RESEARCH HIGHLIGHTS 1991-92

ICAR

DIRECTORATE OF RICE RESEARCH

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Towards Stabilizing Rice Production

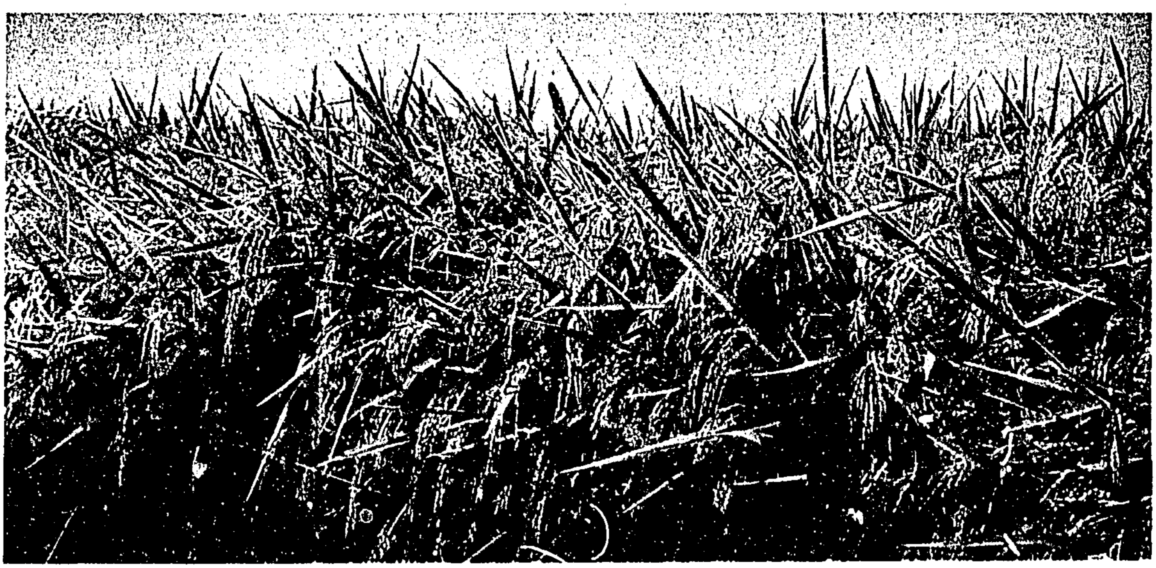
Rice area, production and productivity in India remained fairly stable during the last three consecutive years. The climatic conditions, in general, during 1991-92 were favourable for rice in the country. Although a target of 76.5 mt was set for rice production, the actual production was 73.7 mt. In other words, 96.3% of the targeted production was achieved. The marginal shortfall in production could be attributed to late arrival of monsoon in Haryana, Himachal Pradesh, Jammu and Kashmir and western Uttar Pradesh; and floods caused by heavy rains under the influence of cyclonic weather during north-east monsoon period in the coastal areas of Tamil Nadu, north coastal districts of Andhra Pradesh, parts of Kerala and Pondichery. In addition, biotic stresses like neck blast in late transplanted Basmati crop in Haryana, bacterial leaf blight in Haryana, Punjab and Pondichery, rice tungro virus in Andhra Pradesh and Tamil Nadu, sheath blight in Andhra Pradesh, gall midge in Andhra Pradesh and Kerala, whitebacked planthopper in Gujarat, and leaf folder in Haryana also affected production.

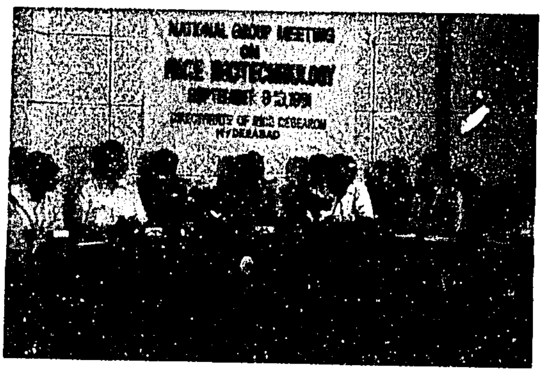
Policy issues for increased production

The Directorate organized a workshop during September 1991 to explore available avenues to eliminate such marginal shortfalls and achieve a sustained stability in production. Eminent scientists, administrators and extension personnel actively participated to prescribe suitable policies to further increase and stabilize the production .

The workshop recommended the following :

Directing breeding efforts towards introducing elements of climate defense mechanisms as also to provide higher levels of resistance to biotic and abiotic stresses; exploitation of hybrid technology; emphasis on input management with special reference to soil health; use of all available organic manurial resources and/or green manuring which proved to be cost effective; efforts to enhance water use efficiency through conjunctive use of surface and ground water potentials; pursue research and extension components of integrated pest management





to improve environmental quality and ecological safety with cost effectiveness; and to selectively mechanise rice farming systems to enhance cropping intensity and reduce the farm drudgery in high productive areas.

To accelerate rice production in eastern India the workshop called for organized seed production, storage and distribution; doubling of the present boro rice area; judicious exploitation of the ground water potential, shifting of area prone to frequent floods to late sali/aman planting; and development of varieties ideally suited to boro and late kharif planting.

The participants concluded that implementation of these policies would further increase rice production and stabilize to meet the growing demand for food.

Frontline demonstrations in Eastern India

Frontline demonstrations initiated in 1990 as part of Silver Jubilee celebrations were continued for the second successive year. In six eastern states, during kharif compact block demonstrations of approximately 8 ha each were organized; 19 in rainfed uplands, 42 in rainfed shallow lowlands and 20 in deep water areas. A wider choice of varieties for various ecosystems was successfully demonstrated. Further, the increased availability of pure seed as a result of compact block demonstrations at various villages in the eastern India offerred a scope for an extensive spread of these high-yielding varieties. The success stories would ensure a rapid spread of the recommended package of practices.

From top :
National Workshop on Policy Issues for Increasing Rice Production; Group Discussion on Management of Change in All India Coordinated Crop Improvement Projects, ICAR; National Group Meeting on Rice Biotechnology; Dr. V.L. Chopra, Director General, ICAR, laying foundation for 'Jaya' Hostel

Varietal Improvement

Breeding for rainfed uplands

Nearly 6 m ha of rice is under rainfed uplands in India. The rainfed upland areas can be broadly grouped into two catogories:

1) Favourable uplands - areas with high rainfall but without assured irrigation. Most of the areas in southern states, Assam and north eastern states where rice is either transplanted or direct-seeded and the productivity is dependent on the extent of rainfall come under this category.

2) Unfavourable uplands - areas with limited as well as erratic rainfall thus experiencing moisture stress at either vegetative or reproductive phase of the crop growth.

Rainfed uplands require high-yielding early duration varieties with tolerance to drought, acid soils, blast, brown spot and gundhi bug. Several cultures possessing characteristics of adaptation to drought such as deep root system and early seedling vigour have been identified for direct-seeded and transplanted conditions.

Breeding for rainfed lowlands

Over 17 m ha area under rainfed lowlands is broadly classified into three groups: shallow lowlands - water logged and water depth ranging from 30 to 50 cm; semideep water areas - water depth from 50 to 100 cm where the level recedes gradually at the time of maturity; and deep water areas - water depth above 100 cm where water does not recede completely till November. Unlike in upland conditions, where several crop species can easily replace rice, in deep water and tidal wetland ecosystems, rice is often the only choice. Varieties should possess drought tolerance during early stages,

[illegible]

***IET* [illegible]** (Pusa 51[illegible]) from [illegible]/Pusa 1[illegible], 112 days duration, long slender grains, tolerant to leaf folder

IET 10370 (Pusa 598-187) from IR 50/Pusa 39, 108 days duration, long slender grains, tolerant to leaf folder

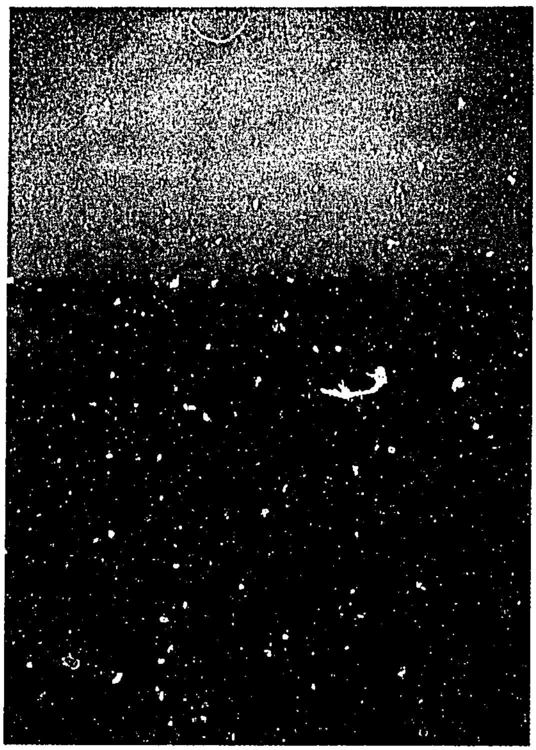
IET 12138 (OR 752-38-1) from IRAT 138/IR 13543-66, 110 days duration, long bold grains

Transplanted

IET 12029 (RP 2533-7488-18) from M 63-83/Sarya// IRAT 8/M 63-83, 92 days duration, long bold grains

IET 11674 (Pusa 834-106) from IR 50/P 33-BP, 122 days duration, long slender grains

IET 12081 (TM 4309) from BAM 3/IR 50, 116 days duration, long slender grains



[illegible]

[illegible] from RP [illegible]/TN 1, 120 days duration, short bold grains, resistant to blast

[illegible] from RP 31-49-2/Patnai 21, 150 days duration, long slender grains, resistant to blast, tolerant to brown spot and becterial leaf blight

Seema from Jagannath (natural), 150 days duration, long slender grains, resistant to blast

Promising elite cultures

Shallow lowlands (30 to 50 cm water depth)

IET 11524 (KAU 1001) from IR 20/IR 25, 135 days duration,, long slender grains, moderately resistant to blast

IET 11531 (CR 260-292-108-58-36) from CR 151/CR 1014, 142 days duration, long slender grains

IET 11371 (CR 682-166) from Pankaj/T 141, 140 days duration, medium slender grains, tolerant to sheath blight and sheath rot, resistant to rice tungro virus and bacterial leaf blight

IET 12236 (CR 210-1006) from Pankaj/Jagannath, 156 days duration, short bold grains

IET 11572 (WR 35-12-2-5) from Kranti/Sasyasree, 147 days duration, short bold grains

IET 12199 (RP 2544-86-53-362) from Swarnadhan/RP 1579-43, 140 days duration, long slender grains

Semideep water areas (50 to 100 cm water depth)

IET 11183 (RAU 73-16-1-40) from Pankaj/IR 8, 148 days duration, long slender grains

IET 11196 (C 340-22-5) from Pankaj/ SR 26 B, 155 days duration, long bold grains, resistant to leaf blast

IET 11187 (CR 1022-27) from Madhukar/Jagannath, 148 days duration, long slender grains, moderately resistant to sheath blight

IET 11198 (C 340-22-17) from Pankaj/ SR 26 B, 160 days duration, long bold grains

Deep water areas (more than 100 cm water depth)

IET 11870 (TC 20 A), selection from tall composite, 173 days duration, long bold grains

IET 11869 (Ansphal), pure line selection, 185 days duration, long bold grains

IET 10556 (PLA 4196) from Mahsuri/Gautami, 181 days duration, long bold grains

submergence tolerance and elongation ability during later stages, tolerance to problem soils, adaptation to low light and photosensitivity. After critical evaluation of test entries for seedling survival ability, elongation and kneeing ability, elite cultures with adaptability to these ecosystems and high yield potential have been identified.

