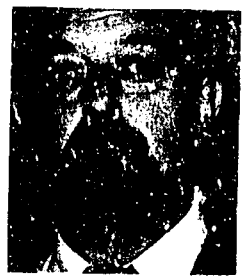
PN - NBN - 1656

# RESEARCH HIGHLIGHTS 1990-91

## SILVER JUBILEE YEAR



भाकृअनुप
ICAR

**DIRECTORATE OF RICE RESEARCH**

PN-ABN-656

# RESEARCH HIGHLIGHTS 1990-91

**DIRECTORATE OF RICE RESEARCH**

Formerly All India Coordinated Rice Improvement Project (AICRIP)

Rajendranagar, Hyderabad-500 030. A.P. India.

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ICAR

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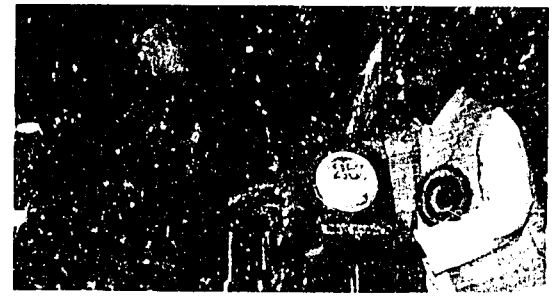
# AICRIP Celebrates Silver Jubilee

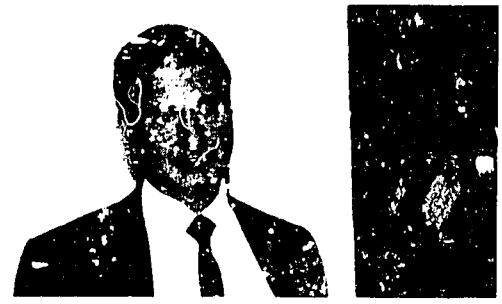
The establishment of All India Coordinated Rice Improvement Project (AICRIP) in the mid-sixties is generally hailed as one of the most significant events in the history of agricultural research and development in India. AICRIP was primarily designed to buttress and coordinate research activities in the States which had the responsibility to generate technologies for the farmers in their service area but lacked organisational support and interdisciplinary approach to problem solving.

AICRIP (now known as Directorate of Rice Research) helped States in the rapid identification and dissemination of appropriate variety and management technology through the unique mechanism of multilocation testing. AICRIP enabled the scattered, often isolated and remote, research stations to gain access to the vast pool of rice genetic material available throughout the country and from abroad.

AICRIP which became a model for similar projects worldwide including International Rice Testing Programme (IRTP) celebrated the completion of 25 years of service to the farmers by holding an International Symposium on Rice Research: New Frontiers, during November 15-18, 1990.

As a part of the Silver Jubilee celebrations, a large number of Frontline Demonstrations were organised in compact blocks throughout the rainfed ecosystems in Eastern India. These Frontline Demonstrations were aimed at both making available large quantities of seeds of the recently evolved high-yielding varieties and for creating an awareness on technologically improved management practices at every block in six rice producing states in the Eastern India (see page 31).





*Early help from Ford Foundation*

At the Silver Jubilee celebrations, citations were presented to Dr.M.S.Swaminathan, the architect of India's green revolution and to Dr.S.V.S.Shastry for building the coordinated rice research and testing programme as a model.

In appreciation of long association and support the following institutions were felicitated:

- Andhra Pradesh Agricultural University
- Central Rice Research Institute
- Department of Agriculture, Government of Andhra Pradesh
- Ford Foundation
- International Crops Research Institute for Semi-Arid Tropics
- International Rice Research Institute
- Ministry of Agriculture and Cooperation, Government of India
- Rockefeller Foundation
- USAID

The Directorate also felicitated the following Scientists cum Administrators for significant contributions:

Appa Rao A, Freeman WH, Mandal B, Pande HK, Parthasarathy N, Patnaik S, Pawar MS, Richaria RH, Seetharaman R, and Siddiq EA.

In appreciation of the long and significant contribution the following were honoured:

**Scientists**

Balakrishna Rao MJ, Biswas S, Chellaiah S, Dasgupta DK, Devdatt S, Ghosh A, Gopalakrishnan R, Hakim KL, Israel P, John VT, Kalode MB, Krishnaiah K, Kulsreshta JP, Mahadevappa M, Mahapatra IC, Mohanty HK, Mourya DM, Muralidharan K, Murthy KS, Murthy VVS, Narasinga Rao M, Pasalu IC, Pathak PK, Pillai KG, Prakasha Rao P, Prasad JS, Prasad SC, Prasada Rao U, Rajagopala Reddy M, Ramakrishna Rao J, Rama Rao K, Rao AV, Rao MV, Rao YS, Reddy APK, Roy B, Saini SS, Saran S, Sastry MVS, Seshu DV, Shahi HN, Shinde JE, Singh RA, Singlachar MA, Srinivasan TE, Srivastava PS, Subbaiah SV, Subba Rao C, Subramaniam A, Subramaniam K, Venkataraman A, Venkateswarlu B and Roy JK.

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**Supporting Staff**

Devaiah M, Gopamma N Venkaiah , Laxmamma D Gandaiah, Mysamma S Sailoo, Pandu T and Yadaiah G.

## International Symposium on Rice Research: New Frontiers, November 15-18, 1990

The Symposium was timed to review the current status of rice research in various disciplines and to identify the technologies that would ensure continued growth in rice production and productivity. The main focus of the Symposium was to look ahead and examine the scope offered by the recent advances in genetics, biotechnology, space technology, information technology and public policy formulations in enhancing the productivity, profitability and stability of rice farming systems on an ecologically and economically sustainable basis.

The Proceedings of the Symposium are being published in two volumes. An Extended Summary of the poster papers has already been brought out in the form of a publication.

# Varietal Improvement

## Breeding for rainfed uplands

Soil moisture stress during the erratic distribution of rainfall, poor crop stand, low panicle density and grain number per panicle, poor soil fertility, loss of applied fertiliser nitrogen due to run off and deep percolation and soil acidity often limit rice production in rainfed uplands. Further, phosphorus and iron deficiency or aluminium/manganese toxicity are commonly encountered. Biotic factors like termites, gundhi bug, mealy bug, stem borer, brown spot and blast also pose problems. The overall socio-economic conditions, the relatively low resource mobilisation capacity and the risks associated with upland environment drastically limit production levels. Our breeding efforts have been directed at increasing rice productivity under such circumstances.

A very early maturing rice variety, Heera has been released by the Central Sub-Committee for the Variety Release for cultivation in rainfed uplands. Heera has tolerance to drought and blast. Heera is also suitable for cultivation under post-flood

**Varieties for rainfed uplands**

**CENTRAL RELEASE**

***Heera*** (IET 10973) from CR 404/CR 289-1208, 72 days total duration, long bold grain, possesses drought tolerance and suitable for multicropping, post-flood situations. Recommended for the states of Orissa, Bihar, West Bengal, Uttar Pradesh, Madhya Pradesh, Andhra Pradesh and Karnataka.

**STATE RELEASE**

**Uttar Pradesh**

***Narendra Dhan 97*** (IET 9210) from N 22/Ratna, 95 days duration, long slender grains

**Gujarat**

***GR 5*** (IET 10415), local pure line selection from CR 319-344, 91 days duration, long slender grains

**Tamil Nadu**

***PMK 1*** (IET 11669) from CO 25/ADT 31, 115 days duration, long bold grains

**Promising elite cultures for rainfed uplands**

***RP 2469-4286-6450-6590*** from RP 1669-24/Prasanna, 83 days duration, long slender grains

***CR 544-1-1*** from CR 404-48/CR 289-1208, 78 days duration, long bold grains

***CR 544-1-3-4*** from CR 404-48/CR 289-1208, 79 days duration, long bold grains

***RP 2220-111-84-20*** from IET 5850/Tellavadlu, 98 days duration, long slender grains, blast resistance

***NDR 1006*** from IR 6729-67-3/Cauvery, 93 days duration, long slender grains

***Pusa 598-167*** from IR 50/Pusa 33, 102 days duration, long slender grains

***RP 2533-7488-18*** from M 63-83/Sarya//IRAT 8/M 63-83, 85 days duration, long bold grains

***BAU 146-10-3*** from M Gora (G)/IAC 25, 93 days duration, long bold grains

***RRU 664*** from Dangar/Chambal, 96 days duration, long bold grains

***RP 2477-10249-553*** from Karavaikalanjian/Rasi, 104 days duration, long bold grains

*Heera : An early maturing variety suitable for rainfed uplands and post-flood situations*

situation and in multiple cropping systems. Other varieties released by various states include Narendra Dhan 97,GR 5 and PMK 1.

## Breeding for rainfed lowlands

The primary problem faced by farmers in rainfed lowlands is the inability to transplant rice in mid-July when water raises (to 20-25 cms level) suddenly in the fields. The unpredictable inundation and flash floods during any time from mid-August to mid-September damages whatever rice is planted successfully. Under such circumstances, fertiliser application almost becomes impossible.

Varieties combining genetic flexibility for date of planting and tolerance to various depths of submergence have been therefore, our immediate breeding goals to raise the yield levels. After extensive testing, PY 4, CO 45 have been released for cultivation in lowlands.

A critical evaluation of the entries for tiller mortality under waterlogged conditions, adaptability to varied conditions and high yield potential helped in identification of several elite cultures. For areas with less than 50 cms water depth, the most promising cultures include CR 682-166, KAU 1001, OR 443-80-4, CR 629-246, RP 2081-265-115-54 and RP 1822-112-5-8. At water depth more than 100 cms, MTC 23A and CN 573-221-7-1 were promising. Semideep water elite cultures included CN 706-2-26 and CR 1028-144.

**Varieties for rainfed lowlands**

**STATE RELEASE**

**Tamil Nadu**

***PY 4*** (IET 7238) from IR 8/H 4, 150 days duration, long slender grains

***CO 45*** (IET 9879) from Ratu Heenati/IR 3403-267-1, 140 days duration, long slender grains

**Promising elite cultures for rainfed lowlands**

**Shallow water areas (30 to 50 cm water depth)**

***CR 682-166*** from Pankaj/T 141, 155 days duration, medium slender grains

***KAU 1001*** from IR 20/IR 25, 145 days duration, long slender grain

***OR 443-80-4*** from IR 36/OR 127-1, 140 days duration, long bold grain

***CR 629-246*** from Vijaya/T 141, 155 days duration, medium slender grains

***RP 2081-265-115-54*** from Phalguna/Andrewsali, 145 days duration, long bold grains, resistant to leaf blast and moderately resistant to sheath rot

***RP 1822-112-5-8*** from Pankaj/Swarnadhan, 150 days duration, short bold grains

**Semideep water areas (50-100 cm water depth)**

***CN 706-2-26*** from Bashpair/Pankaj, 175 days duration, medium slender grains

***CR 1028-144*** from PJ 746/CR 1014, 170 days duration, short bold grains

**Deep water areas (more than 100 cm water depth)**

***MTC 23A*** a selection from tall composite, 200 days duration, short bold grains

***CN 573-221-7-1*** from Patnai 23/Jaladhi 2, 201 days duration, short bold grains

## Evaluation for water logged conditions

Varieties were evaluated under continuous water logged condition (50 cm water depth) from 25 days after transplanting till maturity. Among the tested entries, IET 9776 was superior for low tiller mortality across the centres. IET 10717, IET 9751, IET 10097, IET 10115 and NC 678 were found superior for total dry matter. For panicle number, IET 9747, IET 9776, IET 9758, Roupsail, Badshabhog and NC 678 were superior, IET 9747, IET 10115, IET 11195, IET 10097, IET 10563, NC 678 and Bhasamanik for grain yield and IET 9758, IET 9747, IET 10563, Roupsail, NC 678 and Badshabhog for high density grain number.

