

GRAIN DISCOLOURATION OF RICE

By

A.P.K. Reddy and V.T. John

All India Coordinated Rice Improvement Project

Hyderabad 500 030, India

The qualitative and quantitative fungal microflora associated with discoloured rice grains was studied by agar and blotter methods. Four fungi, *Alternaria padwickii*, *Acrocyndrium oryzae*, *Helminthosporium oryzae* and *Curvularia lunata* were isolated in high frequency from discoloured grain of 50 seed samples collected from nine locations in India. The composition of fungal microflora associated with discoloured grain was dependent upon season and location. Among several fungi isolated from discoloured grains three fungi, *Acrocyndrium oryzae*, *Helminthosporium oryzae* and *Curvularia lunata* were pathogenic on T(N)₁ rice when inoculated at flowering-milk stage. The infectivity of the three fungi progressively decreased with increasing maturity of the kernel. Flowering-milk stage was more susceptible for fungal invasions. Others were either weakly pathogenic or did not produce any grain discolouration in inoculation tests.

Discoloured grains of T(N)₁ and IET 2895 varieties were lighter in weight (lower thousand grain weight), had low milling recovery and reduced germination percentage. Seed dressing with fungicides Agallol and Thiram improved germination. Field evaluation tests showed that systemic fungicides, Benlate, Bavistin and MBC effectively checked grain discolouration and increased yield. Varietal differences in susceptibility for grain discolouration and increased grain yield. Varietal differences in susceptibility for grain discolouration were observed. Among the released varieties TKM 6 derivatives were more susceptible.

INTRODUCTION

The early maturing dwarf rice cultivars grown in wet season are often subjected to rainy weather during flowering to harvest stages of the crop. Due to incessant rains and high humidity post flowering diseases, particularly grain discolouration has become a serious problem in some parts of the country. The poor grain quality associated with discoloured grains results to farmers.

Rice grains are known to be infected by various organisms before or after harvest causing discolouration externally on the glumes or internally on kernels or both (Neergaard, 1970; Ou, 1972; Padwick, 1950). A large number of fungi

associated with discoloured grains are reported from India (Bedi and Dhalicoal, 1970; Govinda Swamy, 1955; Mathur and Neergaard, 1970; Mathur *et al.*, 1972; Padmanabhan, 1949, 1947; Padwick, 1950; Rao and Baruah, 1972; Rao and Salam, 1954; Schroeder, 1964; Vaidehi and Rama Rao, 1972). They may be divided into two major groups: one group consists of fungi which are more or less parasitic and infect the grains before harvest; the others include storage moulds which usually are saprophytes and develop after harvest (Neergaard, 1970; Ou, 1972; Padwick, 1950). When infections are by field fungi the main effects are reduced viability (Padwick, 1950) and grain quality (Fazli and Schroeder, 1966). and seedling blights (Govinda Swamy, 1955; Martin, 1939).

Although considerable information is available on qualitative and quantitative fungal microflora associated with discoloured rice grain from India, little or no information is available on the effects of field fungal infection on seed and grain quality. We studied major field fungi associated with discoloured grains in different rice growing regions, optimum growth stage for infections, effects on seed grain and quality and methods to control seed discolouration the problem through chemicals and varietal resistance. The research results are reported in this paper.

Seed samples

Rice panicles of T (N) 1 variety showing grain discolouration were collected from AICRIP experimental plots in 1975 wet season and 1976 dry and wet seasons. The panicles were air dried and fungal microflora was analysed on discoloured grains. Fifty rice seed samples (ca. 1-2 Kg) were obtained from nine locations and fungal population associated with discoloured grains were determined.

Fungal microflora estimation :

The agar and blotter methods were used for qualitative and quantitative assay, since both the methods are supplementary to one another. The discoloured seeds were surface sterilized (1 min in 80% alcohol + 1 min in 0.001% HgCl_2 followed by washing thrice in sterile distilled water) and 200 seeds were placed in moist blotter (moistened with water and sterilized at 121°C for 30 min) and plain agar (2.0% agar + 0.05% streptomycin sulphate). Usually 10 seeds were placed in blotter and 5 seeds in agar plates. The plates were incubated at

26°C for 5 days and 23-27°C at room temperature under fluorescent lamps for 2 days. On eighth day individual organisms were recognised by colony characters and structural morphology.