Low light and water logging are the major constraints to yield in lowlands. In rainfed lowlands under the lowlight stress, IET 12062 (Pankaj/Swarnadhan) recorded the highest grain yield and biomass production. Under water logged conditions IET 11271 (Pankaj/Patnai 23) recorded high biomass and grain yields. Tiller mortality, one of the expressions of the lowland stress, was minimum in IET 11271, IET 11183 and IET 11189.

Breeding varieties for irrigated areas

In India, around 45% of the rice area is grown under irrigated conditions. Even though the irrigated rice contributes nearly 60% of the total production, sizeable yield reservoir still remains untapped. Promising cultures with 100-135 days maturity duration have been identified.

Ajaya : A hgh-yielding medium duration variety with resistance to bacterial leaf blight

Breeding varieties for high altitude areas

In the north western hill region of India covering Kashmir, Himachal Pradesh and Uttar Pradesh, rice is cultivated in about 500,000 ha. Of this, 350,000 ha is under irrigated transplanted condition while the remaining is under direct-seeded rainfed upland conditions. Rice is grown only under irrigated and transplanted condition in Jammu and Kashmir, while in 50 % of the area in Himachal Pradesh and 75 % of the area in Uttar Pradesh hills, rice is grown under direct-seeded rainfed conditions.

[illegible]

[illegible] duration, long slender grains

IET [illegible] mutant from [illegible] days duration, long bold grains

IET [illegible] (R 321-49) from Samridhi/IR 36, 127 days duration, long slender grains

Medium duration

IET 12174 (HKR 86-7) from PR 108/OBS 528, 131 days duration, long bold grains, resistant to blast, moderately resistant to sheath rot and bacterial leaf blight

IET 12175 (HKR 86-104) from HKR 101/IR 36, 130 days duration, long bold grains, moderately resistant to bacterial leaf blight, tolerant to leaf folder

IET 12253 (TNAU 88115), anther culture line from CO 37/CO 40, 131 days duration, short bold grains

IET 10456 (NDR 330) from Jaya/TN 1, 135 days duration, long slender grains

IET 12168 (CR 331-6-1) from Jagannath/Mahsuri, 132 days duration, medium slender grains, moderately resistant to bacterial leaf blight and rice tungro virus

IET 12170 (R320-101) from Asha/Kranti, 129 days duration, long bold grains, resistant to gall midge (biotype 1 and 2), tolerant to stem borer

[illegible]

[illegible] from IR [illegible] duration, medium slender grains, resistant to blast

Promising cultures for hilly areas

Irrigated and transplanted

IET 10645 (HPU 845) from IR 5868-112-1-2/IR 5867-45-22, 120 days duration, long slender grains

IET 11223 (VL 29) from IR 16924-265-3-HW 11, 124 days duration, long bold grains

IET 11968 (K 343-33-4) from K 21-9-10-1/IR 8, 110 days duration, long slender grains

IET 11983 (VL 42) from IR 15429-268-1-2-1, 119 days duration, long bold grains

Upland hills

IET 12592 (HPU 862) from IR 39385-124-3-3-2-3/DR 92, 112 days duration, medium slender grains

IET 12004 (VR 395) from VL 191/Culture 2058, 105 days duration, long bold grains

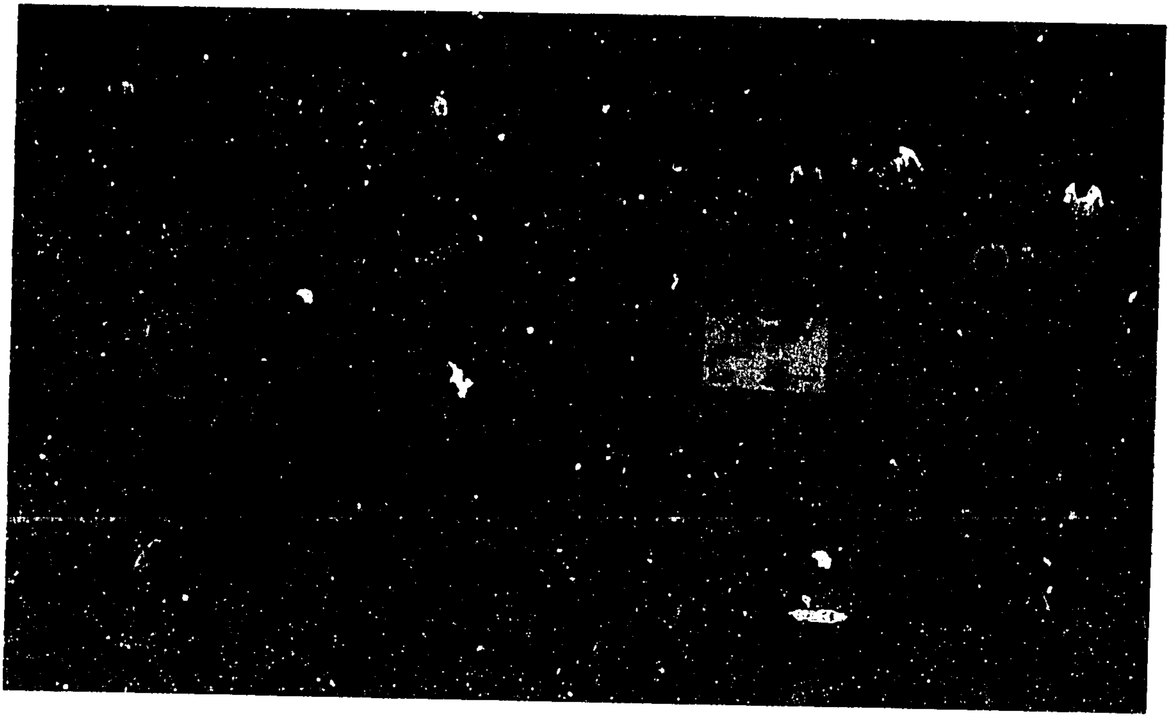
IET 12589 (VR 381) from VHC 1253/Tetep, 110 days duration, long bold grains

HPR 869 from IR 41985-111-3-2-2/IR 9758 - K2, 111 days duration, medium slender grains

Breeding for basmati quality rices

In view of the increasing demand for export quality rices, research efforts have been intensified. In coordinated trials, IET 12021 and IET 12609 recorded yields on par with Pusa Basmati 1 with grain quality comparable to Karnal Local (Table 1). Among the elite cultures identified, DRR lines such as RP 3238 (Pusa Basmati 1/IET 8585), RP 3121 (RP 2695/Pusa Basmati 1) and RP 3138 (Pusa Basmati 1/Phalguna) have an edge in yield over Pusa Basmati 1 and quality features comparable to Basmati 370. Lines like PAU 739 from Kapurthala and HKR 86 from Kaul possessing bacterial leaf blight and blast resistance were equally promising.

Screening of scented rice germplasm led to the identification of valuable donors possessing resistance to pests/diseases of target environment in the basmati background. Among them, Karnal Local, Basmati 1,



Characterisation and evaluation of germplasm accessions

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Kernel length (mm)	7.6	7.9	7.3	7.7	6.9
L/B ratio	4.16	4.51	4.13	4.42	3.74
Alkali value	5.0	3.6	7.0	3.3	6.2
Volume expansion	3.8	4.0	3.7	3.7	3.5
Cooked kernel length (mm)	14.7	13.9	15.2	12.8	13.8
Elongation ratio	1.9	1.8	2.1	1.7	2.0
Amylose(%)	22.6	16.3	22.2	17.4	21.9
Aroma	Strong	Strong	Strong	Strong	Strong

Basmati 372, Basmati Sufaid 100 and Basmati 6131 for bacterial leaf blight; Ambemohar 159, Karjat 13-21 and Kasturi for leaf blast; Dulhamiya, Dehradun Basmati, Basmati kota, Bindli, Karnal Local and Basmati 123 for white-backed planthopper are important.

Best Indian entries in International Trials (INGER)

Rainfed upland - CR 222-MW 10 (Annada) in Thailand, Vietnam and Bangladesh; Rasi (IET 1444) in Bangladesh and the Philippines.

Shallow water - IET 7191 (RP 1057-184-5-3-2) in Burma and Thailand, IET 5742 (RP 967-4-7-3-7) in Thailand and IET 7598 (RP 1486-833-1) in Nepal.

Irrigated - HPU 5410 in Burma and Bangladesh, CR 156-5021-202 and R 22-2-10-1 in Paraguay, RP 2151-23-2 (possessing bacterial leaf blight resistance) in China and Bangladesh.

8

Genetics of gall midge resistance in rice

Inheritance of gall midge resistance was studied in 25 crosses of resistant donors with hypersensitivity positive type (Bhumansan, NHTA 8, Banglei, T 1432) as well as hypersensitivity negative (Eswarakora, W 1263) with susceptible T(N) 1. The F_1, F_2 and F_3 populations of appropriate crosses along with respective parents were screened under green house and field conditions against gall midge biotypes 1, 2 and 4.

The results revealed that irrespective of the type of resistance, hypersensitive positive (HR+) or hypersensitive negative (HR-) a single dominant gene governs resistance in all the donors against any given biotype. Reciprocal combinations in selected crosses showed no maternal influence on expression of resistance in respect of all the three biotypes. The genes governing HR+ and HR- types of resistance appear to be independent of each other

Allelic relationships of resistance genes studied in respect of various biotypes revealed the genes conferring resistance to biotype1 in Eswarakora, W 1263 and NHTA 8 (HR- types) to be allelic to each other but non-allelic to and independent of the gene that confers resistance in the varieties Bhumansan, Banglei and T 1432 (HR+ types), which are allelic to each other. In respect of the biotype 2, the gene conferring resistance in NHTA 8 (HR- type), Banglei and T 1432 (HR+ type) is allelic but non-allelic to that of Bhumansan (HR+ type). The resistance gene against biotype 4 found in Banglei, T 1432 and T 1477 (HR+ types) is same (allelic) but independent to that of NHTA 8 (HR- type).

Based on the mode of inheritance and allelic relationships, genetic constitution of the donor sources against the different biotypes of gall midge has been designated as follows:

Donor	Genotype	Resistance to biotype
Eswarakora and W 1263	*Gm1 gm3 gm4 gm5 gm6 gm7*	1
Bhumansan	*gm1 Gm3 Gm4 gm5 gm6 gm7*	1 & 2
NHTA 8	*Gm1 gm3 gm4 Gm5 Gm6 gm7*	1, 2 & 4
Banglei and T 1432	*gm1 Gm3 gm4 Gm5 gm6 Gm7*	1, 2 & 4
T 1477	? ? *gm6 Gm7*	1, 2 & 4

Study of mode of inheritance of HR types of resistance and their allelic relationships in selected crosses against biotype 4 revealed hypersensitivity (HR+) and non-hypersensitivity (HR-) types of resistance also to be governed by single dominant genes each but are non-allelic to each other.

Hypersensitivity (HR+) appears to be epistatic over non-hypersensitivity when they remain together. There could be more than one gene conferring HR+ type of resistance tightly linked like a complex locus as evident from occasional HR- recombinants in HR+ or HR+ crosses.

Breeder seed production

Sixty four tonnes of breeder seeds of 65 released varieties were produced as against the targeted 53 tonnes.

In addition, 50 tonnes of seeds of popular state released varieties were produced by the concerned state breeders or state seed agencies.

Evaluation of hybrids

Under the Hybrid Rice Research Network, 126 hybrids were evolved and evaluated at 11 locations. Eleven hybrids recorded an yield advantage of more than one tonne per hectare. Four of them were found to be widely adapted (Table 2).