**Table 1. Promising multiple resistant elite cultures for rainfed lowlands**

| IET No | Designation | Grain yield (t/ha) | Flowering duration (days) | Resistance/Tolerance | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GM | BPH | WBPH | SB | BI | ShBI | RTV |
| 10773 | RP 1579-1633-55-43 | 6.9 | 110 | R | R | S | MR | R | MS | S |
| 12875 | RP 2542-194-301 | 7.1 | 110 | R | R | MR | S | MS | S | MR |
| 11517 | RP 2543-1419-21-25 | 6.5 | 115 | MR | MR | R | S | MR | S | S |
| 11507 | RP 1746-1821-26-9 | 6.9 | 115 | R | MR | MR | R | S | R | S |
| 11508 | RP 2543 1422-24-16 | 6.9 | 115 | R | R | R | MS | S | S | S |
| 12360 | RP 1746-209-304 | 6.4 | 115 | R | R | S | S | S | R | S |
| 12197 | RP 1579-86-55-358 | 7.2 | 120 | R | R | S | R | R | MR | S |
| 12779 | RP 2543-1444-46-315 | 7.4 | 113 | R | R | S | S | S | S | MS |

GM = Gall midge; BPH = Brown planthopper; WBPH = White backed planthopper; SB = Stem borer; BI = Blast; ShBI = Sheath blight; RTV = Rice tungro virus; R = Resistant; MR = Moderately resistant; MS = Moderately susceptible; S = Susceptible

Intensive evaluation of the cultures to biotic stresses led to the identification of several multiple pest /disease resistant elite lines (Table 1)

## Breeding for aromatic rice

The leading aromatic fine quality rices in the world trade popularly known as basmati, are traditionally grown in the north and north-west regions in Indian sub-continent for centuries. For the choicest preparations like *Biryani* and *Palao*, basmati rices are the most preferred and, therefore earn high premium prices in both international and domestic markets.

Characterised by extra long superfine slender grains, basmati rices possess pleasant and exquisite aroma, sweet taste, soft texture, delicate curvature and extra elongation with a least breadth-wise swelling on cooking. The successful yield improvement of basmati rice through the release of Pusa Basmati 1 and Kasturi led to further breeding efforts.

The newly identified varieties include IET 11341 (Pusa 615-114-9-8) and IET 12019 (HKR 239). Theses cultures give grain yields more than traditional Basmati 370 or Karnal local and possess all characters of Basmati rices. These semidwarf selections are under on-farm testing in traditional basmati growing areas of Uttar Pradesh, Punjab and Rajasthan. These cultures possess pleasant aroma, and good cooking quality. Other promising cultures were IET 12014 and IET 12020. Yield potential and quality characters of elite entries are given in Table 2.

**Basmati varieties released**

**CENTRAL RELEASE**

***Haryana Basmati 1*** HKR 228 (IET 10367) from Sona/Basmati 370, 140 days duration, scented rice with resistance to blast and white backed planthopper

**STATE RELEASE**

**Bihar**

***Kamini*** a pure line selection from local katarnibhog, 130 days duration, long slender grains

**Table 2. Grain quality characteristics of promising basmati cultures**

| Character | IET 11341 | IET 12019 | IET 12014 | IET 12020 | Bas. 370 |
|---|---|---|---|---|---|
| Yield (t/ha) | 3.61 | 3.50 | 2.53 | 2.95 | 2.91 |
| Head rice recovery(%) | 42.5 | 44.0 | 40.5 | 48.0 | 47.0 |
| Kernel length (mm) | 6.77 | 6.71 | 6.91 | 7.27 | 7.01 |
| L/B ratio | 4.28 | 4.22 | 4.28 | 4.53 | 4.31 |
| Alkali value | 6.2 | 7.0 | 2.0 | 3.6 | 5.2 |
| Volume expansion | 3.92 | 3.75 | 4.50 | 4.21 | 3.88 |
| Cooked kernel length (mm) | 13.08 | 12.59 | 14.50 | 12.50 | 15.42 |
| Elongation ratio | 1.93 | 1.88 | 2.10 | 1.75 | 2.20 |
| Amylose(%) | 19.55 | 22.71 | 14.74 | 17.88 | 18.66 |
| Aroma | Strong | Mild | Strong | Strong | Strong |

## Breeding for multiple resistant cultures for irrigated areas

Many varieties are developed with specific resistance to single insect pest/ disease. Simultaneous occurrence of more than one pest and/or disease at a given time results often in greater yield losses. Intensive evaluation of breeding lines for different biotic stresses led to the identification of multiple resistant varieties. Varieties released were TRC 246-C-10, ASD 18, MDU 4, GR 103, Aruna, Makom, Kanakom.

IET 9994 (RP 1920-979-1097-2) from the cross Sona/ARC 14529 with resistance to tungro virus disease was nominated for extensive on-farm testing. IET 9994 also showed resistance to sheath rot, brown planthopper and white backed planthopper. This culture with long slender grains matures in 125 days. Another elite culture IET 9976 (RP 2199-14-2-6-1) from the cross Phalguna/TKM6 showed consistent resistant reaction to gall midge, blast and sheath rot. IET 9976 is suitable for irrigated areas, particularly in the southern states, has long slender grains and matures in 120 days.

*IET 9994 : A promising medium duration culture with long slender grains and resistance to rice tungro virus disease*

*IET 9976 - An early maturing multiple resistant elite culture for irrigated areas*

**Multiple resistant varieties released for irrigated areas**

**STATE RELEASE**

**Tripura**

***TRC 246-C 10*** (IET 9877) from Thimpu/IR 9219-102-2//KN 18-361, 118 days duration, short bold grains with tolerance to cold, blast, brown spot and bacterial leaf blight

**Tamil Nadu**

***ASD 18*** from ADT 31/IR 50, 110 days duration, medium slender grains, resistant to blast, moderately resistant to sheath rot, brown planthopper, gall midge and rice tungro virus

***MDU 4*** (IET 9302) from AC 2386/Jagannath, 125 days duration, long slender grains, resistant to blast, sheath rot, moderately resistant to brown planthopper and brown spot

**Gujarat**

***GR 103*** (IET 11093) from GR 11/Mahsuri, 110 days duration, medium slender grains, resistant to blast, moderately resistant to leaf folder and stem borer

**Kerala**

***Aruna*** (MO 8), IET 9287 from Jaya/Ptb 33, 110 days duration, long bold grains, resistant to gall midge, sheath blight, sheath rot, moderately resistant to stem borer and brown planthopper

***Makom*** (MO 9), IET 9268 from ARC 6650/Jaya, 100 days duration, short bold grains, resistant to gall midge and sheath rot, moderately resistant to brown planthopper and blast

***Kanakom*** (MO 11), IET 9380 from IR 1561/Ptb 33, 130 days duration, long bold grains, moderately resistant to brown planthopper, rice tungro virus, blast and bacterial leaf blight

## Breeding for saline and sodic soils

**Varieties released for saline and sodic soils**

**CENTRAL RELEASE**

***CST 7-1*** (IET 9341) from Damodar/IR 24, 140 days duration, long bold grains, suitable for saline and water inundated areas of West Bengal, Orissa and Andhra Pradesh

## Breeding varieties for high altitude areas

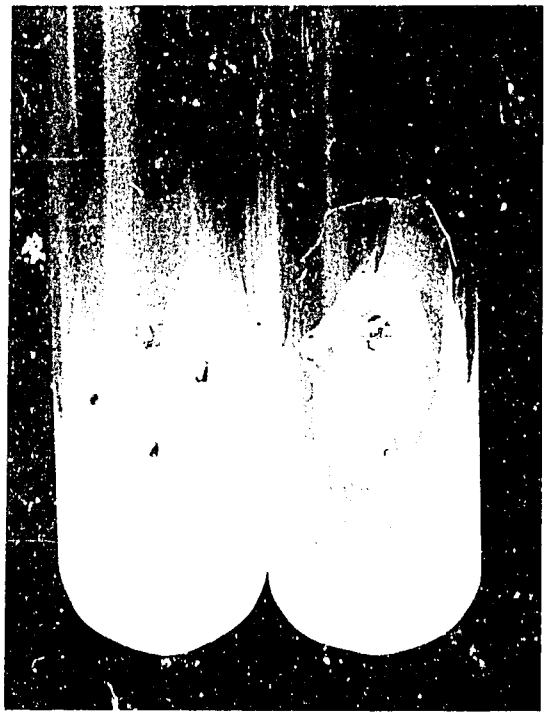
From an extensive critical analysis of test entries at high altitude locations, IET 11242 (RP 2421-100-2-3-2) was identified as the most promising culture. This has been recommended for minikit testing in hilly areas of Himachal Pradesh and west Uttar Pradesh.

**Varieties for hilly areas**

**STATE RELEASE**

**Uttar Pradesh**

***VL Dhan 21*** (IET 9112) from IR 2053-521/K 116//Kn 18-361, 136 days duration, long bold grains, blast resistant



## International trials

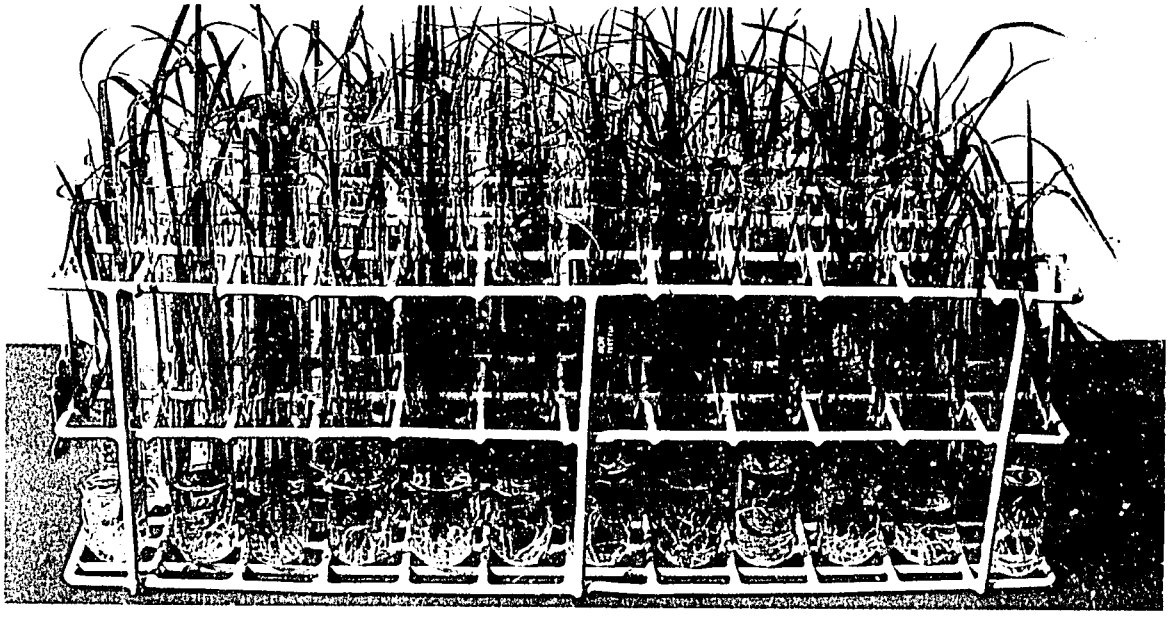
Five international yield trials from INGER nurseries were conducted at ten locations in the country and promising entries identified in different nurseries are as under.

| Trial/Entry | Yield (kg/ha) | Flowering duration (days) |
|---|---|---|
| ***International Rice Yield Nursery - Very early*** | | |
| AT 77-1 | 6303 | 90 |
| IR 50404-57-2-2-3 | 5688 | 82 |
| ***International Rice Yield Nursery-Early*** | | |
| DR 79-21 | 5279 | 86 |
| IR 52290-117-1-1-3 | 5277 | 87 |
| ***International Rice Yield Nursery - Medium*** | | |
| IR 49500-54-1-2-3 | 5911 | 96 |
| B 3894-226-78-5 | 5663 | 97 |
| ***International Upland Rice Yield Nursery*** | | |
| B 3623-G-TB-48 | 4093 | 77 |
| B 3619C-TB-8-1-4 | 3829 | 74 |
| ***International Deep Water Rice Yield Nursery*** | | |
| BKNFR 78023-38-1K-1-1 | 3000 | 123 |
| CR 149-4156-226 | 3180 | 120 |

## Anther culture

Among the two anther culture lines viz., AC 561 and AC 570 from the cross V20A/PR 106 tested under Initial yield Trial-Irrigated mid-early during kharif at four locations, the culture AC 561 (IET 12899) out-yielded the check variety, Rasi. AC 561 recorded a mean yield of 4.61 t/ha.