Pathogenicity tests :

T(N) 1 plants were grown individually in plastic pots (6" x 6") in flooded conditions. Adequate nutrients were supplied. The plants were inoculated at flowering—milk stage. Individual fungal cultures isolated from discoloured grains were multiplied on rice grain (soaked in water for 3 hrs., sterilized at 121°C for 15 min in conical flasks for 15 days. The spores were washed in to distilled water strained through muslin cloth and used as inoculum. (The spore suspension contained ca. 2000 multicelled conidia/ml and 10000 single cell conidia/ml). Three inoculation methods, spraying, panicle dipping and boot injection were used. In boot injection method 2-3 ml of spore suspension of *A. oryzae* were injected into the boot 2-3 days prior to panicle emergence to create sheath rot and as well grain discolouration symptoms. For each fungal isolate a minimum of 5 replicates were maintained. The inoculated pots were left in the humid chamber for 72 hours and later they were transferred to glass house benches. Three panicles from central culms for each pot were collected before harvest and discoloured grains were counted and expressed in Per cent proportion of total grains set on the panicle.

Kernel growth and fungal infectivity :

In this experiment staggered planting of T(N) 1 was done and the plants were inoculated uniformly at flowering-milk ripe, soft dough and hard stages dough with spore suspensions of 5 fungi, *Acrocyndrium oryzae*, *H. oryzae*, *A. padwickii*, *C. lunata* and *Fusarium* spp. For each growth stage and fungus isolate combination 5 replicates were maintained. The percent incidence of discoloured grains were recorded at harvest in all the treatments.

Grain quality and viability :

In glass house 300 each of T(N) 1 and IET 2895 plants were spray-inoculated with spore suspensions of *A. oryzae*, *C. lunata* and *H. oryzae* and the plants were left in humid chamber for 72 hours and were transferred to glass house benches. Another set was maintained in a separate glass house chamber

(healthy). The seeds of both the sets were bulked individually. The percentage grain discolouration was 5.6 and 2.0 in inoculated seed set and healthy seed set respectively. The two sets of seeds were used in grain quality experiments and viability studies. Five samples of 100 g each of discoloured and healthy seeds were milled to 6.7 per cent polish in 'Kett' micro mill. The unbroken and broken grains were separated normal unbroken grains were weighed expressed as percentage grain recovery. Seed germination tests were conducted on discoloured and healthy grain seed lots in blotters at 26°C and in unsterilized soil at 23–28°C in semi-wet condition. The samples (200 seed/sample) were used in both methods and germination percentage was recorded on 6th day after sowing and expressed in percentage. The efficacy of few seed dressing fungicides Agallol, NEMC 3% (Bayer); Thiram 75% W. P. (Indofil); Phenoctin 100% EC (IDPL experimental seed dressing fungicide) and Bavistin 50% WP (BASF); were tested by wet seed dressing method. Two hundred grams of discoloured seed was treated with these 4 fungicides in conical flasks. The treated seeds were air dried and germination percentage and fungal recovery followed after treatment were determined.

Field evaluation chemicals against grain discolouration :

Two experiments were conducted in 1976 and 1977 wet seasons to study the feasibility of chemical control of grain discolouration complex. Five fungicides Bavistin, 50% WP, (BASF) M.B.C 50%WP, (H.M.P.) Benlate, 50%WP (DUPONT) Dithane M-45 75%WP, and Dithane 78, 75%WP (Indofil) were tested on IET 2895 rice selection which is susceptible to grain discolouration. Seven treatments were included in the experiment (Table 8). The experimental layout was randomized block design (RBD) and each treatment was replicated 3 times. The test plots were 5 x 3 m spaced 20 cm between rows and 15 cm within a row. All the test plots received a uniform dose of NPK fertilizers (N 150, P 75, K 50) and plant protection chemicals. The field plots in 1976 wet season were inoculated at flowering-milk stage with spore suspensions of *A. oryzae*, *C. lunata* and *H. oryzae* on three consecutive evenings. Five days later the 5 test fungicides were sprayed (3-4PM after anthesis) on panicles