[illegible]	[illegible] (days)	[illegible] yield (t/ha)	[illegible] (%)
IR 62829A/ Swarna	132	5.31	28
PCMS 2A/ IR 31802	127	5.19	26
ORI 161	128	5.17	25
PCMS 1A/ IR 31802	127	5.17	25
IR 36 (Check)	122	4.14	-

Monitoring hybrid rice trails by chief consultant, Dr. S.S. Virmani and other FAO experts

FAO consultants - Dr L.P. Yuan, Father of Hybrid Rice, discussing with Dr X.L. Deng (Right)

Production packages were optimized to obtain up to 2.0 t/ha of hybrid seed and 1.5 t/ha of CMS seed. For both, a row ratio of 2B : 8A gave the highest seed yields. Depending on the parental combinations, location and season, the seed yied varied.

Resistance to pests and diseases in hybrids

The experimental hybrids and a set of restorers were screened against leaf blast, brown planthopper and gall midge. Amcng the restorers, Narendra 80, Pratap, T 1154, IET 10370, IET 9206 and IR 21015-12 were found resistant to brown planthopper and gall midge.

Of the hybrids, IR 58025A/IR 21567-18-3R and IR 58025A/IR 54R were resistant to leaf blast and brown planthopper (Table 3).

[illegible]

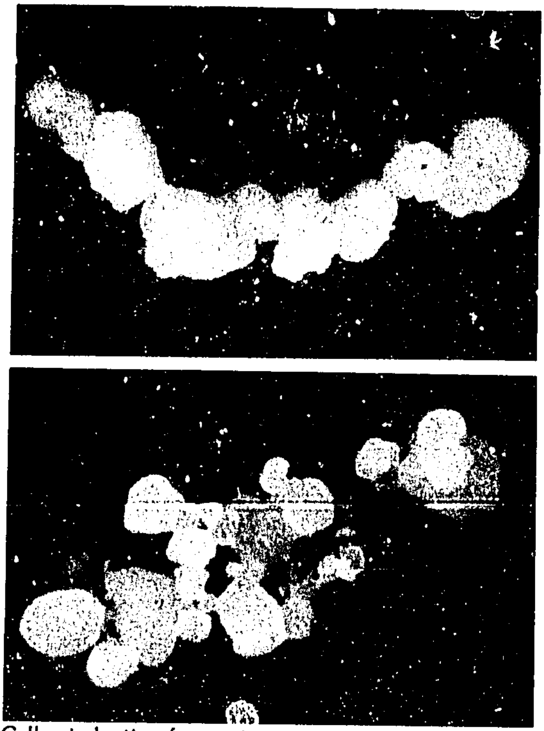
[illegible]					
IR 34	[illegible]	[illegible]			
C 71 IR-?	[illegible]	[illegible]			
Nanhigore	T 1154	[illegible]	[illegible]	[illegible]	
Suweon 332 R	IET [illegible]	IET [illegible]	[illegible]	[illegible]	
ARC 11353	IET [illegible]	IET [illegible]	[illegible]	[illegible]	[illegible]
Nanjing 00-2-143	IR 27315 R	IET [illegible]	[illegible]	[illegible]	[illegible]
IR 78723			IR [illegible]	[illegible]	[illegible]
-143-3-2-1R	IR 21916-12-8	IET 9206	[illegible]	Nanhigore	[illegible]
IR 46 R	IR 35366-62-1-2-2-3R	IET [illegible]	IR [illegible]	[illegible]	
	Suweon 332 R	[illegible]	[illegible]		
	Mulyeng 46	IR 50	3-3 R		
	Nanhigore	Kulipid [illegible]	IR 58025A/IR	CR 151	
	HKR 120	IR 21015-12	54 R #		
	White ponni	IR 29692-65	PMS 8A/PAU	CR 145	
	BG 367-4	IR 31858-90	1106-6-2		
			V 20 A/IR 30864		

* Resistant to brown planthopper and gall midge # Resistant to leaf blast and brown planthopper

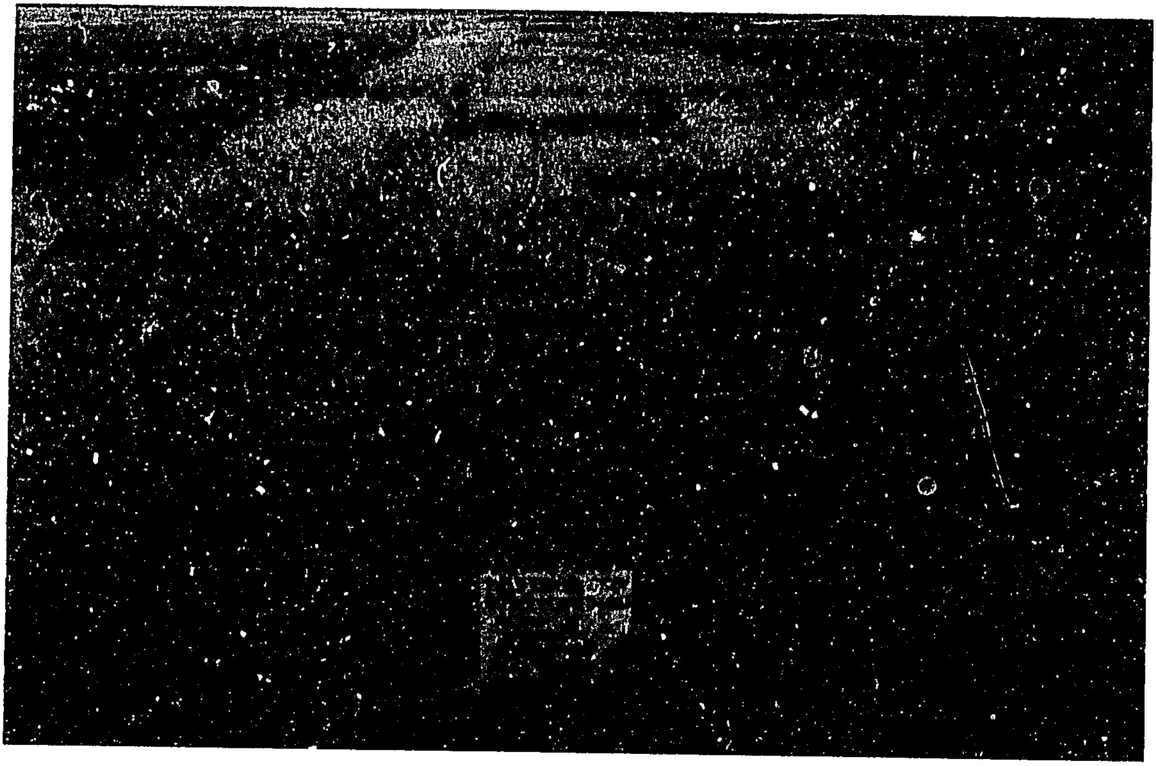
Cell and tissue culture

With the objective of obtaining dihaploids with near maximal vigour manifested in F_1 hybrid, anther cultures were initiated from three intervarietal crosses - RP 2905 (Ptb 21/Leuang 152), RP 2866 (Banglei/ Eswarakora) and RP 2870 (Banglei/IET 7923) and 11 heterotic hybrids from National Hybrid Rice Trial along with three *indica* - IR 54, IR 64 and IR 72 and one *japonica* - Taipei 309. The callus induction frequency on N6 medium was high (17.2%) in Taipei 309 but low (1%) in IR 64.

More than 100 double haploids from anther culture of two heterotic hybrids IR 58025 A/IR BB 7 and IR 58025 A/IR 24 were evaluated for yield performance along with the F_1 hybrids and standard varieties. In some of the double haploids, it was possible to realize 85-93% of the potential yield possible in the F_1 hybrids.

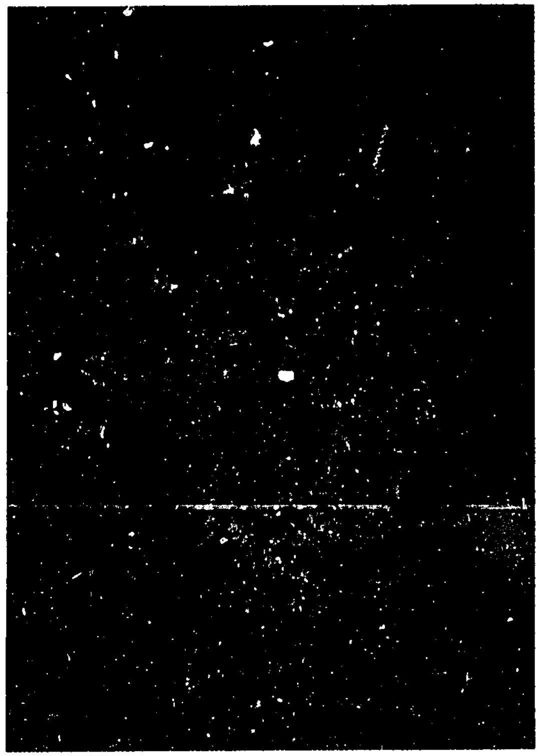


Callus induction from microspores



Anther derived plants

Suspension culture



Proliferaton of suspension culture

Suspension culture for protoplast isolation

Suspension cultures were initiated from embryogenic calli induced in the variety, Khonorullu. Continuous suspesion cultures were established at the end of 14 passages (near about 100 days). These suspension cultures showed growth, increase packed cell volume for every 3 to 4 days and also exhibited a high degree of regeneration capacity. Efforts are underway to use the suspension cultures for isolation of protoplasts and to study the *in vitro* response to salt stress.

Isozyme and RFLP analysis in rice breeding

Molecular marker techniques have enabled to precisely monitor the gene introgression in breeding lines and aid in efficient selection of the target traits linked to the makers. With the assistance of International Centre for Genetic Engineering and Biotechnology, New Delhi, it has been possible to map the rice gene (Gm2) conferring resistance to biotype 1 of gall midge. The mapping population of 47 recombinant inbreed lines were derivatives of cross between high yielding gall midge resistant cultivar, Phalguna and the susceptible land race ARC 6650. The resistance phenotype segregated closely with Phalguna allele of probe RG 214 from chromosome 4. High degree of polymorphism between Phalguna and other *indica* varieties at locus RG 214 indicates the possibility of using this molecular marker to follow the introgression of gall midge resistance gene in recombination breeding.

Wide hybridization for diversification of cytoplasmic male sterility

For detecting cytoplasmic diversity, 65 accessions of wild rices belonging to five 'A' genome species *(O. rufipogon, O.nivara, O. glaberrima, O. longistaminata* and *O. barthii)* were test crossed with known restorers (IR 54 and IR 64) and maintainers (V 20 B, IR 58025B, PMS 2B, IR 66 and IR 70 of WA cytoplasm). Of the 133 hybrids evaluated, a few combinations showed 100% pollen sterility in the F_1 and sustained the sterility in first and second back cross generations indicating the possibility of cytoplasmic diversity. These combinations included: *O. rufipogon* (Acc. 1-1) with PMS 6 B and V 20 B, *O.nivara* (Acc. 2-1)/IR 66 and *O. nivara* (Acc. 2-2)/IR 66.

Two elite cytosterile stocks Pushpa A and Mangala A with MSS 577 cytoplasm and IR 64 A (*O. perennis* Acc. 104823 cytoplasm) for which no restorers have been identified yet were test crossed with 70 accessions of *O. rufipogon* and *O. nivara.* Fertility restoration up to 70% was observed in four F_1 hybrid combinations.

Wide hybridization to diversify cytoplasmic male sterility

Crop Production and Resource Management

Crop yields and food supplies to consumers are directly linked to energy use. Sufficient energy either human, animal or fossil is needed to increase crop production. Experiences show that in fossil-energy driven systems, the high energy use explains the relatively high productivity. Such energy intensive systems exhaust rapidly resource reserves and affect viability of the soil. In an integrated system where organic sources are used, the need for fossil energy is curtailed. It is, therefore, important to identify judicious combinations of organic manures and inorganic fertilizers to stabilize production and sustain vital resource base over a period of time.