Normally wide hybridisation involving wild species of rice is less successful due to compatibility barriers. In most of the crosses embryo gets aborted after fertilisation. The embryo rescue technique to overcome the barriers of wide hybridisation has been successfully used in 133 interspecific crosses aimed at diversifying cytoplasmic male sterile sources. The $F_1$ hybrid embryos 10-14 days after fertilisation had been isolated and cultured aseptically in 1/2 MS basic medium to obtain seedlings. Fertility of $F_1$ seedlings from all these crosses is being studied.



*Interspecific hybrids obtained through embryo rescue technique*

## Interspecific hybridisation

Identification of restorer gene(s) for the cytoplasmic male sterile lines viz, Pushpa A, Mangala A and IR 64 A has been attempted. Pollen fertility of $F_1$ from these crosses is being studied. Further, such wide crosses were also aimed at diversification of CMS sources.

## Seed production and distribution

A total quantity of 2.7 t of nucleus seed of 18 varieties was raised for production of breeder seed stage II. Nearly 5.1t breeder seed was supplied to national and state seed corporations and to Directorate of Rice Development, Patna.

**Interspecific hybridisation**

| Parents | No. of crosses | Parents | No. of crosses |
|---|---|---|---|
| ***For identifying restorer gene(s) for the CMS lines*** | | ***For diversification of CMS sources*** | |
| Pushpa A, Mangala A / *O. rufipogon* (22) | 22 | *O. nivara* / *O. sativa* (36) (16) | 90 |
| Pushpa A Mangala A / *O. nivara* (18) | 22 | *O. rufipogon* / *O. sativa* (15) (7) | 25 |
| Pushpa A Mangala A / *O. glaberrima* (3) | 4 | *O. barthii* / *O. sativa* (8) (4) | 11 |
| IR 64 A / *O. rufipogon* (12) | 12 | *O. longistaminata* / *O. sativa* (3) (4) | 4 |
| IR 64 A / *O. nivara* (3) | 3 | *O. glaberrima* / *O. sativa* (3) (2) | 3 |

Figures in parentheses represent the number of wild accessions or cultivated varieties involved

## Hybrid rice

Critical evaluation of the recently developed hybrids revealed the influence of test locations on grain yields. The hybrids which showed a tonne extra yield compared to best check variety are given in Table 3.

Two other hybrids IR 58025A/IR 9761-19 and IR 58025 A/IR 887 recorded higher N-use efficiency under different N application levels up to 130 kg N/ha. The increase in grain yields of these hybrids ranged from 9 to 44% over Jaya and 22-50% over Rasi at different N levels.

In CMS seed production plots, the mean yield ranged from 0.27 t/ha at Maruteru to 2.29 t/ha at Coimbatore during kharif season. For increasing out-pollination, foliar spray application of gibberellic acid (GA 3) with either leaf cutting or rope pulling or both was most effective. Compared to the control, such treatments increased seed yields from 30 to 100%.

**Table 3. Performance of hybrid rice**

| Hybrid | Grain yield (t/ha) | | |
|---|---|---|---|
| | Hybrid | Best check | Increased yield |
| ***Hyderabad*** | | | |
| IR 62829 A/IR 10198-66 | 6.77 | 5.26 (Rasi) | 1.51 |
| IR 62829 A/IR 29723-143 | 6.38 | 5.25 | 1.13 |
| IR 52025 A/IR 29723-143 | 6.19 | 5.25 | 0.94 |
| ***Mandya*** | | | |
| IR 62829 A/IR 9761-9 | 9.50 | 8.06 (Annada) | 1.44 |
| IR 58025 A/IR 29273-143 | 7.03 | 5.74 (Jaya) | 1.29 |
| ***Maruteru*** | | | |
| IR 62829 A/Milyang 46 | 4.33 | 3.40 | 0.93 |
| ***Karnal*** | | | |
| IR 62829 A/IR 10198-66 | 5.58 | 4.58 | 1.00 |

Further, the seed yield obtained through out-pollination in rabi was higher. In hybrid seed production plots, maximum yield obtained was 2.40 t/ha.

*Hybrid rice : IR 62829 A/IR 10198-66*

## Inheritance of iron chlorosis

Studies in sandy upland field under high pH with progenies of susceptible parents (ARC 5723 - purple) crossed to resistant parent (Sathi, Dular or Browngora) showed iron chlorosis tolerance in all $F_1$ plants. The $F_2$ populations segregated in a ratio of 9 tolerant to 7 susceptible for iron chlorosis in all the crosses studied. Such results further confirmed the earlier report of 2 dominant complementary genes *Ic*1 and *Ic*3 for tolerance to iron chlorosis in the parents.

## Inheritance of seed viability in rice

Seed viability is a complex physiological character. The primary studies indicated that the duration of seed viability in rice varied with varieties. In general, late maturing varieties showed a longer period of seed viability.

An early drought tolerant variety from Nigeria showed a seed viability for a short period of 12 months while N 22 expressed a longer period of seed viability of 24 months. Hence, these two cultivars were crossed for studying the inheritance of seed viability.

The $F_1$ seeds of IRAT 8/N 22 showed viability for the longer period of 24 months. Seeds from 940 $F_2$ plants showed a segregation ratio of 3-longer period viability to 1-shorter period viability indicating a simple dominance for longer period of seed viability. This genetic relation was confirmed with 120 $F_3$ families. The gene for seed viability has been tentatively designated as *Sv(t)*.

## Genetics of brown planthopper resistance

Confronted with the increased outbreaks of brown planthopper, efforts were made to understand the genetic architecture of the factors governing yield and resistance. The relative parental potential was assessed to identify the desirable brown planthopper resistant donors and crosses based on general combining ability (GCA), specific combining ability (SCA) and heterotic effects.

Resistant improved cultures (IET 6238, IET 6309 and Nagarjuna) were chosen as females and tall resistant donors (Chennellu, ARC 6650, Rathu Heenati, Horanamavee) as male parents were used in a line tester design. Sixteen hybrids and parents were studied for yield and resistance governing factors.

The GCA effects were greater than SCA effects for three characters only. While the preponderance of SCA over GCA was noted for many characters studied indicating non-additive gene action, significant SCA effects were noticed for yield components in different crosses. In eight hybrids heterotic to four characters, yield improvement *per se* was detected only in six hybrids. The extent of heterobeltiosis for single plant yield varied from 27.7 (IET6283/Horanamavee) to 108.2 (Nagarjuna/Chennellu).

## Inheritance of resistance to gall midge

Inheritance of resistance to gall midge(*Orseolia oryzae*) was studied in crosses between susceptible and resistant parents. The resistance to biotype 4 was found to be governed by two dominant complementary genes in the $F_2$s of the crosses, viz., IET 9278/IET 11161, IET 11161/IET 10077 and IET 9278/IET 11158. The $F_1$s in all the crosses showed resistant reaction and the breeding behaviour of the $F_3$ families confirmed the $F_2$ data.

In the cross Ratna/Banglei, the resistance was found to be governed by one dominant gene to biotype 4. However, in the same cross, the resistance was conditioned by a single recessive gene to biotype 1 indicating that the genes governing resistance to both the biotypes are different as shown in the following table.

**Inheritance of resistance to gall midge**

| Cross | Reaction of $F_1$ plants | | Segregation in $F_2$ population: Resistant | Segregation in $F_2$ population: Susceptible | Expected ratio | $\chi^2$ | P value |
|---|---|---|---|---|---|---|---|
| ***Biotype 4*** | | | | | | | |
| RP 2732 IET 9[illegible]/IET 11161(S) | | OBS | 184 | 139 | | | 0.75-0.90 |
| | R | EXP | 181.7 | 141.3 | 9:7 | 0.07 | |
| RP 2731 IET 9278(R)/IET 11158(S) | | OBS | 239 | 160 | | | 0.10-0.25 |
| | R | EXP | 224.4 | 174.6 | 9:7 | 2.16 | |
| RP 2752 IET 11161(S)/IET 10077(R) | | OBS | 131 | 82 | | | 0.10-0.25 |
| | R | EXP | 119.8 | 93.2 | 9:7 | 2.39 | |
| RP 2400 Ratna(S)/Banglei(R) | | OBS | 297 | 84 | | | 0.10-0.25 |
| | R | EXP | 285.8 | 95.2 | 3:1 | 1.77 | |
| ***Biotype 1*** | | | | | | | |
| RP 2400 Ratna(S)/Banglei(R) | S | OBS | 114 | 404 | | | 0.25-0.50 |
| | | EXP | 137 | 411 | 1:3 | 0.48 | |

OBS = Observed; EXP = Expected; R = Resistant; S = Susceptible

*Manually operated 5-row transplanter*

# Crop Production and Resource Management

Sustainable development is the management and conservation of the natural resource base. This requires a reorientation of technological and institutional changes to ensure continued satisfaction of human needs. Such sustainable development increases land capacity to produce more of rice or other agricultural products and is environmentally non-degrading. Some of the major highlights relating to resource management for sustainable rice production are reported hereunder:

### Varietal choice for stability of production in irrigated areas

Among the late maturing rice cultures, MTU 9992 and Swarna at Maruteru, Salivahana at Mandya and IET 9746 at Upper Shillong were the most promising with economic responses up to 100 kg N/ha. In the medium duration group, IET 8585 and IET 9910 at Rajendranagar, Jaya at Nagina, and Jaya and PR 108 at Gurdaspur recorded the best results, while IET 9978 and IET 7959 at Aduthurai, IET 8883 and IET 8886 at Cuttack, IET 7959 at Rewa and IET 9590 and IET 9612 at Malan were the best early maturing cultures compared to Cauvery or Rasi.

Yield maximisation trials pursued at 16 irrigated locations have clearly shown that a one-third increase in plant population or fertilizer application could amount to an extra grain yield (0.3 t/ha). Growing a green manure crop *in situ* and its incorporation followed by supplementary application of N along with a one-third increase in plant population in general, helped recording the overall best grain yield.

### Varietal choice for rainfed lowlands

In the evaluation of varietal responses to N levels both IET 9746 and IET 9168 at Pusa, Kharagpur and Ghagraghat registered high grain yield and response to applied nitrogen. However, Salivahana continued to be the best variety at Kharagpur, while IET 9572 at Upper Shillong and IET 9188 at Faizabad were promising. For late planted conditions Chaitanya and IET 9557 at Maruteru; IET 9757 and Swarna at Ragolu; NC 492 at Chinsurah; IET 10334 and IET 7251 at Mohanpur; IET 7251 and IET 9757 at Chiplima; Swarnadhan and IET 9757 at Kharagpur; Rajashree at Pusa; Andrewsali at Titabar; and KMJ 1-52-3 at Karimganj were the most suitable varieties.

### Evaluation of 5-row manually operated transplanter

Transplanting rice with a 5-row manually operated transplanter resulted in several advantages. Compared to manual planting, only 10% missing hills were recorded with 5-row transplanter. The average field capacity worked out to 0.32 ha in a day of 8h, with 65 to 70% efficiency. It is necessary to have two operators working on a shift, as otherwise a single operator gets exhausted in a heavy clay soil system. It is estimated that almost 88 man h/ha could be saved by using a 5-row manually operated transplanter, compared to manual transplanting.There was only a marginal difference in the mean grain yield of manually transplanted crop and crop planted with 5-row transplanter.

### Integrated plant nutrition system

The basic concept underlying the integrated plant nutrition system is the maintenance or adjustment of soil fertility and of plant nutrients supply to an optimum level for sustaining the desired level of crop productivity through optimisation of the benefits from all possible sources of plant nutrients in an integrated manner.

Field evaluation of modified urea materials proved that placement of N as urea super granules is both efficient and economical especially in soils with low permeability. Among

the coated urea materials tested, Nimin coated urea applied in two split doses at planting and panicle initiation stages recorded maximum N use efficiency and increased grain yields. Partial substitution of the N requirements of rice to the extent of about 50% either through the application of farm yard manure or by raising and incorporating a green manure crop *in situ* before transplanting rice appeared to be promising. Green manure-N or farm yard manure-N supplemented smaller amounts of N to rice plants over a period of time. In cases where the green manure is raised *in situ* for incorporation before transplanting rice, the amount of biomass production within a short span of 60-75 days becomes crucial. Significant yield responses to potash applied at maximum tillering and panicle initiation stages have been reported from many locations in the north-eastern high rainfall regions of the country, where iron toxicity related yellowing syndrome appears under continuous lowland rice culture.