and foliage uniformly. The healthy check plots received no inoculum and only the diseased check plots received inoculum. The discoloured grain percentages were recorded 3 days prior to general harvest on 10 panicles collected from 10 randomly selected hills of a plot in all the test plots. The grain yields were recorded from central rows (leaving 2 border rows) of a plot and expressed in kg/ha at 14% moisture level.

Natural incidence of grain discolouration :

Due to favourable weather conditions different levels of grain discolouration were observed at AICRIP farm and seed multiplication plots of village development officers training centre in wet season 1975. From Ca. 500 m² plots ten panicles were collected at random on 17 rice varieties selections and percentage grain discolouration incidence was recorded.

RESULTS

Field symptoms

Normally brown to blackish blotches or grey blotches with dark brown margin were observed on glumes which may be small flecks or sometimes these flecks merge and cover the entire glumes. This kind of severe infections were commonly observed on half filled grains and sterile spikelets, whereas completely filled grains had in general discrete flecks. No systematic pattern of discolouration was observed in a panicle and the spikelets were affected randomly. However, in plants affected by sheath rot grain discolouration was more pronounced in lower spikelets of a panicle. The discolouration was also observed on kernels. But the degree of discolouration was comparatively lesser than on glumes. The kernels of discoloured grains are shrivelled, ill-developed chalky and lightly discoloured. In varieties having orange coloured hull the lesions are light yellow or pale greyish or straw coloured in the centre with a dark brown margin.

Microflora associated with discoloured grains :

The fungal microflora associated with discoloured T(N) 1 rice seed in three

rice seasons is presented in table 1. The weather data for wet and dry season is presented.

Table 1. Frequency of isolation of different fungi from discoloured T(N) 1 rice seed in three seasons at AICRI P, Rajendranagar

Organism	Wet season/ 1975	Dry season/ 1976	Wet season* 1976
<i>Alternaria Padwickii</i> Ganguli	20	—	16
<i>Alternaria longissima</i> Deighton and Macgervie	—	16	3
<i>Alternaria tenuis</i> auct.	6	10	9
<i>Acrocyldrium oryzae</i> Saw.	11	14	7
<i>Curvularia lunata</i> (Wakker) Boed	18	16	22
<i>Helminthosporium oryzae</i> Breeda de Haan	8	—	17
<i>Helminthosporium</i> sp.	4	10	5
<i>Nigrospora oryzae</i> (Berk & Br.) Petch.	1	12	6
<i>Fusarium</i> sp.	2	13	2
<i>Phoma glumarum</i> Ell. & Tr.	16	3	—
<i>Penicillium</i> sp.	—	3	2
Unidentified + sterile mycelium	5	2	9
Total	91	99	98

* Average values for blotter and Agar tests (100 seeds/sample). *Helminthosporium* sp include *H. halodes*, *H. australiense*.

In wet seasons of 1976 and 1977, 3 fungi, *A. padwickii*, *Curvularia lunata* and *Helminthosporium oryzae* were observed in high frequencies. Whereas in dry season *A. longissima*, *A. tenuis*, *Acrocyldrium oryzae*, and *Nigrospora oryzae*, *Fusarium* sp. were recorded in high frequency. *Curvularia lunata* and *Acrocyldrium oryzae* were isolated in similar frequency in both the seasons.

Quantitative microflora associated with discoloured grain samples collected from 1976 crop in different geographical regions of the country is presented in table 2. In all locations (except at Pattambi) four fungi, *A. padwickii*, *A. oryzae*, *C. lunata* and *H. oryzae* were isolated in higher frequencies. From the seed samples of Pattambi (collected in brown spot infected fields) *H. oryzae* was isolated in higher frequency. In all the samples tested *A. oryzae* was absent. The above mentioned commonly occurring fungi were also isolated from kernels of discoloured grains, indicating the deep seated nature of infections (Table 3).