With the escalation of fertilizer cost, a need has arisen to partially substitute urea with organic sources. Three years of agronomic investigations revealed that 50% of urea used in crop production can be substituted with green manures like *S. cannabina* with no loss of either grain yield or fertilizer use efficiency (Table 4).

[illegible]

Treatment	Grain yield (t/ha)		[illegible]	
	Kharif	Rabi	Kharif	Rabi
Urea in 2 splits (100 kg N/ha)	4.77	6.17	10.4	22.3
Green manure* (*S. cannabina*) +urea topdress*	4.95	5.93	19.2	18.9
C.D. (0.05)	0.52	0.79	-	-

* 50 kg N/ha

Integrated approaches to plant nutrition

In integrated plant nutrition system the soil fertility is adjusted to sustain the desired level of crop productivity. There has been growing concern about the intensive use of nitrogen in crop production programmes. In irrigated areas, farmers now use nitrogen above the economic optimum. Nitrogen alone does not contribute to increased soil fertility. Long-term trials on monitoring soil fertility and crop productivity in rice-rice sequence showed sustained responses to P, K, and Zn when applied with a moderate level of N. There is a decline in soil organic matter in many north western parts of the country under the rice-wheat system. An additional application of organic matter alleviated the problem. In rice-wheat system at Pantnagar, recent observations indicate phosphorus to be the limiting nutrient. Olsen's P level was reduced from 9 ppm recorded in 1984 to 6 ppm after five seasons. Supplementary application of farmyard manure proved useful in maintaining higher productivity.

Yield maximization in relation to soil fertility

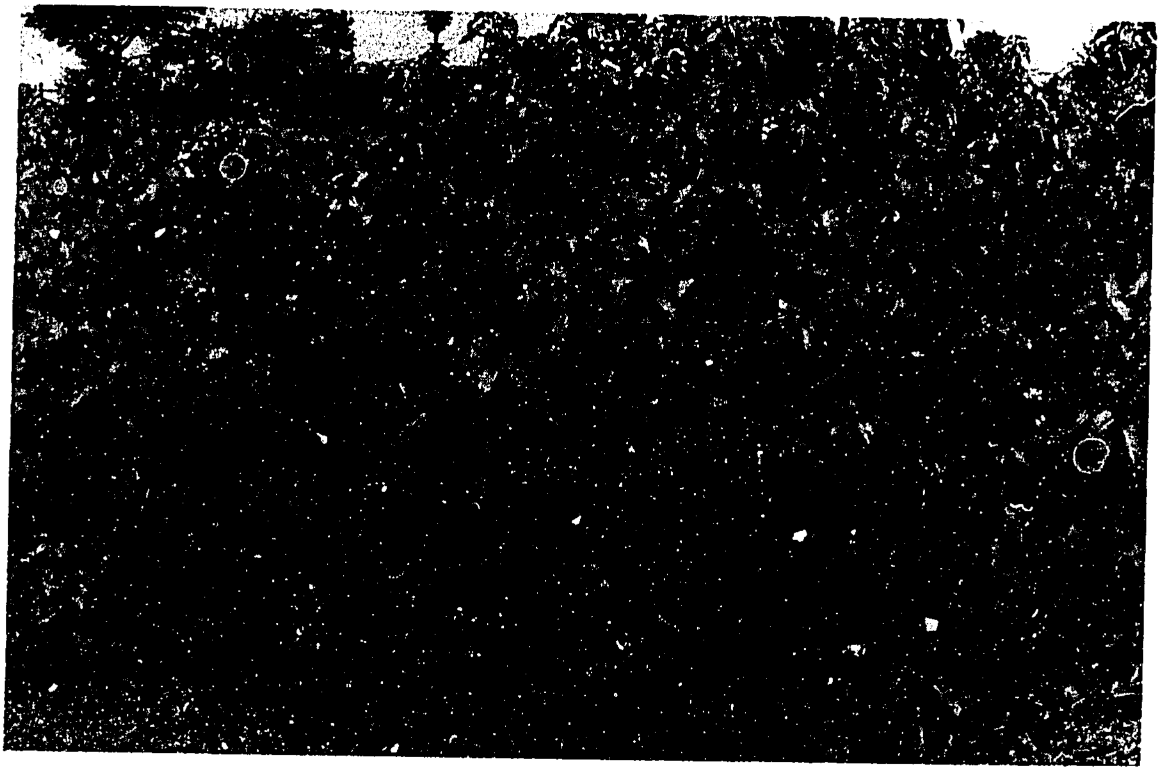
The supplementary use of organic manures (10-12 t/ha) with low to high levels of nitrogen (180 kg N/ha) under varying population density (33 to 66 hills/m^2) was evaluated to maximize irrigated rice yields. Increasing plant population from 33 to 50 hills/m^2 yielded significantly higher harvest in vertisols. In rabi, higher population density and supplementary use of organic manures resulted in higher grain yields; but in kharif maximum response was recorded at 33 hills/m^2. Application of compost (at the rate of 10-12 t/ha) on the overall response to N application was positive .

Water management and agronomic efficiency of green manure and urea-N

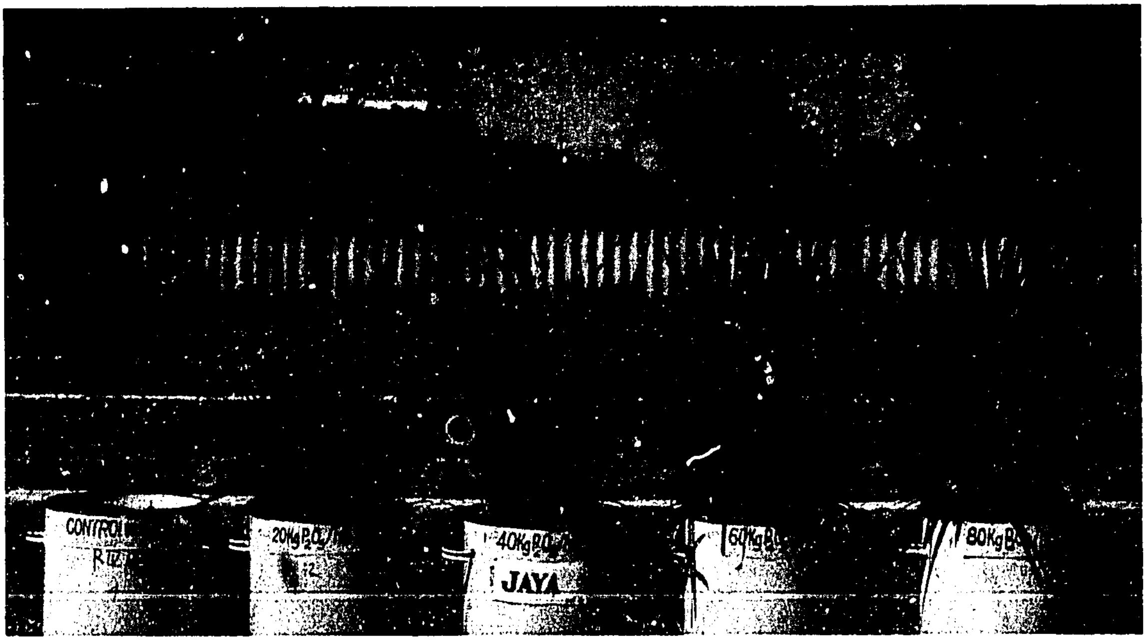
Productivity depends on the duration and time of occurrence of water deficit. The low efficiency of water and nitrogen in wetland rice is attributed to an extensive loss of water mainly due to deep percolation, and nitrogen from the soil-plant system. A decrease in grain yield was recorded when irrigation was withdrawn two weeks after planting rice for a period of 15 days compared to continuous shallow submergence. But with a similar deficit irrigation imposed around panicle initiation stage, such a reduction was only marginal. The yield loss due to early season water stress may be attributed to the loss of nitrogen applied before transplanting. But when green manure *(Glyricidia maculata)* was incorporated (@ 20 t/ha equivalent to 100 kg N/ha) a day before planting, the adverse effect of deficit irrigation in the early tillering stage was more acute. Correspondingly, the agronomic efficiency of green manure-N reduced from 31.5 to 21.3 kg grain/kg N applied. The low efficiency of incorporated green manure-N is due to greater loss of mineralized organic-N through nitrification and denitrification. The peak values of mineralized N observed between 2-4 weeks after soil incorporation coincided with drying cycle. The yield loss due to early season water stress may be compensated partly by applying urea in split doses.

Nutrient management in direct-seeded rice

In direct-seeded wetlands, plants take almost three weeks for stand establishment and the nutrient (particularly N) requirement is relatively low. The acidity and heat generated from the decomposing green manures might affect emerging seedlings from sprouted seeds. But green manuring



Ipomaea carnea as green manure increases rice yelds



Effect of phosphorous application on rice in vertisols

with fresh *Glyricidia* (10 t/ha) two days prior to sowing sprouted seeds significantly increased grain yields from 3.5 to 4.7 t/ha which further improved to 5.6 t/ha with an additional dose of urea-N . Corresponding increase in N uptake and recovery of applied N was also recorded in the crop.

Incorporation of the recommended dose of N (100 kg/ha) through green manure, *Ipomaea carnea,* two days before sowing; or applying 50% N as green manure and the rest topdressed as urea at panicle initiation stage were equally efficient in increasing the grain yield of direct - seeded wetland rice. Application of nimin coated urea in one single dose at sowing or prilled urea in two splits to direct-seeded rice proved inefficient.

Soil fertility evaluation in rice-based cropping systems

The trends in the grain yield responses over five cropping seasons to nitrogen was significant in the long-term trials under rice-rice, rice-wheat or rice-groundnut cropping sequence. Phosphorus application was effective only in rabi at Mandya and Maruteru. The response to potassium was significant in the sandy loams at Mandya and Faizabad, and in the high rainfall zone of Titabar, while at Maruteru it was significant in the first two seasons only. Skipping zinc and sulfur application gradually increased the grain yield response to significant levels at Titabar (clay loams, pH 5.3) after four seasons; such a response to sulfur was of a higher order at Mandya (sandy loam, pH 6.2). At Maruteru the response to sulfur was not significant after the first two seasons probably due to increased availability of organic-S, as indicated by the increase in SO_4-S status in these alluvial clay soils (pH 7.2).

Effect of sources and methods of phosphorus application

In vertisol, water soluble P sources such as single super phosphate and partially acidulated Mussorie phosphate rock @ 80 kg P_2O_5 / ha were highly effective in increasing the plant growth height, tiller number, dry matter production, straw yield and grain yields (4.45 to 5.54 t/ha) compared to control (0.73 to 0.98 t/ha). The P content in shoots increased to 0.35% with single super phosphate and to 0.16% with partially acidulated Mussorie phosphate rock during inititial tillering to flowering stage. Correspondingly, an increase in P uptake was also recorded; 2.1 kg/ha and 16.6 kg/ha. At maturity, the mean total P uptake by grain and straw also followed a similar trend recording respectively 20.8 to 23.0 kg/ha. Among different methods of application of water soluble P, single super phosphate mixed with cowdung and applied as granules on soil surface was the most effective in increasing soil available P, plant growth characters, P uptake and grain yield (4.01 to 4.27 t/ha). Root dipping method (16 kg P_2O_5 / ha), although was comparable during initial stages, was found to be least effective during later stages of growth.

With both sources and methods of P application, significant varietal differences were observed in terms of crop growth, grain yield, P use efficiency and productivity per unit time. Rasi was found to be efficient at lower P levels. But with root dipping method Rasi recorded grain yield comparable to Jaya under higher P doses.

Evaluation of genotypes for phosphorus utilization efficiency

Exploitation of genetic variability in the capacity to extract and utilize soil and applied nutrients like phosphorus is an important consideration for sustaining high rice productivity. In addition to identification of such varieties it is also important to understand their adaptive mechanism. Therefore, at four locations responsive to applied P, a coordinated trial was organized to evaluate rice varieties at graded levels (0, 20, 40 and 60 kg P_2O_5 / ha) of phosphorus application.