Studies on the effect of moderate levels of N, P and K either alone or in combination with 300 kg lime/ha applied in furrows before seeding rice in acid upland soils indicated the useful effect of moderate liming towards improving crop productivity and soil fertility under these conditions.

## Long-term monitoring of soil fertility and crop productivity

In case of rice-wheat sequence, long-term trials at Pantnagar since 1984 clearly showed that nitrogen is the most limiting nutrient for rice and wheat production, which is closely followed by zinc and phosphorus. It is possible to sustain rice production with balanced use of these nutrients in judicious combinations. Improvements in management of the dry-wet transition period in rice-wheat system may be needed to prevent losses of soil N and reduce the N fertilizer requirements for the component crops.

## Rice-based cropping systems

An increased seed rate ensured better stand establishment while a moderate level of fertilizer use significantly improved productivity of *utera* crops in rice fallows.

The production potential of alternate rice-based cropping systems were studied. Rice-sorghum sequence gave the maximum productivity and gross income at DRR with two supplementary irrigations to the sorghum crop in rabi season. Puddling and transplanting rice in kharif in general, did not reduce the grain yields of pigeon pea or sorghum grown in rice fallows during the subsequent rabi season.

Studies on varietal compatibility in rice-wheat sequence at seven locations indicated that a medium duration rice variety in kharif followed by a wheat variety of normal duration sown in rabi recorded the maximum productivity at most locations.

## Increasing productivity in basmati rices

The planting of traditional basmati type rices beyond 15th July increased spikelet sterility and reduced both number of panicles per unit area and grain yields. Irrespective of the planting dates, Katarni produced significantly higher grain yields than Basmati 370. Among the scented semidwarfs, HKR 228 produced a marginally higher grain yield followed by Pusa Basmati 1 and Kasturi when planted by middle of June in Punjab and up to 15th of July elsewhere. The maximum head rice recovery was recorded by Pusa Basmati 1 irrespective of the planting dates. The kernel length after cooking and the elongation ratio were higher in Kasturi. Age of seedlings did not influence the grain yields in general, irrespective of the spacing adopted and date of p[illegible]g during the season. However, early, planting before 15th July using 30 to 40 days old seedlings and a spacing of 15 x 15 cm gave the best grain yield.

Studies on N response at graded levels of application indicated that HKR 228 and Kasturi at Kaul, HKR 228 and Pusa Basmati at DRR and Kasturi and HKR 228 at Pantnagar were promising with high grain yields and N response compared to the traditional Basmati 370. In these semidwarfs, N application increased the grain yield significantly up to 60 kg N/ha at Kaul and up to 90 kg N/ha at DRR and Pantnagar.

**Evaluation of P sources**

Due to application of different P sources, three distinct patterns in soil available (Olsen P) were observed during rice crop growth period in P deficient vertisol (pH 7.9-8.1). Among P sources, water soluble single super phosphate was highly effective in significantly increasing the available P to 12-15 ppm during initial four week growth period which declined rapidly to 5-6 ppm during remaining crop growth period. The phosphocompost (Mussoorie rock phosphate incubated with compost) exhibited an uniform available P status of 7-8 ppm throughout the crop growth period. The phosphocompost was effective up to 50 kg $P_2O_5$/ha only. Its efficacy was equivalent to 40 kg $P_2O_5$/ha applied as water soluble P. The P use efficiency of phosphocompost was 51%.

**P sources and zinc availability**

In irrigated system the studies on interaction of phosphorus with zinc nutrition of wetland rice showed that the grain yield response to zinc and phosphorus application was moderate (0.5 to 0.9 t/ha) over control. Zinc concentration in grain was significantly higher in ammonium polyphosphate applied plots with 13 to 40% increase in zinc uptake at harvest over that in diammonium phosphate applied plots. Only at Faizabad (alluvial, inceptisols), a significant response to zinc was observed in diammonium phosphate applied plots. At this location, a marginally higher grain yield with ammonium polyphosphate in the absence of zinc application was also obtained indicating higher availability of soil zinc through the sequestering action of ammonium polyphosphates

**Coated urea fertilizers for increasing N use efficiency**

In rainfed lowlands,excessive standing water acts as a physical barrier for effective top dressing of urea, leading to poor N use efficiency. Soil texture appeared to influence the overall performance of coated fertilizers, such as neem cake, Nimin, mussoorie rock phosphate and gypsum coated urea. In fine textured soils of Aduthurai, Chiplima, Ghagraghat, Patna and Titabar, a single basal coated fertilizer application was superior, while in light textured soils at Faizabad, Cuttack, Kharagpur and Umsuing, which are prone to heavy leaching losses, split application of N as urea was equally good. In terms of N use efficiency, on an average about 2-6 kg of higher grain per unit kg N applied was recorded with coated fertilizers. The mean grain yield responses recorded with prilled urea and coated urea indicate that depending on the location, about 6 to 44% of N in terms of urea fertilizer could be saved by the use of coated fertilizers.

**Yield and N uptake of direct-seeded flooded rice**

Direct seeding in puddled soil is re-emerging as an important crop establishment technique in rice due to various reasons. It is important to ascertain the grain yield levels and nutrient uptake of rice under this system of rice culture for working out its fertilizer requirement. The performance of six rice cultivars viz, Rasi, Sasyasree, Vikas, IET 7959, IET 9219 and IET 9978 was evaluated in kharif to estimate fertilizer requirement both under direct-seeded and transplanted conditions on a submerged soil. Similar grain and straw yields and N uptake were observed with the two crop establishment methods. Only the N concentrations in both grain and straw were

higher in transplanted rice than in direct-seeded crop.

## Changing response pattern in wetland

A long-term field experiment was initiated to study the changing productivity and fertilizer response pattern under intensive rice-rice cropping. While the first crop in rabi responded significantly to nitrogen and sulphur, the yield in the second crop increased significantly due to potassium also. The increase in grain yield due to sulphur application was more in kharif (20.0%) than in the rabi (9.8%) season.

## Green manures as sources of N

Incorporation of *Sesbania aculeata*, *Crotalaria juncea* and *Vigna mungo*, and tender loppings of *Glyricidia maculata* and *Ipomoea carnea* in a vertisol at 100 kg N/ha a day before planting produced grain yields comparable to urea application. Among the green manures *Sesbania* and *Glyricidia* treatments registered significantly higher N uptake compared to urea.

*Green manure: Glyricidia maculata*

## N use efficiency from organic manures

Organic N sources viz., compost and green manures such as sunhemp and *Sesbania aculeata* were evaluated during rabi and kharif in a vertisol. At 100 kg N/ha, a significant response to N application was obtained with all combinations of organic manures. Ligninaceous material in the organic manures are known to influence significantly the mineralization and immobilization of nitrogen in soil. The exception was compost applied as the only source of N (Table 4). This is essentially due to immobilization of nitrogen in the soil up to 5 weeks after incorporation. A combined application of N as green manure and urea recorded a higher grain yield response and N recovery at equivalent C/N ratios. Similarly, a combination of green manure and compost was superior to a combination of compost and urea in terms of cumulative N release, uptake and grain yield response.

In the experiment to study time of incorporation of green manures on N use efficiency, comparable yields were recorded with *S.aculeata* and *C.juncea* irrespective of the time of incorporation (1,8, 15 days prior to planting). However, higher uptake of nitrogen (83 kg N/ha) by rice recorded with green manure incorporated 8 and 15 days prior to transplanting suggests the need for allowing a minimum decomposition period of 8-15 days for improved N use efficiency.

## Evaluation of rice cultures for low light stress

Diffused light conditions reduced both crop growth and biomass, and enhanced tiller mortality. Low light stress induced poor grain filling, sterility and low yields. Low tiller mortality was recorded in IET 9757, IET 9760, IET 9776, IET 9186, IET 9747, IET 10300, IET 10109, IET 10115, Bhasamanik and Roupsail. The extent of sterility in cultures differed depending on location; low at Calcutta in IET 11195 and at Maruteru in IET 10097.

**Table 4. Organic N source for wetland rice (N rate 100 kg/ha)**

| Treatments | Grain yield (t/ha) | Total N-uptake (kg/ha) | Apparent N recovery (%) | Cumulative N release (mg $NH_4$/kg) |
|---|---|---|---|---|
| Control | 2.6 | 45 | - | - |
| Compost, all basal, incorporated (C/N-28) | 2.9 | 48 | 2.3 | - |
| Sunhemp (2/3N) + urea (1/3N), all basal, incorporated (C/N-9.7) | 4.8 | 84 | 38 | 60 |
| Compost (2/3N) + urea (1/3N), all basal, incorporated (C/N-18.2) | 3.5 | 60 | 15 | 20 |
| Compost (1/3N) + urea (1/3N)+ urea 1/3 N (TD) (C/N-9.5) | 3.8 | 73 | 28 | 7 |
| Sunhemp (2/3N) + compost(1/3N), all basal, incorporated (C/N-18.7) | 4.2 | 74 | 30 | 23 |
| C.D. (0.05) | 0.5 | | | |

TD = Top dressing at panicle initiation

IET 10558, IET 10563, IET 11195, Roupsail, Bhasamanik and NC 678 were found superior for panicle number. In general under shade, superiority for spikelet and grain number was observed in IET 9757, IET 9758 and IET 9760. For grain yield and increased biomass production (16 t/ha), IET 9758, IET 9757, IET 11195 and IET 10558 were superior. Potential grain filling was high in IET 11195, IET 10097, Bhasamanik and NC 492.

## Biomass, harvest index and yield

Fifty three medium duration cultures were assessed for biomass, harvest index and economic yield. In the biomass, leaf sheath emerged as a major component (15-30%) followed by leaf blade (11-25%) and culm (7-18%). The harvest index ranged between 18 to 56%. Positive relationships were observed between biomass and grain yield, and harvest index and economic yield among the varieties studied. For higher biomass, IET 9945, IET 10451, IET 11130, IET 11106, IET 9849, Suraksha, Phalguna, BPT 5204, Jaya and BPT 3291 were superior. IET 11144, IET 11142, IET 9876, IET 11126, IET 11146, Chambal, Vikramarya, Hari, Vijaya and Jaya were rated superior for higher harvest index.

## Variation in rice hull weights at maturity

Of fifteen cultivars of early, medium and late durations assessed, distinct varietal differences were observed for hull and kernel weights among different grades of grain indicating increased hull size in accordance with grain size. Hull weight ratio (proportion of hull weight to kernel weight) was constant among the grades indicating that it is a stable varietal character in rice.

## Influence of source and sink on high density grain and yield

Reduction in leaf area (source) through defoliation of the top four leaves in varied combinations indicated the importance of 1st top two and the 3rd leaves in the order while monitoring the production of high density grains and grain yield in greenhouse. The 4th leaf was least important. Panicle clipping studies suggested the role of top and middle portion of the panicle in contributing to higher spikelet filling as well as grain yield.

## Growth analysis for vigour

Studies on early vigour during rabi indicated that up to 4 weeks after planting IET 9691 closely followed by Akashi had higher growth rates than Swarna Prabha, considered to possess better early vigour. In the following 3 weeks, Akashi and IET 9691 exhibited higher growth rates. At harvest, IET 9619 registered a moderately higher yield compared to Swarnaprabha and Akashi. Another two cultures, IET 9219 (6.61 t/ha) and IET 9691 (6.36 t/ha) also gave more grain yields than Swarnaprabha (5.60 t/ha). Bhuban (8.00 t/ha), Lalat (6.87 t/ha) and Tulasi (6.61 t/ha) were better while Akashi (4.06 t/ha) and IR 64 (3.86 t/ha) had lower yields. During rabi season, early vigour had no specific advantage in grain yields.

