan, M. Sc. (Ag.), Ph. D.
	D. Panda, M. Sc. (Ag.), Ph. D.
	T. K. Adhya, M. Sc.

	R. N. Samantaray, M. Sc.
	S. K. Pradhan, M. Sc. (Ag.), D. I. I. T., Ph. D.
	K. R. Mahato, M. Sc., Ph. D.
	M. M. Panda, M. Sc. (Ag.), Ph. D.
	D. P. Singh, M. Sc. (Ag.), Ph. D.
Scientist	M. V. R. Murty, M. Sc. (Ag.), Ph. D.

Plant Pathology

Principal Scientists	A. Anjaneyulu, M. Sc. (Ag.), Ph. D. (Head)
	J. Veeraraghavan, M. Sc., Ph. D.
	S. Devadath, M. Sc., Ph. D. (on deputation to Vietnam)
	K. V. S. R. Kameswar Row, M. Sc., Ph. D.
	A. P. Dath, M. Sc., Ph. D.
	P. R. Reddy, M. Sc., Ph. D.
Selection Grade Scientists	R. Sridhar, M. Sc. (Ag.), Ph. D.
	P. Nayak, M. Sc. (Ag.), Ph. D.
	B. Padhi, M. Sc., Ph. D.
	S. K. Mohanty, M. Sc., Ph. D.
	L. P. Kauraw, M. Sc., Ph. D.
	Urmila Dhua, M. Sc., Ph. d.
	U. D. Singh, M. Sc. (Ag.)
	S. N. Tiwari, M. Sc. (Ag.), Ph. D.
	G. Bhaktavatsalam, M. Sc. (Ag.), Ph. D.
Scientist	S. K. Singh, M. Sc. (Ag.)

Entomology

Principal Scientists	B. C. Misra, M. Sc. (Ag.), Ph. D., F. E. S. (Head)
	Y. S. Rao, M. Sc., D. I. C., Ph. D. **
	K. C. Mathur, M. Sc., Ph. D.
	P. S. Prakasa Rao, M. A., Ph. D.
	Y. R. V. J. Rao, M. Sc., Ph. D.
Selection Grade Scientists	V. N. Rao, M. Sc.
	S. Rajamani, M. Sc., Ph. D.
	J. S. Prasad, M. Sc., Ph. D.
	Gouri Padhi, M. Sc., Ph. D.
	Prabhati Samal, M. Sc., Ph. D.
	Ananda Prakash, M. Sc., Ph. D.
	R. C. Dani, M. Sc.

	S. Sasmal, M. Sc.
	P. K. Das, M. Sc.
	Jagadiswari Rao, M. Sc.
	S. C. Sahu, M. Sc. (Ag.), Ph. D.
	K. S. Behera, M. Sc.
Scientists	M. S. Panwar, M. Sc. (Ag.)
	Mayabini Jena, M. Sc., Ph. D.

Agricultural Engineering

Principal Scientists	G. T. Kurup, M. Tech., Ph. D. (Head)
Selection Grade Scientists	F. C. Das, M. Tech. (Head)
	B. Mahapatra, M. Sc.
	N. Sahoo, M. Tech.
	P. C. Mahapatra, M. Tech.
	A. K. Choudhury, M. Tech.
	P. Misra, M. Tech.
	B. C. Parida, M. Tech.
	A. K. Behera, M. Tech.
	S. P. Patel, M. Tech.
	D. K. Jaiswal, M. Tech.

Statistics

Principal Scientist	S. Rawlo, M. A., P. S. C. C., Dip. (Ag.), A. H. (Statistics)
Selection Grade Scientists	A. V. Suriya Rao, M. Sc. P. S. C. C.
Scientists	N. K. Mahana, M. Sc., P. S. C. C.
	K. M. Sahu, M. Sc., P. S. C C.

Economics

Selection Grade Scientists	Salik Ram, M. Sc. (Ag.), Ph. D.

Communication and Training

Principal Scientist	J. K. Roy, M. Sc., Ph. D. (Head)
Selection Grade Scientist	S. K. Mohanty, M. Sc., Ph. D.

Central Rainfed Lowland Rice Research Station, Kharagpur

Selection Grade Scientists	S. N. Shukla, M. Sc, Ph. D. (Officer-in-Charge)
	K. Panda, M. Sc. (Ag.), Ph. D.

Scientists	S. K. Singh, M. Sc. (Ag.) N. C. Pande, M. Sc. (Ag.)

Central Rainfed Upland Rice Research Station, Hazaribagh.

Principal Scientist	V. S. Chauhan, M. Sc., Ph. D. (Officer-in-Charge)
Selection Grade Scientists	V. D. Shukla, M. Sc. (Ag.) G. N. Mishra, M. Sc. (Ag.) P. K. Sinha, M. Sc. J. S. Chauhan, M. Sc., Ph. D.
Scientists	R. K. Singh, M. Sc., Ph. D. M. Variar, M. Sc. D. Maiti, M. Sc. (Ag.) C. V. Singh, M. Sc., R. K. Tomar, M. Sc., Ph. D.

* Left during the year
** Retired during the year.