The overall grain yield response to P application was significant up to 60 kg P_2O_5 / ha at Maruteru (coastal alluvium, pH 7.0), Raipur (clay loam, pH 7.8) and Titabar (alluvial, pH 5.3). Based on yield responses recorded, the optimum level of P application was between 20-40 kg P_2O_5 / ha for the early duration varieties; while mid-late duration varieties responded significantly up to 40 or 60 kg P_2O_5 / ha. Varieties efficient in phosphorus included: Rasi, IET 5854, Jaya and Chaitanya at Maruteru; Rasi and TTB-14-1 at Titabar, and IET 5854, Ruchi and Madhuri at Raipur. In terms of root volume, root surface area and root adsorption capacity, IET 5854, Rasi and Jaya were superior.

Assessment of potential yields

Practically attainable potential yields of Rasi and Jaya in irrigated system were assessed during kharif at multilocations. The average location specific yield was 438 g/m² for Rasi and 544 g/m² for Jaya. The highest site potentials recorded with Rasi (893 g/m²) and with Jaya (1200 g/m²) indicated the genetic potential. Thus, only 50% of the potential yields of genotypes was actually realized in both the varieties.

Evaluation of self propelled paddy reaper harvester

Rainfall during harvest period and shortage in labour availability aggravate the problem of a timely harvest. Use of appropriate machines is vital to achieve higher economic returns, minimize field losses and reduce drudgery. The main parts of a self propelled reaper consist of crop row dividers, standard cutter bar having 76 mm wide knife section, vertical conveyor belts, steel lugged wheels and a 5 HP single cylinder diesel engine with a power transmission system. The effective cutter bar width is one metre.

The field capacity to harvest varied from 0.22 to 0.31 ha per hour. An average

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Self propelled paddy reaper harvester

performance of 0.28 ha per hour was associated with a forward speed of 2.75 kmph. The field efficiency of this repear harvester is 60%. The labour requirement for collection of harvested sheaves varied from 22 to 34 man hours per ha. Skilled labour required for machine operation ranged from 3 to 6 man hours per ha. The fuel consumption is 1.8 litres per ha and the harvesting losses are 2%. Compared to manual harvest, use of reaper harvester results in a labour saving of 125 man hours per ha. The performance of this paddy reaper harvester costing Rs. 22,000 is good.

Integrated weed management practices

New low dose high efficiency herbicide formulations were studied as mixtures. Most herbicides showed broad spectrum weed control and proved economical in transplanted rice (Table 5). But, in direct-seeded rice under puddled conditions, butachlor and anilophos were the most effective herbicides.

[illegible]	[illegible]
[illegible] (Hoechst) 30 EC, @ 0.40 kg a.i./ha	[illegible]
Cinmethylin 10 EC, @ 0.10 kg a.i./ha	[illegible]
Naproanilide 50 WP, @ 1.00 kg a.i./ha	6.43
Anilophos (Hoechst) 30 EC, @ 0.40 kg a.i./ha + Naproanilide 50 WP, @ 1.00 kg a.i./ha	6.36
Pretilachlor 50 EC, @ 0.75 kg a.i./ha	6.49
Bentazon 40.5 EC, @ 1.00 kg a.i./ha	6.09
Weed free check	6.49
Two hand weedings	6.17
Non-weeded control	4.78
CD (0.05)	0.88

Crop Protection

Host-plant resistance to insect pests

The multilocation testing confirmed resistance in BPT 4358 (BPT 3291/ARC 6650), RP 2337-273-146-7 (Ratna/IET 6858) and RP 2365-171-128 (Nagarjuna/Majila) to brown planthopper. At DRR, mass screening greenhouse tests identified 89 cultures with low damage reactions to this pest.

Field and greenhouse evaluation of elite cultures across the country confirmed the presence of a wide spectrum of resistance to four gall midge biotypes in R 302-111 (Samridhi/IR 8608-298) and RP 2547-100-255 (ARC 5723/ARC 6650//RP 1579-38). Greenhouse studies at DRR, led to the identification of 227 breeding lines with good degree of resistance to biotype 1 and another 17 to biotype 4. Several multiple resistant cultures and germplasm also showed resistance to both the gall midge biotypes (Table 6).

[illegible]	[illegible]
IET [illegible]	IET 10300
IET 9709	IET 10744
IET 9710	IET 11384
IET 9711	IET 11452

Stem borer damage was consistently low in RP 2633 selections (Ratna/IR 36) at vegetative stage and in RAU 83-82-4 at vegetative and heading stages. Akiyudaka and SR 26 B were identified as two new sources of resistance to stem borer.

Only RP 2332-29-19-16 (Ratna/ARC 10654) exhibited consistency in resistance to whitebacked planthopper.

Low leaf folder damage reaction was confirmed in BPT 1768 (BPT 3301/Mutant

[illegible]	*	*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
OR [illegible]	*	*	*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RP [illegible]	*	*	*	*	*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HKR 50	*	*	*	*	*	*	*		[illegible]	[illegible]
R 435-106	*	*	*	*		*	*		7	[illegible]
									6	[illegible]
OR 890-3-168	*	*	*	*	*					
PAU 1126-23-4	*	*	*	*	*	*	*		6	84
R 296-120	*	*	*	*				*	7	77
BPT 3328	*	*	*	*		*	*		5	76
RP 2643-147-283	*	*	*	*		*	*		6	72
									6	72
WGL 3910	*	*	[illegible]	*		*	*			
VL Dhan 163	*	*	*	*	*		*		6	72
CR 157-212	*	*	*	*		*			6	72
RP 2541-169-281	*	*	*	*		*			5	70
									5	70

* Promising reaction, @ product of no. of pests against which the entry is promising and no. of locations showing promising reaction; BPH = Brown planthopper; WBPH = Whitebacked planthopper; GLH = Green leafhopper; GM = Gall midge; SBDH = Stem borer - dead heart; SBWE = Stem borer - white ear; LF = Leaf folder; GB = Gundhi bug

[illegible] Common name Trade name	[illegible] (kg a.i./ha)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		(16)	(12)	(7)	(5)	(3)	(3)	(1[illegible])
Isazophos (Miral) 3 G	1.0	4.45	5.04	6.1	45.3	6.3	21.3	4262
MIPC 4 G	1.0	8.00	6.92	10.6	45.5	6.6	22.2	3834
Lindane 6 G	1.0	4.96	6.25	10.9	52.4	6.8	28.9	4069
Carbofuran (Furadan) 3 G	1.0	5.17	4.80	13.7	51.5	5.9	19.2	4241
Ethofenprox 10 EC (Trebon)	0.075	8.51	6.86	13.1	31.3	7.6	23.3	3868
Carbaryl 48 F (Sevin XLR plus)	0.75	7.88	7.86	11.2	48.6	6.2	20.6	3698
MIPC 50 WP	0.5	7.90	8.12	11.3	50.3	7.2	23.4	3801
BPMC 50 EC	0.5	7.95	7.71	10.7	43.1	8.2	19.6	3773
Chlorpyriphos 20 EC (Corobon)	0.5	6.63	7.05	10.2	35.9	5.8	24.7	3911
Untreated control	-	14.54	16.57	17.8	113.8	31.2	33.5	3178

DH = Dead heart; WE = White ear ; SS = Silver shoots; ADL = Average damaged leaves; AN = Average number

Mahsuri), RP 2573-24-236 (Parasanna/IET 5688), RP 2572-2-304 (Rasi/Chittraikar//IET 5688) and TNAULFR 842718 (Bhavani/ARC 10550). Germplasm accessions such as AC 1224-1, JR 14, Pandy and Velluthacheera recorded a low leaf area damage in greenhouse evaluation. A search through the germplasm for sources of resistance to potential and sporadic insect pests proved useful. Accessions like ARC 6157 to gundhi bug, ARC 5764, ARC 5778 to rice hispa and ARC 7080 to rice thrips showed promising resistant reactions. In rainfed uplands RP 1678-1995-98 (M 83-83/Akashi) was found to be the most promising culture to the prevalent insect pest complex.

From an extensive evaluation at 4 locations, 14 multiple resistant cultures were identified with relatively good level of resistance to five or more insect pests (Table 7).

Prevalence of insect biotypes

Studies on gall midge, besides confirming the prevalence of four distinct biotypes, indicated a major deviation in reaction pattern from Kerala. Similar studies on brown planthopper revealed a general uniformity in reaction of differentials.

Chemical control

Among new insecticide formulations isazophos granules and ethofenprox foliar sprays were comparable to carbofuran granules or monocrotophos spray in controlling insect pests and increasing the yield (Table 8). In greenhouse, cartap granules was superior to both isazophos and carbofuran in quick knock down kill of adults of green leafhopper. Cartap was also superior to monocrotophos in persistent toxicity.

Attempts were made to develop an alternative technology to seedling root dip for the control of early stage pests like stem borer, gall midge and whorl maggot up to 30 days after transplanting. Granular broadcast of carbofuran, cartap or quinalphos at the rate of 2.0 kg a.i./ha in nursery 5 days before uprooting seedlings proved effective at multilocations.

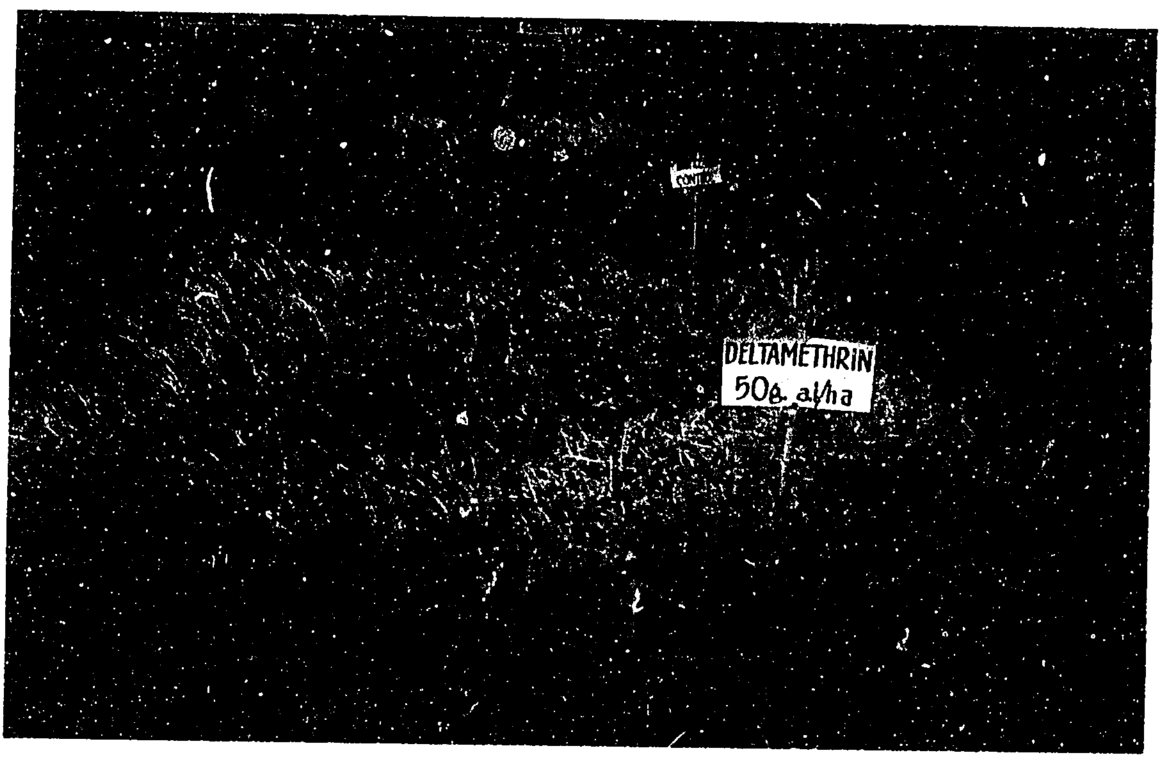
Granular insecticides were found to be relatively safe to larval-pupal parasite of gall midge and predators of leaf and planthoppers.