During kharif the studies indicated that cultures IET 12419 and IET 12428 had better early vigour than Ratna. At reproductive phase, these cultures also had higher crop growth rate, relative growth rate and net assimilation rate values. IET 12419 recorded lower yields (8.27 t/ha) compared to cultures with low vigour. Sravani also out yielded Swarnaprabha and Abhaya, the two varieties known for high vigour. Higher growth vigour alone, therefore, may not contribute to higher yield.

## Remobilisation of reserves

Attempts were made to induce a better remobilization of reserves from culms to panicles of Akashi with a mild spray application of desiccants such as paraquat (0.5 ml/l), boric acid (5 g/l) and common salt (50 g/l). Paraquat had a depressing effect on yield (3.74 t/ha) compared to control (4.71 t/ha) while boric acid and common salt gave yields on par with control.

## Photosensitivity

In glass house pot culture study, various inductive cycles (0 to 10 inductive cycles of extended darkness) were given at 21 to 31 days after sowing. There was no change in days taken to panicle emergence probably due to lower threshold (critical) dark periods relative to natural dark period that was available during early rabi. This is apparently clear from the behaviour of these two cultures in kharif (Table 5).

**Table 5. Sowing time and flowering behaviour**

| Time of sowing | Flowering duation (days) | |
|---|---|---|
| | IET 10300 | IET 10717 |
| 1st June | 135 | 136 |
| 1st July | 122 | 117 |
| 1st August | 98 | 90 |
| 1st September | 84 | 82 |
| 1st January (After winter solstice) | 69 | 61 |

The photosensitivity indexing of semideep water and deep water cultures indicated that IET 11865 was extremely photosensitive. The photosensitivity indices varied from 0.432 in IET 10543 to 0.335 in IET 11865 based on the data collected from four sowings. The photosensitive phase varied from 75 days in IET 11865 to 31 days in IET 10543, while the basic vegetative phase varied from 63 days in IET 10543 to 35 days in IET 11867.

## High temperature stress

For inducing tolerance to high temperature stress at anthesis the effect of antioxidants like cysteine, ascorbic acid, mercaptoethanol on Tella Hamsa and Swarna were studied. Foliar application of cysteine and ascorbic acid sprays improved the ability of the plants to tolerate and withstand high temperature (45° C) and survive for a longer period (10 - 12 days) than controls (3 - 4 days) when irrigation was also stopped at anthesis.

# Crop Protection

## Host plant resistance to insect pests

Four selections each from the cross Swarnadhan/RP 1579-36 (RP 2541) and Rasi/RP 1579-38 (RP 2543) and one selection from Swarnadhan/RP 1579-37 exhibiting a consistent resistant reaction to brown planthopper under both greenhouse and field conditions for the second consecutive year. In addition, 21 cultures showed promising reaction in atleast 80% of tests. In DRR, greenhouse evaluation of national and international nurseries, 92 entries showed resistance and some promising cultures are given in Table 6.

The overall reaction to gall midge indicated eight cultures with consistent low damage during second year also. Among new cultures, RP 2547-111-259 and R 296-120 proved promising. In greenhouse screening for resistance to gall midge biotypes 1 and 4 at DRR, 279 entries against biotype 1 and 93 against biotype 4 recorded nil or low damage. Some of the cultures resistant to both biotypes

**Table 7. Selected cultures showing nil damage to gall midge biotype 1 and 4 in greenhouse**

| Trial | Designation/IET No. | Cross |
|---|---|---|
| GMS | RP 2547-111-259 | ARC 5723/ARC 6650 |
| | | RP 1579-38 |
| | R 296-120 | CR 157-392/OR 57-21 |
| | CR 157-212 | Vijaya/Ptb 10 |
| MRST | RP 1551-79-76-1 | IET 2815/CR 57-MR 1523 |
| | RR 217-1 | — |
| | RP 2068-18-3-5 | Swarnadhan/Velluthacheera |
| | CR 309-268 | Orumundakan/CR 10398-M-6-106 |
| | R 281-12 | Poorva/IR 8608-298 |
| NSN | 10885 TNAU 842805 | TNAU 9426-6/IR 36 |
| | 10850 R 321-43 | Samridhi/IR 36 |
| | 11786 OR 776-SSP-26 | Daya/IR 36 |
| NSN(S) | 12871 WGL 46753 | Surekha/WGL 16145 |
| | 12873 RP 2547-130-272 | RP 2205/RP 1579-38 |
| | 12364 MTU 6203 | MTU 4570/IR 50 |

**Table 6. Selected cultures showing resistance to brown planthopper in greenhouse**

| Trial | Designation/IET No. | Cross | Damage score |
|---|---|---|---|
| NSN | 11677 | Ratna/ARC 5981 | 2.9 |
| | 11747 | Ratna/ARC 5981 | 2.4 |
| | 11547 | Jagannath/Natural cross | 2.5 |
| NSN(S) | 12364 | MTU 4570/IR 50 | 2.7 |
| | 12767 | Ratna/ARC 5981 | 3.0 |
| | 12523 | Phalguna/Velluthacheera | 2.4 |
| | 12773 | Swarnadhan/RP 1579-36 | 1.6 |
| BPHST | KAUM 34-2-1 | Rasi/MO 5 | 2.1 |
| MRST | RP 2081-110-90-56 | Phalguna/Andrewsali | 3.0 |
| | RP 2068-18-3-5 | Swarnadhan/Velluthacheera | 2.2 |
| IRBPHN | IR 28222-9-2-2-2-2 | IR 19660-73-4/IR 1416-131-5//IR4510-74-22-3 | 2.9 |
| | IR 31429-14-2-3 | Kurkasuppar/IR 1060-90//R 13426-19-2 | 2.8 |

NSN = National Screening Nursery; NSN (S) = National Screening Nursery Special; BPHST = Brown Planthopper Screening Trial; MRST = Multiple Resistant Screening Trial; IRBPHN = International Brown Planthopper Nursery

are listed in Table 7. Assamchudi (IET 12343) and Calrose 76 (SC 305) are the new donors identified against biotypes 1 and 4.

RP 2572-17-315 from the cross Rasi/Chittaraikar//IET 5688 was the only entry displaying some degree of resistance to stem borer at the vegetative stage consecutively for two years. BPT 4229 recorded a low stem borer damage at the heading stage. At DRR, IET 2815, IET 9576, KU 82, IET 2645, Suweon 339 and Tainung Sen Glutinous 2 at the vegetative stage, and ARC 11281, ARC 11744, MNP 762 and Velluthacheera at the heading stage were found promising. Exclusive prevalence of yellow stem borer was noted at Mandya, Karjat, Ludhiana and Pantnagar while pink borer was prevalent at Almora.

Two selections of RP 2332 from the cross Ratna/ARC 10654 exhibited consistent resistant reaction to whitebacked planthopper. In greenhouse screening at DRR, IFT 12797, RP 1528-1225-27, BG 379-2 and IR 2035-117-3 recorded low damage.

BPT 3328 and BPT 4239 consistently exhibited low leaf folder damage. Evaluation of resistant donors revealed the following cultures with low damage, ARC 5764 and ARC 5778 to hispa at Malan and Titabar; ARC 6619, ARC 7255, GS 531 and ARC 6107 to gundhi bug at Siddipet; Aganni, Chemban, GS 531, ARC 5500A, Ptb 12, T 1477 and Velluthacheera to whorl maggot at DRR and Aganni and ARC 7080 to thrips at Rajendranagar.

The multiple resistant cultures evaluated at 23 locations led to the identification of 16 cultures with promising reaction to five or more pests (Table 8). Among these, TNAULFR 831311, WGL 47998 and RP 2068-18-3-5 (IET 9853) showed multiple resistance consistently.

**Table 8. Reaction of multiple insect pest resistant cultures**

| IET No. | Designation | Reaction | | | | | | | | | Promising against pests | Multiple resistance index@ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BPH | GM | SB DH | SB WE | WB PH | LF | GLH | RH | WM | | |
| - | TNAULFR 831311 | * | | * | * | * | * | * | | * | 7 | 98 |
| - | WGL 47998 | * | * | * | * | * | * | * | | * | 8 | 88 |
| 9853 | RP 2068-18-3-5 | * | * | * | | * | * | * | | | 6 | 78 |
| 10810 | OR 621-20-1 | * | * | * | | * | * | * | | | 6 | 60 |
| 11478 | CPM 25 | * | * | * | | * | * | * | | | 6 | 60 |
| - | RP 1551-79-46-1 | * | * | * | * | * | | | | | 5 | 80 |
| - | PAU 1126-69-1-3-2 | * | * | * | * | * | * | * | | | 7 | 56 |
| 9760 | RP 2087-194-2-2 | * | | * | * | * | * | * | | * | 7 | 56 |
| - | RP 2081-322-145-48 | * | | * | | * | * | * | | | 5 | 55 |
| - | 1528-1225-27 | * | * | | | * | * | * | | | 5 | 55 |
| 11164 | R 281-12 | | * | * | * | | | * | | * | 5 | 55 |
| - | HKR 120 | * | | * | | * | * | | | * | 5 | 55 |
| - | RP 2332-259-174-130 | * | * | * | | * | | * | | * | 6 | 54 |
| - | TNAUBPHR 831305 | * | | * | | * | * | * | * | | 6 | 54 |
| 10445 | CN 746-3-1 | * | | * | | * | * | * | | * | 6 | 54 |
| 10751 | R 435-756 | * | * | * | | * | * | * | | | 6 | 54 |

* Promising reaction; @ Product of no.of pests against which the entry is promising and no.of tests showing promising reaction; BPH = Brown planthopper; GM = Gall midge; SBDH = Stem borer at dead heart stage; SBWE = Stem borer at white ear stage; WBPH = White backed planthopper; LF = Leaf folder; GLH = Green leaf hopper; RH = Rice hispa; WM = Whorl maggot

## Prevalence of insect biotypes

Gall midge biotype population studies revealed the prevalence of biotype 1 at DRR, Raipur and Sambalpur; biotype 2 at Cuttack and Mangalore; biotype 3 at Ranchi and Iroisemba; and biotype 4 at Ragolu and Sakoli. Brown planthopper population studies, like in earlier years, showed an uniformity in reaction of differentials over locations.

## Chemical control

Cartap (Padan) granules at 1.0 kg a.i./ha consistently was on par with carbofuran 1.0 kg a.i./ha is providing effective control of insect pests and increased grain yields. Among sprays, ethofenprox at 0.075 kg a.i./ha gave better control of insect pests and more grain yield than chlorpyriphos, while ethofenprox at 0.05 kg a.i./ha was on par with chlorpyriphos. BPMC at 0.75 kg a.i./ha was slightly inferior to chlorpyriphos (0.5 kg a.i./ha).

Of the new insecticide formulations tested during the year at DRR, isazophos granules (0.75 kg a.i./ha) and TIA 230 spray (0.5 kg a.i./ha) gave good control of whorl maggot, gall midge and leaf folder. Ethoprop granules (0.75 kg a.i./ha), sprays of ethofenprox (0.05 kg a.i./ha) and carbaryl (0.5 kg a.i./ha) were effective against whorl maggot, while cartap granules (0.75 kg a.i./ha) gave an effective control of leaf folder.

Treatments involving seedling root dip followed by need based application of either

**Table 9. Performance of different methods of insecticide application**

| Treatment | Stem borer (% Dead hearts) 50 DAT | Gall midge (% Silver shoots) 50 DAT | Leaf folder (ADL/10hills) 60 DAT | Grain yield (kg/ha) |
|---|---|---|---|---|
| Soil incorporation of carbofuran (@ 0.75 kg a.i./ha) and need based monocrotophos spray | 1.50 (1.41) | 30.90 (33.74) | 4.67 (2.15) | 3064 |
| Seed soaking (SS), seedling root dip (SD) and need based monocrotophos spray | 1.77 (1.41) | 11.27 (19.48) | 8.33 (2.82) | 3615 |
| Seedling root dip (SD) and need based monocrotophos spray | 0.27 (0.85) | 11.37 (19.59) | 6.00 (2.43) | 3554 |
| Seedling root dip (SD) and need based carbofuran granules application | 1.40 (1.37) | 4.70 (12.34) | 43.33 (6.41) | 3554 |
| Need based monocrotophos spray | 0.70 (1.01) | 33.40 (35.12) | 7.00 (2.64) | 2574 |
| Need based carbofuran and cartap granules application | 2.57 (1.75) | 16.67 (24.01) | 18.33 (4.15) | 3125 |
| Untreated control | 2.90 (1.83) | 15.53 (23.16) | 32.00 (5.16) | 2819 |
| CD(0.5) | 0.61 | 5.81 | 2.65 | 351 |
| CV(%) | 24.90 | 13.60 | 40.40 | 6.2 |

SS=Soaking of sprouted seeds in 0.2% chlorpyriphos for 3 h before sowing; SD = Seedling root dip in 0.02% chlorpyriphos emulsion for 12 h before planting; DAT = Days after transplanting; ADL = Average damaged leaves; Figures in parentheses are transformed values

*Predatory mirid bug (Cyrtorhinus lividipennis)*

monocrotophos spray or two rounds of granules - first with carbofuran and second with cartap gave good protection from pest complex and significantly increased the grain yield (Table 9). Either soil incorporation or one need based application of carbofuran granules at 10 DAT failed to control gall midge.