Table 2. Frequency of isolation of different fungi from discoloured rice seed collected from 9 locations of India

Organism	Patna (Bihar)	Gagra- Ghat (UP)	Raipur (MP)	R'Nagar (AP)	R'Puram (AP)	Chin- surah (WB)	Can- ning (WB)	Patt- ambi Ker ala)	Cuttack (Orissa)
<i>Alternaria padwickii</i>	36	22	31	30	27	42	25	20	40
<i>Acrocyllindrium oryzae</i>	10	2	18	8	10	4	2	—	22
<i>Curvularia lunata</i>	8	9	5	12	15	14	9	7	16
<i>Helminthosporium oryzae</i>	5	11	13	6	21*	22	11	51*	8
<i>Curvularia</i> sp.	1	1	2	1	1	—	—	1	—
<i>Helminthosporium</i> sp.	5	—	2	6	6	1	1	—	1
<i>Fusarium</i> sp.	1	—	2	10	5	2	3	7	2
<i>Alternaria</i> sp.	6	—	5	6	5	2	3	—	1
<i>Nigrospora oryzae</i>	—	—	—	4	1	1	1	1	1
<i>Penicillium</i> sp.	—	10	—	2	1	1	—	4	—
<i>Phoma glumarum</i>	3	2	—	—	1	—	—	—	÷
Unidentified	—	—	—	—	—	—	—	—	—
— sterile mycelium	1	6	2	3	1	1	—	1	1
Total	86	63	80	88	90	90	54	91	92
No of samples tested	5	5	6	5	4	10	3	4	8

Average number of fungal colonies (%) isolated by blotter and agar method.

XX—Crop was affected by brown spot.

Helminthosporium sp. include *H. australiense*, *H. balodes* and *H. Hawaiiense*Alternaria sp. include *A. tenuis*, *A. bongissima*Curvularia sp. include *C. geniculata*, and *C. davata*

Table 3. Fungal microflora associated with discoloured seed and kernel; frequency of colony appearance on plain agar with streptomycin sulphate (500 ppm)

Fungus	Location							
	Cuttack		Patna		Chinsurah		Raipur	
	Seed	Kernel	Seed	Kernel	Seed	Kernel	Seed	Kernel
<i>Alternaria padwickii</i>	47*	24	33	24	64	45	33	24
<i>Acrocyllindrium oryzae</i>	24	62	17	8	8	4	17	8
<i>Helminthosporium oryzae</i>	5	8	4	1	10	4	4	—
<i>Curvularia lunata</i>	13	4	4	—	8	4	4	—
<i>Helminthosporium</i> sp.	5	—	2	—	—	—	2	—
<i>Curvularia</i> sp.	2	—	—	—	—	—	2	—
<i>Phoma</i> sp.	—	—	3	4	—	—	—	—
<i>Fusarium</i> sp.	—	—	1	—	—	—	—	—
<i>Alternaria</i> sp.	—	—	7	—	—	—	—	—

* Values expressed in percentage

Among blotter and agar methods of isolation, *A. oryzae* was isolated in higher frequency on agar plates. On blotter, colony development was restricted to the seed surface only and easily not detectable. Other fungi were isolated with equal facility on agar and blotter (Table 4).