Limits to use of botanical pesticides

Botanical pesticides derived from *Azadirachta indica, Madhuca longifolia* var *latifolia* and *Calophyllum inophyllum* have been extensively tested to study their effectiveness in controlling rice pests. Botanicals showed limited persistence of 3 to 5 days only but are considered to be safer to natural enemies. Unlike synthetic pyrethroids, botanical pesticides do not cause pest resurgence. Generally adult insects are not killed by botanicals but their fecundity is reduced. Except neem seed bitters, botanicals in general are not systemic.

Biocontrol studies

Studies on the natural enemies of the leaf folder *Cnaphalocrocis medinalis* revealed mortality of eggs (34.6%) by *Trichogramma* nr. *chilonis*, of larvae (16.4%) by *Apanteles* sp. and of pupae (20%) by *Brachymeria lasus* at Nawagam. At Coimbatore, *Goniozus* sp., *Trichoma cnaphalocrocis* and *Elasmus* sp. were the main larval parasites of this pest.



Synthetic pyrethroid induced resurgence in brown planthopper

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In fields at DRR, Nawagam and Pondichery inundative releases of *Trichogramma* @ 10 adults per sq m with one release site every 100 sq m resulted in increased egg mortality and drastically reduced leaf folder damage. Initial presence of mirid bugs and brown planthoppers in 1:1 ratio in enclosed quadrates nearly halved the population buildup in one generation time. Similarly, other mirid *Tytthus parviceps* also showed a high degree of predatory potential on brown planthopper.

Pathogenecity studies on entomopathogenic fungi showed a high degree of infectivity when nymphs of planthoppers and larvae of leaf folder were allowed to crawl on fungal mat. *Metarrhizium anisopliae* was the most effective entomopathogen on brown planthopper. *Beauveria bassiana* against leaf folder and all fungi evaluated against whitebacked planthopper were most effective when these insects were released on plants sprayed with the respective conidial suspensions at various concentrations.

Pest management

In optimum pest control trial several elite cultures were studied under both protected and unprotected conditions. IET 12772 with a high degree of multiple resistance conceded only 7.1% of grain yield to insect pest damage. In contrast, another culture IET 9853 lost 30.5% of yield under the same pest pressure.

Varying economic threshold levels of insect pests at different locations caused significant yield losses. The threshold values varied with locations and the pest.

[illegible]
[illegible] at Ludhiana
[illegible] planthopper
25 to 50 adults / hill at Pondichery
Rice hispa
10% damaged leaves at Malan
Whitebacked planthopper
25 adults / hill at Nawagam
Leaf folder
20% damaged leaves at Coimbatore
2 to 5% damaged leaves at Nawagam
Gundhi bug
1.9 to 5.3 insects / m^2 at Pondichery

Integrated pest management in gall midge endemic areas (Bhubaneshwar, Sambalpur, Sakoli) and in stem borer endemic areas (Almora, Karjat, and Rajendranagar) cultivation of a resistant/tolerant variety invariably resulted in higher net profit.

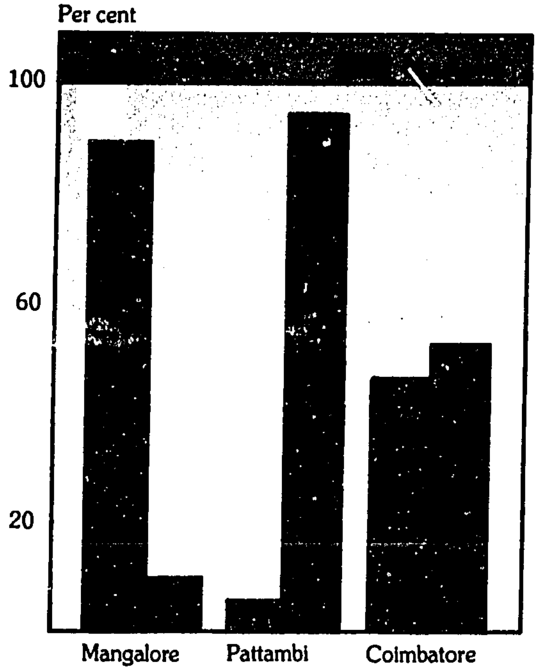
In a newly initiated composite IPM trial all the available tactics of pest control were integrated and adopted to demonstrate its utility in farmers field. During kharif, cultivation of the multiple resistant variety Suraksha, with weedicide application (anilophos on 5 DAT), need based insecticide (monocrotophos on 19, 45 and 70 DAT) against thrips, whorl maggot, stem borer and 9 releases of *Trichogramma* against leaf folder, significantly reduced pest damage and increased grain yield by 15.3%. During rabi with Vikas, a similar package of protection realised 7% increase in grain yield.

Population dynamics of insect pests

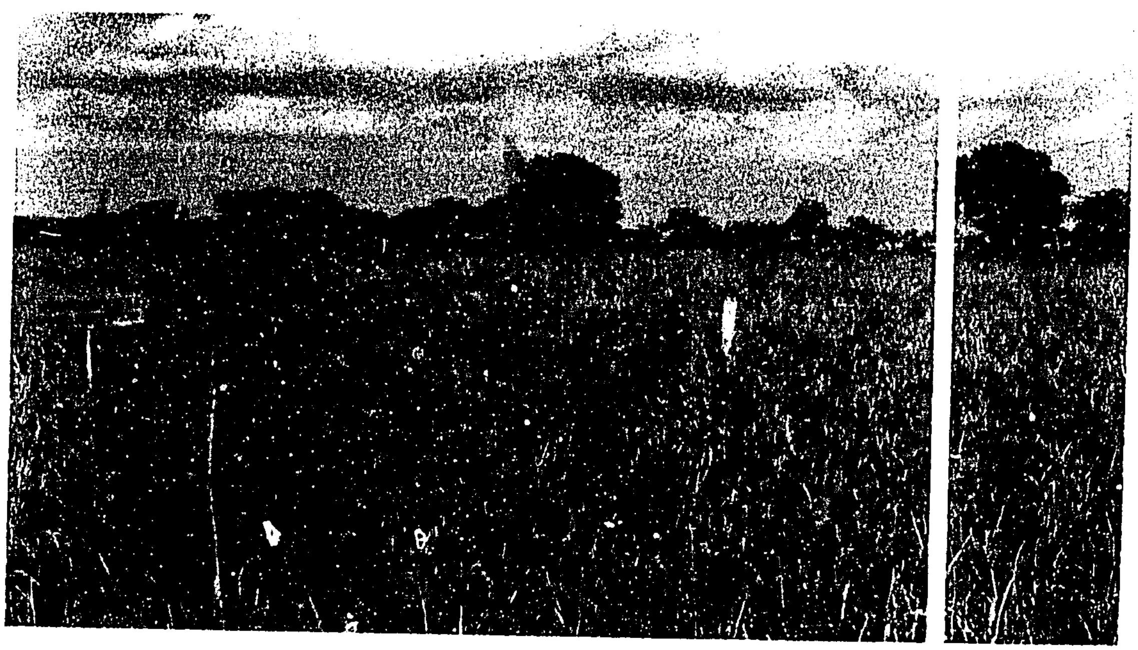
Monitoring of insect pests through light trap showed continued importance of stem borer, wide distribution of leaf folder and brown planthopper, increased area of appearance and intensity of catches of green leafhopper at six locations.

There was an exclusive presence of yellow stem borer at Mandya and pink stem borer at Almora. *Cnaphalocrosis medinalis* was predominant at Mangalore, while *Marasmia patnalis* was dominant at Pattambi. But both the species were prevalent in equal proportion at Coimbatore (Figure).

Ptb 12 - A source of resistance to leaf folder



Distribution of Cnaphalocrosis medinalis and Marasma patnalis



Mating disruption in yellow stem borer

The ability of selibate CS, a polymer based controlled release formulation of the pheromone of *Chilo suppressalis* containing Z 9-16: A1 and Z11-16:A1 by placing the pheromone dispenser stapled on to Im stick at 4, 5 and 7m spacings at 25-30 days after planting was assessed. Weekly record of male moth captures in sleeve traps baited with *Scirpophaga incertulas* pheromone served as the basis of assessing communication disruption. High level of communication disruption was achieved for 4 to 6 weeks with application rates between 10 and 40 g a.i./ha and dispenser spacings of 4 and 5m.

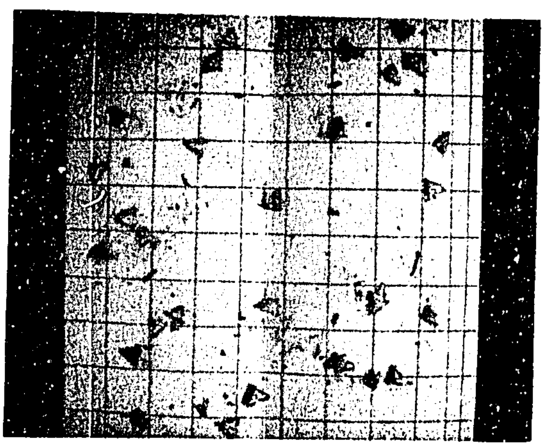
Pheromone dispenser stapled to a stick

Mating disruption in yellow stem borer using a formulation of pheromone from Chilo suppressalis

Optimising leaf folder pheromone blend and trapping system

Three pheromonally active compounds viz., (Z)-11-hexadecenyl acetate (Z 11-16:AC), (Z)-13-octadecenyl acetate (Z 13-18 : Ac) and (Z)-11-hexadecon-1-0l (Z 11-16:OH) identified from the ovipositor washings of *Cnaphalocrocis medinalis*, synthesized and blended in various ranges by the Chemical Entomology Unit, Natural Resource Institute, U.K. were evaluated in the farmers' fields at Medchal, Ranga Reddy district. Although Z 13-18:Ac was attractive to male *C. medinalis*, a binary blend containing Z 11-16: Ac and Z 13-18: Ac in 1:10 ratio was found to be the most attractive. Addition of 10% Z 13-18: OH to the blend reduced the trap catch significantly. Lures dispensed from the ployethene vials caught more male moths than the lures dispensed from rubber septa. Among the four types of traps viz., delta sticky trap, sleeve trap, funnel trap and water trap, delta sticky trap collected larger male moth catch. Deploying the trap at crop canopy height was found optimum for securing maximum capture of male moths.

Evaluation of various types of pheromone traps



Insect catch in delta sticky trap

Studies on nematodes

The multiple insect resistant cultures were evaluated for resistance to root-knot nematode at four locations. IET 12356, CR 309-268, R 296-120, WGL 47877, WGL 47969 and RNR 87877 showed promising reaction. In RP 2334-148-47-11 and WGL 47998 resistance was confirmed. Studies at DRR revealed the resistance in Pranava, Surekha and RP 2081-322-145-48 to root-knot nematode. Fenamiphos and carbofuran granules at 1.0 kg a.i./ha were effective against root - knot nematode.

In general, appearance of white leaf tips in young plants followed by ill emergence of panicles and floret sterility were the common symptoms of white-tip nematode attack. A survey in Andhra Pradesh indicated wider distribution of *Pratylenchus* and *Helicotylenchus* in Guntur and Krishna districts and of *Aphelenchoides besseyi*, *Hirschmaniella* and *Pratylenchus* in Ranga Reddy district.