Carbofuran and phorate granules failed to control leaf folder, while cartap granules even at 0.25 kg gave good control. Treatment with carbofuran led to leaf folder resurgence with increased incidence in IET 9996 and CR 317-166, while IET 9853 and RP 193-1 showed damage similar to untreated control.

Ethofenprox even at 25 g a.i./ha prevented brown planthopper resurgence. A higher brown planthopper/mirid bug ratio (1.83) was recorded with deltamethrin which causes brown planthopper resurgence.

In greenhouse studies, cartap and carbofuran granules at 1.0 kg a.i./ha remained effective against leaf folder larvae even after 15 days of application recording 90% mortality while phorate was ineffective.

Among the six botanical formulations tested in greenhouse, Margoside C.K and Nemark (at 0.5%) showed some toxicity to brown planthopper nymphs.

Studies on the effect of insecticides on the natural enemies revealed that granular formulations of carbofuran, quinalphos and phorate at 1.0 kg a.i./ha are relatively less harmful to mirid bug, spiders and coccinellids than sprays of monocrotophos, chlorpyriphos and quinalphos at 0.5 kg a.i./ha.

In optimum pest control trial, CR 317-166 to both stem borer and gall midge and Suraksha and Abhaya to gall midge exhibited resistance. However, CR 294-54-8 and Suraksha gave similar grain yields over locations under protected and unprotected conditions indicating greater stability. Among multiple resistant cultures studied at DRR, IET 10516

to whorl maggot; IET 9996 to leaf folder; IR 25924-92-1-3 to stem borer at the vegetative stage and CR 317-166 to stem borer at heading stage showed low pest damage. IET 9996 with no significant yield loss due to insect pests confirmed its suitability in IPM.

**Biocontrol studies**

At Mandya, dryinids and nematodes accounted for 18 and 17% brown planthopper nymphal mortality, respectively. The extent of gall midge parasitism was 6% at Raipur, 78% at Sambalpur and 16% at Sakoli. The stem borer egg parasitism at Coimbatore was due to *Tetrasticnus* (32%), *Telenomus rowani* (24%) and *Trichogramma japonicum* (2%). Total parasitism due to these parasites ranged from 15 to 45% at Chinsurah and 3 to 20% at Nawagam. Eight larval parasites from leaf folders, *C. medinalis* and *M.patnalis* at Coimbatore and six pupal parasites at DRR were recorded.

*Wolf spider (Lycosa pseudoannulata) : An active predator found in rice ecosystem*

*Nymphal parasite (Pseudogonatopus) : Predator of brown planthopper and white backed planthopper Larva in sac (left)*

In plots inundated @ 10 *Trichogramma* adult parasites per sq.m, a higher egg parasitism corresponding with lower damage to crop (13 to 42%) was recorded at Pondichery, Nawagam and DRR.

Spore suspensions of *Beauveria bassiana* (at 1.46 x $10^5$ to 2.52 x $10^7$) and *Metarhizium flavoviridae* or *M.anisopliae* (at 4.61 x $10^6$ to 5.4 x $10^8$) by dipping method caused more than 50% mortality in brown planthopper, whitebacked planthopper and green leafhopper. Infection rate of *B.bassiana* was relatively much higher.

Field evaluation of available commercial formulation of *Bacillus thuringiensis* at 1.5 and 1.0 l/ha was not effective in checking leaf folder. But, 1.0 l/ha in combination with monocrotophos (0.5 kg a.i./ha) *B thuringienis* recorded less larval population and leaf damage than other treatments.

**Economic threshold levels**

For different pests the economic threshold level of damage varied depending

on locations; stem borer from 2-7% dead hearts at Kapurthala and 5-10% dead hearts at other locations; gall midge from 1.5 to 7.0% silver shoots at Sambalpur and Raipur; brown planthopper 5-10 insects/hill at Maruteru and 11-25 insects/hill at Pondichery; whitebacked planthopper 26-50 insects/hill at Nawagam and Kaul; leaf folder 5-10% damaged leaves; and rice hispa 10% damaged leaves at Malan.

**Integrated pest management**

At stem borer endemic locations (Rajendranagar, Nawagam, Karjat and Almora) use of tolerant variety alongwith a wider spacing (20 x 15 cm) and need based insecticide application resulted in achieving higher yields. In gall midge endemic areas like Sakoli, Sambalpur and Bhubaneswar, selection of a variety with wider resistance alone seemed to be critical as pest management in susceptible variety proved uneconomical. In planthopper stress areas like Pondichery and Kaul, adoption of a resistant variety with need based insecticide application was more profitable.

**Population dynamics of insect pests**

Monitoring of insect pests through light trap showed a wide distribution of stem borer. Both green leafhopper and leaf folder were on the increase in respect of area of incidence. Considerable population of mirid bug was reported from Maruteru and Pondichery coinciding with the peak catches of brown planthopper.

**Biological and ecological studies**

Attempts to rear yellow stem borer on the leaf folder diet revealed a partial survival (50%) of neonate larvae up to five days. Though a high proportion of these larvae survived up to fifteen days, they failed to moult to 2nd instar.

**Studies on rice nematodes**

Surveys for nematode pests in rice revealed occurrence of root lesion nematode (*Pratylenchus* spp) in DRR farm and root nematodes (*Hirschmanniella mucronata* and *H.oryzae*) in Srikakulam, Vizianagaram, Khammam, Nalgonda and Krishna districts.

Field evaluation of chemicals against root nematode showed that fenamiphos, sebuphos and triazophos brought down the populations of the nematode. Soil samples collected from insecticide evaluation trial showed low population of root nematode in carbofuran, phorate and ethoprop treated plots.

**Host plant resistance to major diseases**

Germplasm accessions and advanced breeding cultures were evaluated at DRR in glasshouse under epiphytotic conditions for identifying alternate or additional sources of resistance to various diseases. For the last five years, both ARC 11554 and Balimau putih have shown consistently tolerant reaction to rice tungro virus disease. Hence, these two germplasm accessions were crossed with IR 64 and IR 36, known to posses tolerance to green leafhopper, the vector for tungro. The $F_2$ populations were inoculated with rice tungro virus 30 days after sowing in glass house, through viruliferous green leaf hopper feeding for 24 h. Nearly 12% of the progenies in $F_2$ population of three crosses viz, IR 64/ARC 11554, IR 36/ARC 11554 and IET 6248/Balimau putih did not show any visible tungro virus disease symptoms. These plants showed neither stunting nor reduction in the number of tillers following inoculation with tungro virus (Table 10).

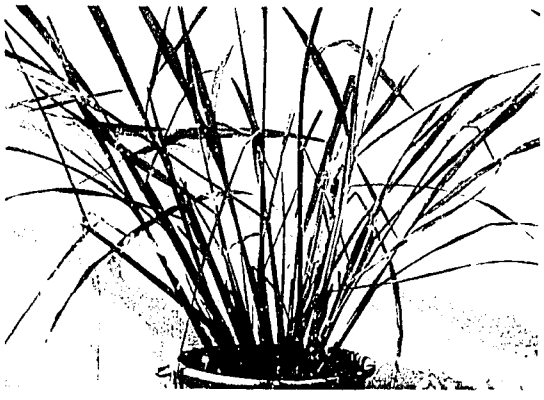
**Table 10. Mean growth characteristics of $F_2$ progeny showing resistance to rice tungro virus**

| Parent/Cross | Before inoculation 15 DAS | | After inoculation 60 DAS | |
|---|---|---|---|---|
| | Plant height(cm) | Tiller No. | Plant height(cm) | Tiller No. |
| IR 64 | 33 | 2 | 66 | 22 |
| ARC 11554 | 30 | 1 | 78 | 12 |
| IR 64/ ARC 11554 | 31 | 2 | 65 | 23 |

Rice tungro virus is caused by a complex of two virus particles, namely rice tungro bacilliform virus and rice tungro spherical virus. For resistance to joint infection of these two tungro virus particles, a large number of breeding lines from six crosses were evaluated. Three lines viz, RP 2327-117-517 (Ratna/ARC 5981), RP 2349-902-607 (Vikramarya/Sonasali) and RP 2344-1149-523 (IET 6858/ARC 5981) were found resistant to rice tungro complex.

In multilocation screening, IET 10885 (TNAU 9426-6/IR 50), IET 11766 (IR 50/ Phalguna) and IET 11081 (Jagannath/Dular) showed only a moderate level of resistance to rice tungro under glasshouse and in field evaluation. IET 12771 (Nagarjuna/ARC 5984) gave a resistant reaction to tungro at CRRI only.

In the past, isolated incidence of rice ragged stunt virus has been reported from several parts of the country. However, the virus disease transmitted by *N.lugens* exhibits a variety of symptoms including slight stunting, ragged appearance of leaves, uneven or serrated leaf edges, twisting of leaves and vein swelling. Although the virus disease does not pose any problem in rice cultivation at the present, our efforts were directed at identifying a source for resistance to this potential virus. ARC 10660 was identified to be a resistant source for rice ragged stunt virus.



*Oryza nivara (Acc. No. DRW 21004-5) : A donor for resistance to grassy stunt virus (GSV II)*

*Rice ragged stunt virus disease symptoms*

Search for a donor with resistance to the new strain of grassy stunt virus (GSV II), responsible for the 1988 epidemic at Kuttanad in Kerala was continued. An accession of *Oryza nivara* maintained at DRR (Accession No. DRW 21004-5) was found to be a good resistant donor.

Among 228 cultures evaluated for leaf blast at many endemic locations in the country, 14 showed resistance (Table 11).

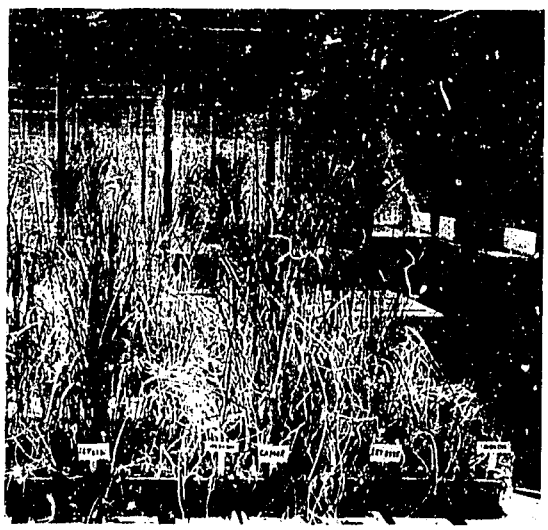
In all eight Assam rice collections, ARC 11829, ARC 11347, ARC 11357, ARC 11361, ARC 11865, ARC 11375, ARC 11381 and ARC 11920 recorded a moderate level of resistance to sheath blight disease. In the multilocation evaluation, entries that showed a moderate level of tolerance to this disease include IET 11611 (OR 73-1183/IR 2075-190-3-1-1), IET 10811 (Rajeshwari/Jajati) and RP 2572-20-6 (Rasi/Chittaraikar//IET 5688). IET 12181 (ARC 5723/ARC 6650//RP 1579-38) showed moderate resistance to sheath blight at two

**Table 11. Promising cultures with blast resistance**

| Cultures | Cross |
|---|---|
| ***Hills*** | |
| IET 9381 | IR 1561/Ptb 33 |
| IET 10371 | IR 36/Pusa 167 |
| IET 10751 | IR 54/Surekha |
| IET 11006 | Pusa 15-21/IR 20 |
| IET 12005 | IAC 5544/Dourado precose |
| IET 12586 | IR 3941-12/JC 99 |
| IET 12609 | Basmati 370/TKM 6 |
| IET 12801 | CICA 4/IR 625-23-3-1//Tetep |
| ***Rainfed uplands*** | |
| IET 11057 | Rasi/IET 7332 |
| IET 11748 | ADT 36/TKM 6 |
| ***Rainfed lowlands/irrigated areas*** | |
| IET 10754 | Phalguna/Andrewsali |
| IET 10785 | Phalguna/Andrewsali |
| IET 11570 | IR 54/Safri 17 |
| IET 12204 | Phalguna/Andrewsali |

locations (Pantnagar and Kapurthala) for the second successive year.