Table 4. Frequency of colony appearance from discoloured grains on agar and blotter (representative samples of 5 locations)

	Location									
	AICRIP		Gograhāt		Cuttack		Raipur		Chinsurah	
	A	B	A	B	A	B	A	B	A	B
<i>Alternaria padwickii</i>	32	20	32	30	47	30	21	22	10	20
<i>Acrocyndrium oryzae</i>	22	—	9	2	24	4	15	4	—	—
<i>Helminthosporium oryzae</i>	16	16	3	2	5	8	8	15	55	45
<i>Curvularia lunata</i>	12	16	3	4	13	16	14	12	8	8
<i>Helminthosporium</i> sp.	2	4	—	—	—	—	—	—	—	—
<i>Fusarium</i> sp.	—	—	2	2	1	2	—	—	4	4
<i>Alternaria</i> sp.	4	—	—	—	—	—	—	—	—	—
<i>Phoma</i> sp.	—	—	2	2	—	—	—	—	5	4
Others (unidentified)	1	—	3	—	2	—	—	—	—	—

A = agar method ;

B = blotter method

Pathogenicity tests :

The fungal cultures isolated from discoloured grains were inoculated on T(N) 1 plants at flowering - maturity stage. The grain discolouration percentage followed after inoculation at harvest with *C. lunata*, *H. oryzae* and *A. oryzae* were 75%, 50% and 53% percent respectively, whereas *A. Padwickii*, *A. longissima*, *Fusarium* sp., *Nigrospora oryzae* produced low percentage of discoloured grains, 8, 5, 7 and 4 percent respectively indicating weak pathogenicity of these fungi. The virulent pathogens such as *A. oryzae*, *H. oryzae* and *C. lunata* produced brown to black lesions on glumes and kernels. Species specific symptoms were not discernable. Reisolations of the three organisms were readily made (80-90%) from the glumes and kernels.

Stage of grain maturity and susceptibility to fungal invasion :

Inoculation of T(N) 1 at three growth stages revealed that at flowering-milk stage, higher incidence of grain discolouration resulted by inoculation of *A. oryzae*, *H. oryzae* and *C. lunata* (Table 5). Whereas *A. padwickii* inoculations resulted in low incidence of grain discolouration at all growth stages. It was concluded that the rice variety T(N) 1 was more susceptible to *A. oryzae*, *H. oryzae* and *C. lunata* at flowering-milk stage than soft dough and hard dough stages.

Table 5. Kernel maturity stage and infectivity percentages when inoculated with 4 different fungi isolated from discoloured grains

Growth stage	Organism				
	<i>A. oryzae</i>	<i>H. oryzae</i>	<i>C. lunata</i>	<i>A. padwickii</i>	<i>Fusarium</i> sp.
	Per cent incidence				
Flowering milk stage	56*	52	75	6	4
Soft dough stage	12	14	8	8	6
Hard dough stage	3	2	5	—	12
Healthy check	2	—	—	—	—

*Average values of 15 panicles collected from 5 replicates.

It was concluded that the rice variety T(N) 1 was more susceptible to *A. oryzae*, *H. oryzae* and *C. lunata* at flowering-milk stage than soft dough and hard dough stages.

Table 6. Effect of grain discolouration on grain quality and viability (germinability) in T(N)1 and IET 2895

Variety		1000 grain weight	Milling recovery	Germination
		(gm)	(%)	(%)
T(N)1	Healthy	22.4a ¹	53.5b	90.0a
	Discoloured	18.3c	38.0c	78.8b
IET 2895	Healthy	22.7a	56.6a	89.0a
	Discoloured	20.3b	52.2b	80.0b

*Average values of 10 samples.

1 - Values followed by the same letter are not significantly different.

Effect of grain discolouration on thousand grain weight, milling recovery and germination:

The data collected on effect of grain discolouration on thousand grain

weight, milling recovery and viability (germination%) in T(N) 1 and IET 2895 are presented in Table 6. The data indicate that the discoloured grains are lighter and break easily in milling and the germination percentage is lower than healthy seed. In both varieties the thousand grain weight, and milling recovery and germination percentage were significantly lower in discoloured grains than in healthy grains. The effect of discolouration on milling recovery and thousand grain weight was more pronounced in T(N) 1 than IET 2895.

Effect of seed treatment on germination of discoloured grain :

An experiment was conducted to study the effect of seed treatment on discoloured grain with different seed dressing fungicides to determine whether the fungicides effectively reduced the microflora associated in with discoloured grain and improved the germination. The results are presented in Table 7.