Host-plant resistance to diseases

Of various disease management strategies, host-plant resistance has been found more reliable and economical. Using extensively the resistance gene sources available in the primary gene pool, varieties combining specific and multiple resistance have been developed. In multilocation coordinated trials these breeding lines were evaluated in disease endemic areas in the country. Several cultures were resistant to blast, sheath blight, bacterial blight and rice tungro virus. A few promising cultures suited to irrigated and upland eco-systems are given below.

In multilocation testing programme three national screening nurseries comprising 700 entries were evaluated at 34 locations for identifying resistance to blast, brown spot, sheath blight, sheath rot, bacterial blight and rice tungro virus.

Among national screening nursery cultures evaluated at 11 locations, IET 11193 (selection from local), and IET 12246 (BA 51/KAU 2332-2-2) exhibited a good degreee of resistance to blast in uplands, hills and irrigated ecosystem. Several other cultures showed resistance at many endemic locations (Table 9).

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	VL 191/Cul 2058
IET 12569	IR 39365/OR 92
Irrigated ecosystem	
IET 11196	Pankaj/SR 26B
IET 11410	CR 404-48/CR 289-1208
IET 11411	CR 404-48/CR 289-1208
IET 12603	UPRM 500/Jaya
IET 12249	Eswarakora/PTB 18//IR 8/Latisail
IET 12125	Prasanna/ARC 10372
IET 12503	M. Gora/IAC 25
IET 13181	IR 13348-38-3-3//IR 25863-61-3-2/IR 58
IET 12696	C 22/CR 298-1208

Screening for blast

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[illegible] bacterial leaf blight and rice tungro virus

***IET* [illegible]** (TNAU 80030) from IR 30/Babawee//IR 2071-625-1-252, 124 days duration, long slender grains, resistant to bacterial leaf blight and tolerant to brown spot and sheath blight

IET 11321 (NDR 4065) from Madhukar/Sona, 168 days duration, resistant to bacterial leaf blight, rice tungro virus, tolerant to sheath blight and sheath rot

IET 11867 (TC 31/A), selection from composite cross, 205 days duration, short bold grains, resistant to bacterial leaf blight, blast, tolerant to sheath blight

IET 12249 (CR 721-354) from Eswarakora/Ptb 18//IR 8/Latisail, 128 days duration, long slender grains, resistant to blast, bacterial leaf blight, and tolerant to sheath blight .

IET 13181 (AS 89044) from IR 18348-38-3-3/IR 25883-61-3-2//IR 58, 124 days duration, long slender grains, resistant to blast and tolerant to brown spot

IET 13272 (UPR 990-17-1-2-1) from IR 2415-90-4-3/ARC 5838, 131 days duration, long bold grains, resistant to blast, and tolerant to brown spot and sheath rot

Resistant entries for brown spot at hot-spot locations were IET 10972 (CR 404-48/CR 289-1208), IET 12024 (RP 1669-1/Prasanna), IET 12294 (Aditya/Mettasanna), IET 10457 (Sarjoo 52/China 4), IET 12624 (ADT 36/IR 50), IET 13300 (IET 10452/IET 7832//UPR 239-151-1-1), IET 11581 (Rajendra/IR 30) and IAC 47/UPR 82-1-7.

IET 12626 (IR 50/ADT 36), IET 12693 (TKM 9/P 312), IET 10810 (Pankaj/Mahsuri), IET 11047 (Namsagui 19/IR 4215//IR 58) showed moderate to high resistance to bacterial leaf blight.

Identification of new sources of resistance for major diseases was continued at DRR. Of the 398 scented germplasm accessions evaluated, Kamod 118, one accession of Bas 370. Bas 386, Bas Surkh 161 and DM 24 were resistant to blast.

From another set of 664 germplasm accessions evaluated, B 321, Kavya, Satya, Ambemohar 159, MTU 6 (Atragoda) and Gopalbhog showed a moderate resistance to sheath blight.

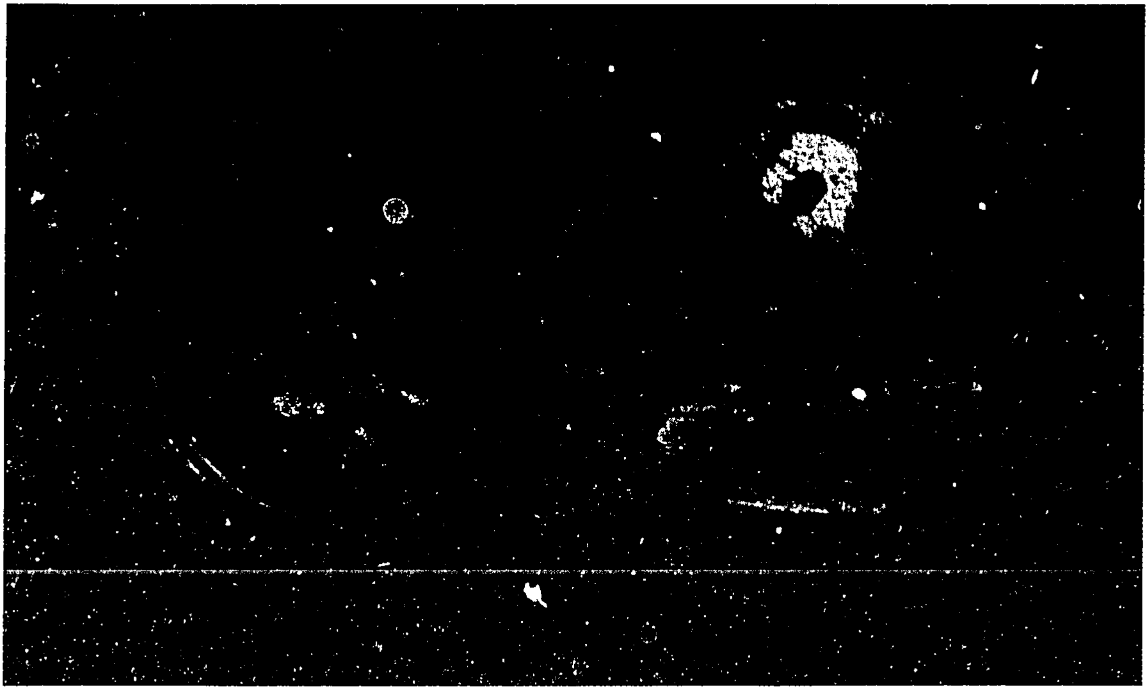
A total of 43 accessions of wild species of *Oryza* were evaluated for resistance to tungro virus in glasshouse. One accession of *O. nivara* (DRW 21019), and three accessions of *O. rufipogon* (DRW 22003, DRW 22007, DRW 22017) had no disease. However, the nature of resistance needs further evaluation.

Chemical control

Spectrum of toxicity is one of the key criteria in development of application schedules of fungicides in disease management. In the light of changing disease scenario in the country, and multiplicity of infections at a specified point of time and place, it is desirable to use fungicidal formulations with broad spectrum of toxicity. Towards this end, the coordinated chemical control trials identified a few triazole compounds. Hexaconazole and priopiconazole were effective against balst, sheath blight and sheath rot and leaf scald diseases (Table 10).

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]					
Hexaconazole (Contaf 5 EC)	***	****	**	**	[illegible]
Propiconazole (Tilt 5 EC)	**	***	***	**	****

**** = highly effective; *** = effective; ** = moderately effective; * = low ; - = not effective. Bl = Blast; ShBl = Sheath blight; BS = Brown spot; ShR = Sheath rot



Bacterial culture antagonistic to sheath blight pathogen

Biocontrol of sheath blight

Among 84 bacterial isolates isolated from soil of DRR farm, Rajendranagar six cultures were antagonistic to growth of sheath blight pathogen *Rhizoctonia solani.*

Development of a sampling method for estimating yield loss

Bacterial leaf streak of rice caused by *Xanthomonas campestris* pv *oryzicola* in north coastal Andhra Pradesh was uneven in distribution and in the damage. Many varieties with varied maturity duration were under cultivation in this area and they exhibited different reactions to the disease. These variations posed problems in arriving at an yield loss estimate. Hence a three stage stratified random sampling method was developed with villages as primary units; field from strata of susceptible (high) and resistant (low disease) in early, medium and late duration groups as secondary units; and plots and / or plants as tertiary units.

Training for transfer of technology

The advanced training centre organised eight short duration training courses on rice production technology for various clientele groups.

[illegible] **Technology :** 5 days, 17 master trainers from Andhra Pradesh, Bihar, Goa, Karnataka, Punjab, Rajasthan, Uttar Pradesh and West Bengal

Rice Production Technology : 2 weeks, 18 extension personnel from Andhra Pradesh, Madhya Pradesh, Uttar Pradesh and West Bengal

Rice Production Technology : 3 days, 10 extension personnel from Andhra Pradesh, Karnataka, and Tamil Nadu

Rice Crop Management for Rainfed Uplands : 2 weeks, 13 extension personnel from Andhra Pradesh, [illegible] : [illegible] extension personnel from Andhra Pradesh, Assam, Haryana, Jammu & Kashmir, Karnataka, Maharashtra, Mizoram, Orissa, Pondichery, Punjab, Uttar Pradesh and West Bengal

Rice Based Cropping Systems : 2 weeks, 11 extension personnel from Andhra Pradesh, Jammu & Kashmir, Madhya Pradesh and Uttar Pradesh

Rice Production Technology : 1 week, 14 executives of the agro-input agencies from Andhra Pradesh and Tamil Nadu

Mr. Sripada Rao, Honourable Speaker of the Legislative Assembly, Andhra Pradesh at exhibition in Rice

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Impact of Operational Research Projects

Operational research projects were conducted in Andhra Pradesh for a period of five successive years to verify and demonstrate the new research findings, directly in farmers fields.

For the operational research project on integrated pest management a cluster of nine villages in Medchal area of Ranga Reddy district was adopted. Both small and marginal farmers together held over 90% of the adopted area. Gall midge and stem borer during kharif and, stem borer and blast in rabi caused considerable damage to rice in the operational area. Rabi rice area was influenced by the availability of water in tanks and wells. Integrated pest management involving use of host-plant resistance, cultural methods and need based insecticide application with an emphasis on conserving natural enemies of insect pests was successfully implemented in the operational research areas. Such demonstrations increased the grain yields and stabilized rice production around five tonnes per hectare in the adopted area.