Of the 285 germplasm accessions screened in glasshouse at DRR, NC 1184, ARC 10980 and ARC 10844 were found resistant to bacterial leaf blight.



High resistance to kresek phase at Gurdaspur, Kapurthala and to leaf blight phase of bacterial blight at other endemic locations was recorded in IET 11130 (RP 106/OBS 528) and IET 12174 (RP 106/OBS 528). IET 11063 (IR 30/Babawee//IR 2071-625-1-252) showed high degree of resistance equal to IET 8585 (IR 8/BJI//IR 22//CR 98-7216) at fourteen locations in the country.

The promising entries for brown spot resistance included IET 12873 (RP 2205/RP 1579-38), IET 10858 (Phalguna/NLR 9674) and IET 10409 (Srinivas/TKM 9). At four locations, IET 11064 (TKM 6/Rasi) showed low score (<4.0) for sheath rot disease.

The screening programme identified nearly 23 accessions with resistance to more than one disease and some of the highly promising cultures are given in Table 12.

## Blast management

In the hills at both Malan and Ponnampet, two foliar applications of carbendazim at panicle initiation and booting stages gave effective control of neck blast incidence and increased the grain yields. However, at Almora an additional seed dressing or foliar application at tillering stage was needed to control early leaf blast incidence. In the rainfed uplands seed dressing (Fongorene @ 4 g/kg seed) followed by a need based foliar application of

**Table 12. Multiple resistant entries**

| IET No. | Cross | Resistance |
|---|---|---|
| IET 8955 | Rasi/CR 98-7216 | Blast and kresek |
| IET 11005 | BG 90-2-4/OE 677 | Blast and leaf blight |
| IET 11063 | IR 30/Babawee// IR 2071-625-1-252 | Sheath blight and bacterial leaf blight |
| IET 11064 | TKM 6/Rasi | Sheath blight and leaf blight |
| IET 11081 | Jagannath/Dular | Sheath rot sheath blight and rice tungro virus |
| IET 12174 | RP 106/OBS 528 | Blast, kresek and bacterial leaf blight |

carbendazim proved useful. Similar seed treatment with pyroquilon followed by two sprays of carbendazim 50 WP (@ 1 g/l) at panicle initiation and booting stages significantly controlled neck blast and gave higher grain yield under irrigated condition at Pattambi. In irrigated conditions among granular formulations evaluated, application of pyroquilon (Coratop 5G @ 40 kg/ha) at tillering stage followed by a foliar spray with carbendazim at heading was found to be effective. However, a single granular application at later crop growth stage under direct seeded condition, effectively controlled neck blast and gave higher grain yields.

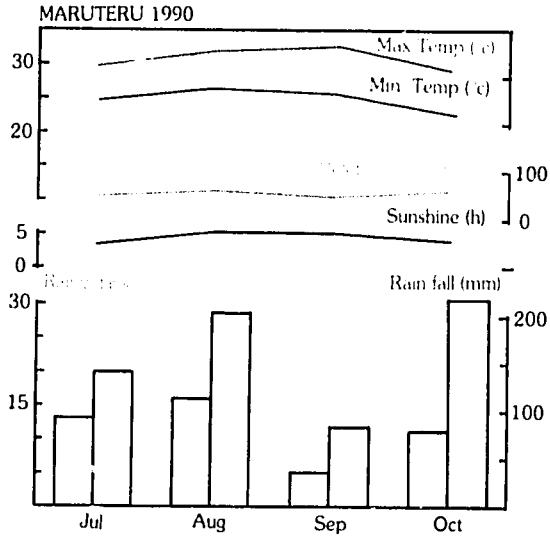
**Sheath blight management**

Among the new fungicide formulations evaluated, Contaf 5 EC at 100 ppm proved highly effective in inhibiting both mycelial growth and production of sclerotia by *Rhizoctonia solani*. Similarly, EC formulation of chlorothalanil was effective at 100 ppm, while the chlorothalanil WP formulation was effective at 1000 ppm.

Sheath blight disease severity was uniformly high in susceptible IR 50, irrespective of crop growth phase wherein infection started. However, in a moderately resistant Remadja, the disease severity nearly doubled at maximum tillering phase compared to heading stage.

**Integrated disease management**

Resistant variety constitutes the focal or key component in the integrated disease management programme. This coupled with a need based application of fungicide such as carbendazim 50 WP (@ 1 g/l) was found to be effective in blast disease management at Lonavala (hill ecosystem) and Hazaribagh (rainfed upland). While at Lonavala, resistant cultivar Indrayani gave a grain yield of 2.9 t/ha, at Hazaribagh Aditya gave 2.0 t/ha.




**Epidemiology of diseases**

Data collected from a sequential sowing of trap nurseries on incidence of disease and weather recorded during the entire experimental period enabled the assessment of disease outbreaks at 17 locations. The observations that would lead to the establishment of disease forecasting system, are presented for three ecosystem specific locations.

In Andhra Pradesh at Maruteru (17° N 80° E 5M) two cultivars, TN 1 and Swarna were sown from July to October 1990 on nine dates. TN 1 showed a moderate incidence of bacterial blight during August on 16th July sown nursery. At this location, during August 200 mm rainfall and 15 rainy days were recorded. However, due to less number of rainy days (5) in September, a precipitation of 217 mm in October with 11 rainy days did not result in any increased severity of bacterial leaf blight disease.

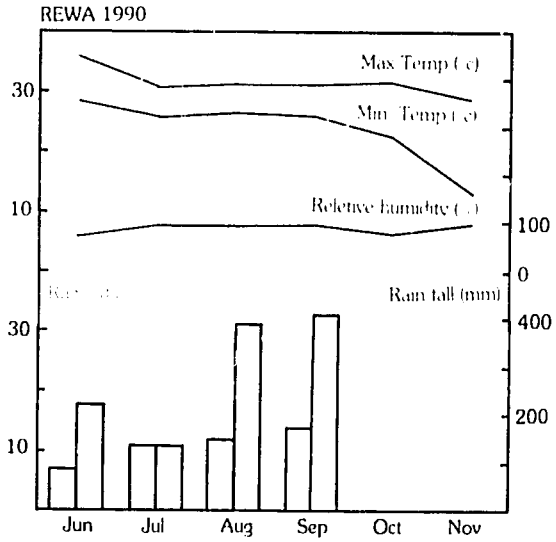
The range of temperature (25°C to 33° C) and humidity (72 to 81%) during July to September resulted in an increased sheath blight severity on Swarna.

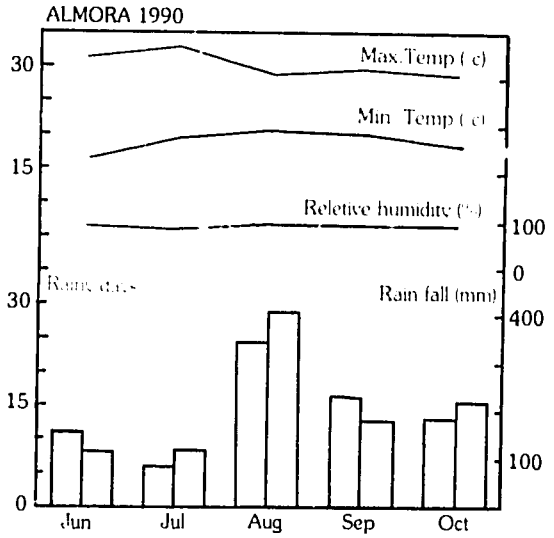
At Almora (29°N 76°E 1660 M) in Uttar Pradesh, six sowings were done from May to July 1990. The early sown nurseries escaped leaf blast but succumbed to neck blast at reproductive phase, when the temporal and spatial variation in precipitation (250 to 400 mm) and relative humidity (92%), enhanced the leaf wetness period which proved congenial for polycyclic infection. Such conditions were also responsible for the heavy incidence of leaf blast in late sown trap nurseries.

In the uplands of Madhya Pradesh at Rewa (26°N, 81° E 360M) five sowings were made with TN 1 from 17th July to 27th August 1990. Blast and brown spot diseases were observed on all dates of sowings and the severity increased with age. During the crop growth period from July to October, the relative humidity was static but above 90% and the temperature fluctuated from 25 to 31.5°C. These conditions were highly conducive for blast and brown spot diseases. Therefore, trap nurseries showed a score of 7.0 and 8.0 respectively, for blast and brown spot diseases after 60-70 days of sowing.

## Slow blasting cultivars

Slow blasting commercial cultivars form an additional component in blast management. Such cultivars are more useful because of




stable and long lasting resistance. An evaluation of twenty two accessions in blast endemic locations revealed several slow blasting cultivars or cultures: IET 10384, IET 9830 and IET 9979 in uplands (Hazaribagh), IET 9779, IET 10396 and IET 10886 in hills (Almora); and IET 9831, IET 10395 and 10396 in irigated areas (DRR).

## Herbicide evaluation

The weed control trials in transplanted rice, pretilachlor, oxadiazon and anilophos applied at 3 to 6 days after transplanting proved to be highly efficient. Under direct sown conditions in puddled soil the new herbicides pyrazosulfuron-ethyl and pretilachlor were most effective while oxadiazon, anilophos and butachlor also recorded promising results. Under rainfed upland conditions pendimethalin continued to be the best herbicide. As compared to hand weeding, 2,4-D Na was found to be the cheapest and most economical herbicide recording a high benefit-cost ratio followed by anilophos. Pyrazosulfuron-ethyl (NC 311), a low dose (at 10-20 g a.i./ha) and high efficiency herbicide newly introduced into the market, recorded wide spectrum weed control properties at DRR and at several other locations. Such herbicides may prove to be the most cost effective for farmers use.

# Assessing technology in farmers fields

The Operational Research Projects (ORP) functioning at this Directorate continued to verify, demonstrate and transfer the research results for adoption by farmers. On-farm Integrated Pest Management (IPM) demonstrations in Medchal area of Ranga Reddy district resulted in yields ranging from 3.90 to 4.90 t/ha under direct sowing in puddle which were on par with transplanted paddy and 4.60 to 5.00 t/ha under semi-irrigated conditions. Abhaya, Suraksha and Pusa Basmati 1 out-yielded the popular local checks by 16, 8 and 8% respectively. Implementation of IPM increased rice productivity by 37.5% and stabilised at 4.80 t/ha in Medchal area.

Introduction of water melon during rabi in rice fallows found acceptance. Raising water melon involved use of less inputs and efforts while ensuring high profits due to higher demand and easy access to markets in Ranga Reddy district.

Mr. V.S. Sampath, Commissioner and Director of Agriculture, Andhra Pradesh inspecting ORP training programme

Ms. Uma Venkata Rama Reddy, Honourable Member of Lesigislative Assembley visiting exhibition

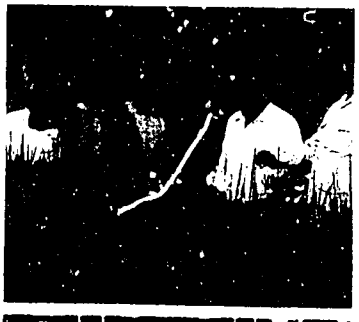
Field evaluation of different blends of sex-pheromones of rice leaf folder, *Cnaphalocrocis medinalis* obtained from Overseas Development Natural Resource Institute, U.K. revealed pheromonal activity with *Z*,13 octadecenyl acetate and *Z*,11-hexadecenyl acetate dispensed in rubber septa in 1000:100 µg.