Table 7. *Effect of different seed dressing fungicides on germination of discoloured grain and qualitative changes in fungal microflora in discoloured grain of IET 2895*

	Active ingredient	Germination percent		%Fungal colonies	Frequency of fungal Colony occurrence
		Blotter ¹	Soil ²		
1. Healthy seed (Check)		96.0a	92.8a	3	<i>Fusarium</i> sp. (2) <i>A. padwickii</i> (1)
2. Agallol (3.0% NEMC)	0.006%	81.0 b	77 b	4	<i>Fusarium</i> sp. (4)
3. Thrim (75% WP)	0.3%	78.0 b	75 b	14	<i>Fusarium</i> (6) <i>A. padwickii</i> (8)
4. Phenochim (EC)	0.2%	76 b	74 b	12	<i>Fusarium</i> (7) <i>A. oryzae</i> (3) <i>A. padwickii</i> (2)
5. Bavistin (50% WP)	0.1%	69 bc	65 c	15	<i>A. tenuis</i> (8) <i>A. padwickii</i> (3) <i>Fusarium</i> sp. (4)
6. Discoloured seed	—	59 c	66 c	50	<i>Fusarium</i> (19) <i>Acrocyllindrium</i> (10) <i>A. padwickii</i> (8) Others (13)

1 Average values of 5 replicates

2 Average values of 10 replicates

3 values followed by the same letter are not significantly different.

The data indicate that Agallol, Thiram and Phenochim significantly improved the germination in discoloured IET 2895 seed. Bavistin was least effective as

seed dresser. The fungal colony recovery studies from discoloured seed, treated with various fungicides showed that Agallol had the highest fungicidal effect followed by Thiram, Phenoxin and Bavistin.

Field evaluation of fungicides to control grain discolouration :

In 1976 field experiment there was very low incidence of grain discolouration in test plots and the treatments differences for grain discolouration and yields were not significant. The data collected on chemical control in 1977 wet season is presented in Table 8. Application of systemic compounds, Bavistin, MBC and Benlate were equally most effective in reducing the disease incidence and increase in grain yields. Dithane M-45 and Dithane z 78 although reduced disease incidence by 13 and 11 percent respectively over inoculated check plots, the yield did not differ significantly from yields of inoculated plots. Apparently there are least effective in controlling the grain discolouration.

Table 8. Effect of different fungicides on grain discolouration and yield of IET 2895 in 1977 wet season

Treatment	% grain* discoloured	Grain weight in kg/ha	% over uninoculated plots
Bavistin	22 b	3860 a ¹	98
Benlate	24 b	4197 a	106
MBC	21 b	3898 a	99
Dithane M-45	35 c	3355 b	85
Dithane Z-78	37 c	3289 b	83
Healthy check (non-inoculated)	18 a	3932 a	100
Diseased check (inoculated)	48 d	3207 b	81

* Average values of 4 replicates

¹ values followed by the same letter are not significantly different at 5% Level.

Varietal susceptibility :

The relative natural incidence of grain discolouration on 17 rice varieties in

wet season 1975 is presented in table 9. Among the early group varieties Ratna and T(N)1 had high incidence followed by Pusa 2-21. Other varieties Rasi (IET 1444), Bala and Tella Hamsa had low ($\leq 10\%$) disease incidence. In mid duration group IR 20 was highly susceptible followed by IET 2895, IR 26, IET 2895, and Vijaya. IET 3005 and Jaya had low disease incidence ($\leq 5.0\%$). In the long duration group Pankaj had low grain discolouration.

Table 9, Grain discolouration incidence on a few commercial rice cultivars in 1975 wet season at Rajendranagar, Hyderabad

Variety	Duration	% discoloured grains
1. Ratna	Early	46.0
2. Bala	"	8.0
3. Tella hamsa	"	4.5
4. IET 1444	"	9.5
5. Pusa 2-21	"	19.0
6. T(N) 1	"	40.0
7. Jaya	Medium	6.0
8. IET 3005	"	3.0
9. IET 2895	"	27.0
10. IET 2815	"	36.0
11. IR 20	"	39.0
12. IR 26	"	30.0
13. Vijaya	"	22.0
14. Sona	"	20.0
15. Mahsuri	Late	12.0
16. Jaagannath	"	18.0
17. Pankaj	"	8.0

* Average values of 10 hills collected at random in Ca 500 sq plots.