Transfer of technology at the farm door step

Training youth in Integrated Pest Management

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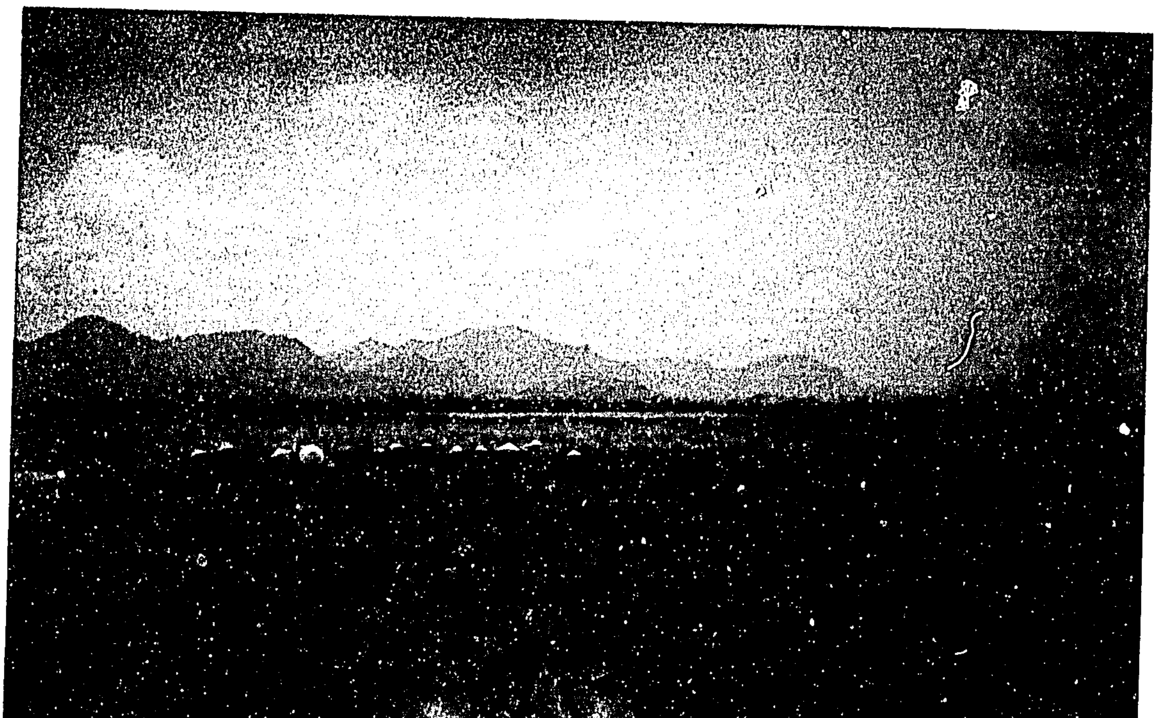
With the advent of new biotype of gall midge in Srikakulam and Vizianagaram districts, in Andhra Pradesh during 1986, popular varieties Phalguna and Surekha succumbed and paralyzed rice production. Immediately the Operational Research Project on integrated pest management undertook massive evaluation of available elite cultures for identifying resistant lines to the new biotype and demonstration of effective granular insecticide application for containing the gall midge damage. Such efforts led to identification of Suraksha and release of an elite culture named Abhaya as resistant to gall midge biotype 4.

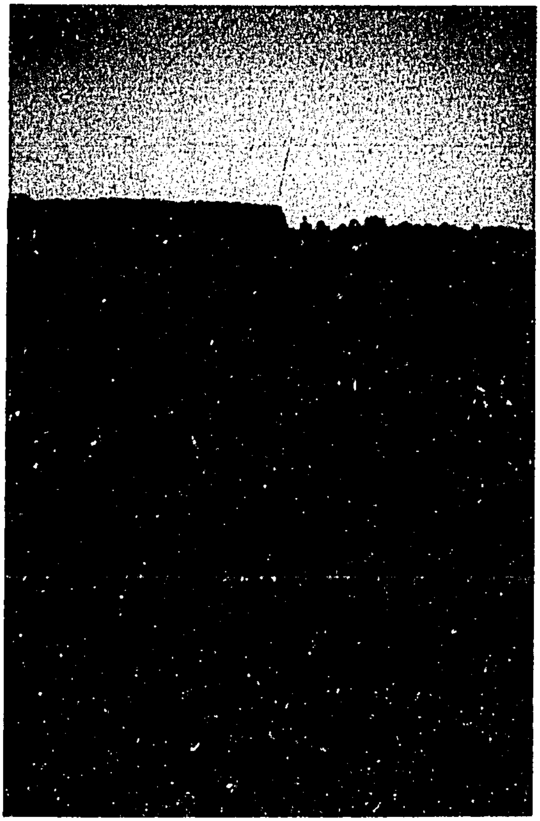
For the control of insect pests in the early stages of transplanting, seedling root-dip in 0.02% chlorpyriphos was evaluated and found to be a cost effective technology. Nursery applciation of carbofuran granules @ 2 kg a.i./ha was found to be another alternative to the seedling root-dip.

[illegible]

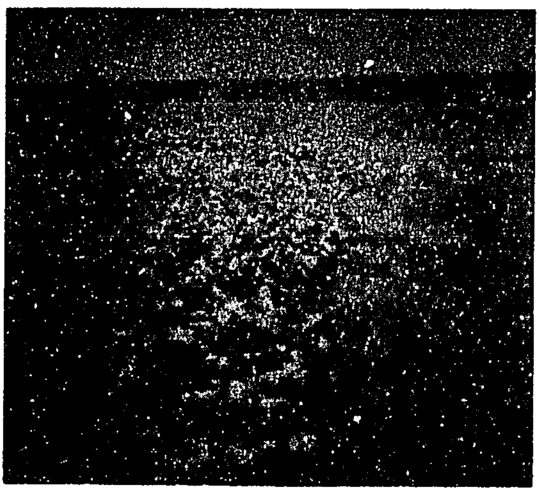
[illegible]	[illegible]
Nursery application of carbofuran (2.0 kg a.i./ha)	Rs. 225
Seedling root dip (0.02% chlorpyriphos)	Rs. 200
Main field granule application (0.75 kg a.i./ha)	Rs. 950



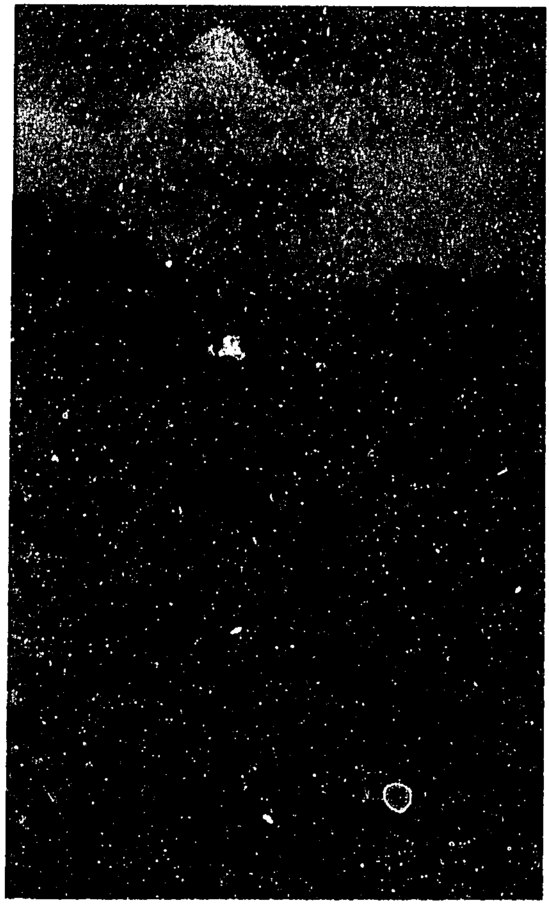
Wide adoption of planting seedlings treated with granular insecticide in nursery five days prior to uprooting for effective management of new gall midge biotype in Srikakulam, Andhra Pradesh



The other Operational Research Project on cropping systems covered an area of over 2500 ha under Nagarjunasagar left canal in Khammam district with the objectives of testing, fine tuning and designing of various technologies in rice based cropping systems on farmers' fields. The cropping intensity in the adopted area was increased from 150 to 230% by growing an additional crop in pre-kharif and / or post-kharif periods in fallows. Raising green gram or sunhemp as a catch crop during pre-kharif fallow period provided additional grain as well as green manure. Cultivating black gram and fodder .sunhemp in tailend rice fallows in rabi also provided similar gains to farmers.



Raising sunhemp/green gram as catch crop during pre-kharif fallow period provides additional green manure or grain



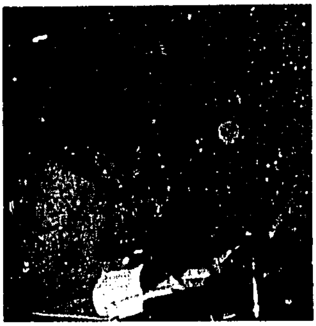
Cultivating blackgram in tail-end rice fallows with residual moisture

Restoring productivity in lowlying saline-alkaline soils with acute zinc deficiency through zinc application

The existing less remunerative and high risk prone rice-groundnut/fallow system was replaced with more remunerative and diversified rice-sunflower/ sesame/soyabean/black gram systems to provide adequate crop choice.

Application of double the recommended dose of zinc (100 kg zinc sulphate / ha / 3 crop seasons) initially followed by normal dose reinforced with 0.2% zinc sulphate foliar spray thrice at tillering helped in restoring normal productivity in low-lying saline-alkaline soils with acute zinc deficiency. Introduction and use of pre-kharif green gram as green manure and use of earth soaked urea, neem cake coated urea or urea super granules could obviate the commonly encountered heavy loss of applied N in the operational area. The superior technology increased the productivity of rice up to 5.0 t/ha from initial harvest of 3.5 t/ha by the farmers in the adopted area

Diversification of risk prone rice-groundnut system in ORP area to more remunerative rice-sunflower/ sesame/soyabean/black gram



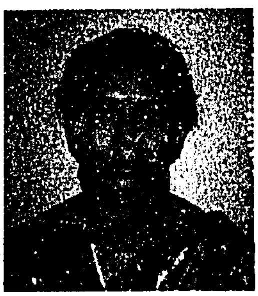
The Rafi Ahmed Kidwai Memorial Prize for Agricultural Research for the biennium 1988-89 was awarded to Dr B. Venkateswarlu and his associate Dr (Ms) S. Padmaja Rao jointly for their outstanding contribution in the discipline of Agricultural Botany (Crop Physiology).

A comprehensive insight into physiological mechanism regulating the development of High Density (HD) rice grain has been accomplished. Studies have elucidated that possible varietal differences, the nature of location of HD grain on the panicle, influence of nitrogen, different density of population, growth duration, temperature ranges, light intensities, relationship with grain size, and relating its association with pre-flowering and post-flowering photosynthetic products are some of the factors which influence High Density grain development.

Both Dr Venkateswarlu and Dr (Ms) S. Padmaja Rao conducted their research at the Directorate of Rice Research, Hyderabad.

The International Rice Research Institute, The Phillipines gave outstanding young woman in Rice Science award for 1992 to Dr (Ms) N. Sobha Rani.

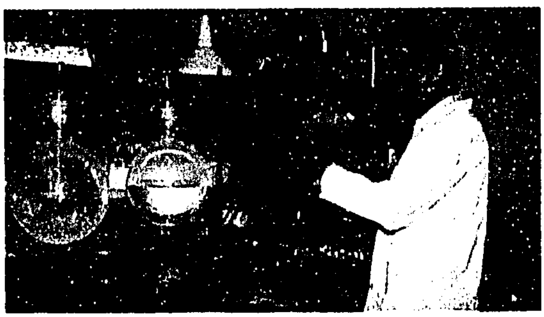
Dr (Ms) N Shoba Rani participated in the development of the high-yielding dwarf scented rice variety Kasturi and is involved in the development of several promising rice lines combining high yield with resistance/ multiple resistance to several pests.



The Jawaharlal Nehru Award for Outstanding Postgraduate Agricultural Research for the year 1988 was awarded to Dr Dilip Kumar Kundu for his significant research contributions in Soil Science.

Dr Kundu has made detailed investigations on the chemical kinetics of upland soils and rice growth.

Dr Kundu conducted his research at the Indian Agricultural Research Institute.



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Operational Research Project, Khammam

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Satyananda Rao, Superintendent(Estt)
Janakirama Sarma P, B.Com, Superintendent (A&A)
Sharma GC, B.Sc.(Ag), Farm Superintendent

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Jagannath M, B.E.(Mech.), Technical Officer

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1 Left on January 21, 92 3 Joined on December 9, 91
2 Joined on August 29, 91 4 Joined on September 27, 91

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Andhra Pradesh Agricultural University:
Rajendranagar, Warangal & Maruteru.

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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):
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Calcutta University (West Bengal):
Calcutta.

Diracetor of Agriculture (West Bengal):
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Director of Agriculture (Manipur):
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 & Ponichak.

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

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Pattambi, Mannuthy & Moncompu.

Konkan Krishi Vidyapeeth (Maharashtra):
Karjat.

Marathwada Agricultural University (Maharashtra):
Tuljapur

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

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, Aduthurai, Madurai & Pondichery.

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Siriguppa, Mangalore, Ponnampet, Mandya & Mugad.

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