The ORP on rice based cropping systems was implemented in irrigated Wyra mandal and in rainfed areas of Bhadrachalam and Kothagudem divisions in Khammam district, Andhra Pradesh. In lowlying saline-alkaline soils, IET 9757 (4.50 t/ha) and Nagarjuna (4.20 t/ha) performed better. In normal, black or red soils in rice-groundnut system or in tail end areas under rice blackgram/sunhemp system, IET 10335 proved superior.

In saline-alkaline soils, application of $ZnSO_4$ at 100 kg/ha prior to planting rice resulted in an additional grain yield of 1.10 t/ha with a benefit cost ratio of 6.67. Rootzone application of 100 kg N/ha with liquid applicator increased the yield by 0.63 t/ha over the farmers practice. Application of butachlor at 1.25 kg a.i./ha at 1-5 DAT effectively checked the weeds and reduced the labor costs thereby increasing the net profit. Integrated pest management involving resistant varieties like Nagarjuna and Suraksha coupled with need based application of insecticides gave an additional yield of 2.14 t/ha over farmers practice. Sunflower and *Sesamum* were introduced for the first time to diversify the rice based cropping system and to increase the cropping intensity and profitability.

**Frontline Demonstrations in Eastern India**

As part of the silver jubilee celebrations, Frontline Demonstrations in 125 compact blocks, of approximately 8 ha each, were organised during kharif in Assam, West Bengal,



Bihar, Orissa, East Uttar Pradesh, East Madhya Pradesh to show the superiority of high-yielding varieties and improved management technologies. These demonstrations included rainfed uplands, shallow water lowlands and semideep water ecosystems.

The major objectives of Frontline Demonstrations included: providing wider and better choice of varieties and management technologies; creating mass awareness of research results among extension functionaries and farmers; ensuring a rapid dissemination of available information to end users; and facilitating rapid multiplication of good quality seed for an organised spread of new high yielding varieties. The programme was funded by the Ministry of Agriculture and Cooperation, Government of India. During the year such Frontline Demonstrations covered successfully an area of 650 ha in different states in Eastern India.

**Promising varieties identified and used in frontline demonstrations under different rainfed ecosystems in Eastern India**

| State | Lowland | | Upland |
|---|---|---|---|
| | Shallow | Semideep | |
| Assam | Lakhmi<br>Salivahana | - | - |
| West Bengal | IR 42, Biraj<br>Manasarovar<br>Suresh | Sabita<br>Joger | - |
| Bihar | Jayashree<br>Rajashree | Sudha<br>Rajashree | Birsadhan 101<br>Birsadhan 201<br>BAU 4045-10<br>Kalinga III |
| East Uttar Pradesh | - | Chakia 59<br>Jalamagna | Saket 4<br>Narendra 80 |
| East Madhya Pradesh | Kranti, Ruchi | - | Aditya, Tulasi |

## Training for transfer of technology

In six short term (3 days to 3-weeks) training programmes, the knowledge gained as estimated from pre- and post-evaluation of the participants varied from 32 to 84%. There was a distinct difference between the extension personnel and the executives from agro-input agencies regarding training content preference. While the extension personnel preferred a coverage of only recommended technologies, the executives of the agro-input agencies showed a keen interest in the recent research findings, experimental data and recommended technologies.

**Training courses - 1990-91**

***Rice Production Technology:*** 3 weeks, 11 trainees from Bihar, Gujarat, Haryana, Karnataka, Madhya Pradesh and Uttar Pradesh

***Rice Production Technology for Irrigated ecosystems:*** 5 days, 21 trainees from Andhra Pradesh, Goa, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Punjab Tamil Nadu and Uttar Pradesh

***Rice Production Technology :*** 3 days, 14 trainees from Andhra Pradesh, Goa, Karnataka and Pondichery

***Rice Crop Management for Rainfed Uplands :*** 3 weeks, 21 trainees from Andhra Pradesh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Punjab and Uttar Pradesh

***Integrated Pest Management :*** 3 weeks, 16 trainees from Andhra Pradesh, Bihar, Haryana and Madhya Pradesh

***Rice Based Cropping Systems :*** 3 weeks, 19 trainees from Andhra Pradesh, Gujarat, Madhya Pradesh, Punjab and Uttar Pradesh

***Integrated Pest Management :*** 1 week, 15 trainees from Searle(I)Ltd., Cynamid(I) Ltd, Rhone-Poulenc, Excel Industries Ltd., HOECHST (I) Ltd and BPM Ltd.,

***Rice Production Technology :*** 1 week, 12 trainees from RCF, Pragati Hybrid Seeds (P) Ltd, PHI-BIOGENE Ltd and Ganga-Kaveri Seeds (P) Ltd.

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*Andhra Pradesh Agricultural University:*
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Jorhat, Karimgunj & Titabar.

*Banaras Hindu University (Uttar Pradesh):*
Varnasi

*Birsa Agricultural University (Bihar):*
Kanke & Pusa

*C.S. Azad University of Agriculture & Technology (Uttar Pradesh):*
Kanpur

*Calcutta University (West Bengal):*
Calcutta

*Director of Agriculture (West Bengal):*
Chinsurah & Bankura

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Imphal

*Director of Agriculture (Meghalaya):*
Upper Shillong.

*Director of Agriculture (Nagaland):*
Kohima

*Director of Agriculture (Tripura):*
Agarthala

*G.B. Pant University of Agriculture & Technology (Uttar Pradesh):*
Pantnagar.

*Gujarat Agricultural University*
Nawagam.

*Haryana Agricultural University*
Karnal & Kaul

*Himachal Pradesh Agricultural University*
Jogindernagar & Palampur

*Indira Gandhi Agricultural University(Madhya Pradesh):*
Raipur & Jagdalpur.

*Jammu & Kashmir Share-E-Kashmir University:*
Khudwani & Pónichak

*Jawaharlal Nehru Krishi Vishwa Vidyalaya (Madhya Pradesh):*
Rewa & Jabalpur.

*Kerala Agricultural University*
Pattambi, Mannuthy & Moncompu.

*Konkan Krishi Vidyapeeth (Maharashtra):*
Karjat.

*Marathwada Agricultural University (Maharashtra):*
Tuljapur

*N.D. University of Agriculture & Technology (Uttar Pradesh):*
Faizabad & Ghaghraghat.

*Orissa University of Agriculture & Technology:*
Sambalpur & Jeypore.

Punjab *Agricultural University*
Kapurthala.

*Punjabrao Krishi Vidyapeeth (Maharashtra):*
Sakoli

*Rajendra Agricultural University (Bihar):*
Patna, Bikramgunj & Sabour.

*Sukhadia University (Rajasthan):*
Kota.

*Tamil Nadu Agricultural University*
Coimbatore, Adutharai, Madurai & Pondicherry.

*University Agricultural University (Karnataka):*
Siriguppa, Mangalore, Ponnampet, Mandya & Mugad.

## PERSONNEL

Siddiq EA, M.Sc.(Ag), Ph.D., Project Director

## VARIETY IMPROVEMENT

Sastry MVS, Ph.D., Principal Rice Breeder & Head[1]
Rao JRK, M.Sc., Principal Rice Breeder & Head[2]
Ish Kumar, M.Sc.(Ag), Ph.D., Senior Rice Breeder
Sarma NP, M.Sc.(Ag), Ph.D., Senior Rice Breeder
Prasada Rao U, M.Sc., Ph.D., Senior Rice Breeder
Hakim KL, M.Sc.(Ag), Ph.D., Senior Rice Breeder
Shobha Rani N (Ms.), M.Sc., Senior Rice Breeder
Balachandran SM, M.Sc. Rice Breeder[3]
Shiv Kumar, M.Sc., Ph.D., Rice Breeder[4]
Prasad GSV, M.Sc., Ph.D., Technical Officer

## AGRONOMY, SOIL SCIENCE AND AGRICULTURAL ENGINEERING

Gopalakrishna Pillai K, M.Sc.(Ag), Ph.D., Principal Agronomist & Head
Rama Rao K, B.Tech.(Hons.), IMISAE, Principal Agricultural Engineer
Sharma SK, M.Sc.(Ag), Ph.D., Senior Agronomist & Head[5]
Subbaiah SV, M.Sc.(Ag), Ph.D., Senior Agronomist
Krishnamurthy P, M.Sc.(Ag), Senior Agronomist
Rao KV, M.Sc.(Ag), Senior Soil Scientist
Kundu DK, M.Sc.(Ag), Ph.D. Soil Scientist

## ENTOMOLOGY

Kalode MB, Assoc IARI, Ph.D., Principal Entomologist & Head[6]
Pasalu IC, M.Sc.(Ag), Ph.D., Senior Entomologist
Krishnaiah NV, M.Sc.(Ag), Ph.D., Senior Entomologist
Bentur JS, M.Sc. Ph.D., Senior Entomologist
Prasad JS, M.Sc. Ph.D., Senior Nematologist
Srinivas PR, M.Sc.(Ag.), Ph.D., Entomologist
Kondala Rao Y, B.Sc. M.A., Technical Officer
Dakshayani Bentur K (Ms.), M.Sc. Ph.D., Post Doctoral Fellow

## PLANT PATHOLOGY

Venkataraman S, M.Sc., Ph.D., Senior Plant Pathologist & Head
Muralidharan K, M.Sc., Ph.D., FPSI, Senior Plant Pathologist
Ghosh A, M.Sc. Ph.D., Senior Virologist
Satyanarayanna K, M.Sc.(Ag), Senior Plant Pathologist
Sadasiva Reddy C, M.Sc.(Ag), Ph.D., FPSI, Senior Plant Pathologist
Reddy APK, M.Sc.(Ag), Ph.D., Principal Plant Pathologist[7]

## PLANT PHYSIOLOGY

Kesava Reddy C, M.Sc.(Ag), Senior Plant Physiologist & Head
Padmaja Rao S(Ms.), M.Sc.(Ag), Ph.D., Senior Plant Physiologist

## STATISTICS

Rao AV, M.Sc., Dip.Ag.Stat., Principal Statistician & Head
Mahajan RK, M.Sc., Dip.Ag.Stat., Ph.D. Senior Statistician
Subba Rao C, M.Stat., PSCC., Dip.Ag.Stat., Ph.D. Senior Statistician
Rama Prasad, B.Sc., Technical Officer

## TRANSFER OF TECHNOLOGY

Krishnaiah K, M.Sc.(Ag), Ph.D., Principal Entomologist & Head
Singh SP, M.Sc.(Ag), Ph.D. Senior Agronomist
Mangal Sain, M.Sc., Ph.D., Senior Plant Protection Specialist
Sandhya Shenoy N, M.Sc.(Ag), Ph.D. Extension Scientist
Reddy BSN, M.Sc.(Ag), Extension Scientist
Doijad PS, M.Sc.(Ag), Communication Specialist
Gawali SR, Dip.Arts., Technical Officer (Photography)
Mahabir Singh, M.Sc.,(Ag) Senior Training Specialist[8]

***Operational Research Project, Ranga Reddy***

Chakrapani Reddy P, M.Sc.(Ag), Ph.D., Senior Plant Pathologist

***Operational Research Project, Khammam***

Narayana Reddy M, M.Sc.(Ag), Ph.D., Senior Soil Scientist
Ashok Reddy A, M.Sc.(Ag), Entomologist

## ADMINISTRATION

Mohan Rao M, B.Com, Administrative Officer
Ghosh RK, B.Com, Superintendent (C&B)
Satyananda Rao K, Superintendent (Estt)
Janakirama Sarma P, B.Com, Superintendent (A&A)
Sharma GC, B.Sc.(Ag), Farm Superintendent

***Workshop***

Sarma ISRP, M.Tech., Technical Officer
Jagannath M, B.E.(Mech.), Technical Officer

***Library***

Venkataramana, M.Com., M.L.I.Sc., PGDCA, Technical Officer[9]

1 Retired December 30, 1990
2 From January 1, 1991
3 Joined on July 6, 1990
4 Joined on October 1, 1990
5 Left on June 30, 1990
6 On deputation till June 8, 1990
7 On deputation to Egypt
8 On study leave
9 Joined on September 6, 1990