DISCUSSION

In the present studies four field fungi *A. padwickii*, *A. oryzae*, *C. lunata* and *H. oryzae* were predominantly isolated from discoloured rice grains of dwarf varieties. Earlier, several workers have reported the association of these fungi

except *A. oryzae* with discoloured rice grains (Fazli and Schroder, 1966; Martin, 1939; Govinda Swamy, 1955; Isao, 1970; Mathur *et. al.*, 1972; Padmanabhan 1949; Vaidehi and Rama Rao, 1972). Isolation of *A. oryzae* in high frequency from different regions of the country might be due to increasing incidence of sheath rot on dwarf rice cultivars (Amin *et. al.*, 1974). Due to the presence of conidia abundantly in the inner side of the boot leaf sheath, the spikelets of emerging panicles readily get infected (Plates I, & II. Figs. 1-2; 4)

Failure to detect the organism by earlier workers might be due to the use of rice medium such as PDA on which the fungal colonies are overgrown by other fast growing fungi or the samples might not have had the pathogen. We isolated these organisms on plain agar plates (with streptomycin sulphate) in higher frequency than blotter method (Table 4). The effect of medium on qualitative and quantitative fungal microflora is well known (Mathur and Neergaard, 1970; Neergaard, 1962; 1970).

Pathogenicity tests indicated that *A. oryzae*, *H. oryzae* and *C. lunata* readily infect the developing spikelet at flowering milk stage (Plates I, & II. Figs. 3a & b; 6). The infections progressively decrease with increasing kernel maturity indicating that tender young seed tissue offer little resistance to fungal penetration (Fazli and Schroder, 1966a, b).

Although *A. padwickii* was isolated in higher frequency, the artificial inoculation tests showed that this organism did not give high infection per cent as compared to *A. oryzae*, *C. lunata* and *H. oryzae*. (Plate II, Fig. 5) However, the cultures readily invade the germinating seedling and eventually kill the seedling. Similar observations were reported by Mathur *et. al.* (1972). Either it is a weak pathogen colonising the injured tissue or we failed to create proper conditions for grain infections to occur. We do not know currently the role of *A. padwickii* in grain discolouration complex.

Studies on grain quality indicate that due to grain discolouration the grains are lighter (reduced 1000 grain weight) and break readily in milling resulting in low milling recovery in head rice. The ubiquitous pathogens and weak pathogens of grain discolouration definitely contribute to grain losses in post harvest phase through low milling recovery. The role of field fungi such as *H. oryzae* in grain quality deterioration is well established in U.S.A. (Fazli and Schroder, 1966a & b).

The systemic fungicides although effectively reduce the grain discolouration in field their wider application by farmers will be limited due to high costs.

Also currently little is known about the residual mammalian toxicity effects of these fungicides. Probably in seed production programmes the systemic compounds may have some use. Our preliminary data indicate the existence of varietal differences in susceptibility to grain discolouration, selection and release of varieties possessing clean hull and good panicle emergence go a long way in reducing the grain discolouration complex.

ACKNOWLEDGEMENTS

The authors thank Dr. R. Seetharaman, Project Director AICRIP (ICAR), for providing facilities to conduct research on this project.

REFERENCES

- Amin, K. S., B. D. Sharma and C. R. Das. 1974. Occurrence in India of sheath rot of rice caused by *Acrocyndrium*. Plant Dis. Repr. 58 : 358-360.
- Bedi, P. S. and D. S. Dhaliwal, 1970. Spermatosphere of rice variety Taichung (Native) 1 from different states of India. Indian Phytopath. 23: 708-710.
- Fazli, S. F. I., and H. W. Schroder, 1966a. Kernel infection of blue bonnet 50 rice variety by *Helminthosporium oryzae*. Phytopathology 56: 507-509.
- Fazli, S. F. I. and H. W. Schroder, 1966b. Effect of kernel infection of rice by *Helminthosporium oryzae* on yield and quality. Phytopathology 56: 1003-1005.
- Govinda Swamy, C. V. 1955. Studies on seed borne fungi of rice. Madras Agric. J. 42 : 50-55.
- Isao, S. 1970. A report on the incidence of discoloured and unfertilized grains on rice panicles in south Kanara Kharif 1969. Indo Japanese Agricultural extension Centre, Mandya, Mysore State, India.
- Johoston, A. 1958. Fungicidal treatment of paddy seed. Malay. Agric. J. 41 : 282-209.
- Martin A. L., 1939 Possible cause of black kernel in rice. Plant Dis. Repr. 23 : 83-84.
- Mathur, S. B., and P. Neergaard, 1970. Seed health testing of rice I. Seed borne fungi of rice in Philippines, India, Portugal and Egypt. Investigations on *Trichochochis padwickii* In plant disease problems Proc. of the first Int. Symp. on Plant Pathology, I. P. S. IARI, New Delhi.
- Mathur, S. B., J. I. Mallaya and P. Neergaard 1972. Seed borne infection of *Trichochochis padwickii* in rice. Distribution, damage to seed and seedlings, Proc. seed. Test. Ass. 37 : 723-730.

- Neergaard, P. 1970. Seed pathology of rice pp. 57-67. In Plant Disease Problems. Proc. of the first Int. Symp. on Plant Pathology, I. P. S. IARI, New Delhi.
- Neergaard, P. 1962. Seed health testing of rice. A contribution to the development of laboratory routine testing methods, Ind. Phytopath. 15 : 85-111.
- Neergaard, P., A.K. Lambat and S.B. Mathur, 1970. Seed health testing of rice III. Testing procedures for detection of *Piricularia oryzae* Cav. Proc. Int. Seed Test. Ass. 35: 157-163.
- Ou, S. H. 1972. Rice diseases. 368 pp. Commonwealth mycological Institute, Kew, Surrey, England.
- Padmanabhan, S.Y., 1949. Occurrence of fungi inside rice kernels. Curr. Sci. 18 : 442-443.
- Padmanabhan, S.Y., 1974. Control of rice diseases in India. Indian Phytopath. 27 : 1-28.
- Padwick, G.B. 1950. Manual of rice diseases 198 pp. Kew, Commonwealth Micological Institute.
- Roy, A.K. and P.K. Baruah, 1972. New records of fungi causing discolouration of rice grains. Sci. Cult. 38 : 405-406.
- Rao, P.N. and M.A. Salam, 1954. *Curvularia* sp. from discoloured grains from Hyderabad on J. Ind. Bot. Soc. 33 : 263-271.
- Schroeder, H.W. 1964. Grain discolouration in Belle Patna Rice Plant Dis. Reprtr. 48 : 283-291.
- Suryanarayana, D. Ramnath and L. Shashi Prabha, 1963. Seed borne infection of stack burn disease of rice, its extent and control. Indian Phytopath 16 : 222-223.
- Vaidehi, B.K., and P. Rama Rao. 1972. Fungi from three varieties of rice seed. Indian Phytopath. 25 : 547-550.

EXPLANATIONS OF PLATES

Plate I

- Fig 1 : Panicles of IET 2895 rice selection affected by grain discolouration.
- Fig 2 : Discoloured and healthy grain of TN (N) 1. Note the shrivelled and slightly discoloured kernels of discoloured grains.
- Fig 3 : Panicles showing grain discolouration when inoculated with
- (a) *C. lunata*
 - (b) *H. oryzae*

Plate II

- Fig 4 : Sheath rot and grain discolouration when inoculated with *A. oryzae*
- Fig 5 : *A. oryzae* colony development on plain agar from discoloured grains (8 days after seeding).
- Fig 6 : Brown lesions on plumule and radicle caused by *A. padwickii* infection.