BREEDING FOR RESISTANCE TO *PIRICULARIA ORYZAE* IN RICE (*O. SATIVA*).

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Introduction.

That fungus diseases cause annually a heavy loss in the important food crops is well recognised. In more advanced countries like Britain, Canada and the United States of America, there are agencies like " National Disease Surveys " which obtain and compile information regarding the range of plant diseases and crop losses due to disease. Such an organisation does not exist for India nor for any other country in the tropics. Neil E. Stevens (1933) compiling all the available information with regard to the diseases occurring in rice, mentions that over 60 diseases have been recognised and reported in available literature. In the list furnished by him, however, we find only six out of the 60 reported, as occurring in India. This does not mean that the rice crop of India is comparatively more free than in other rice growing countries like Japan, Philippines and America. This can only be due to the fact that very little has yet been done with regard to diseases occurring in rice in India. In several cases the incidence of a disease is not recognised except when it occurs in an epidemic form causing very great damage to the crop.

Piricularia in rice is known to occur in all the rice growing countries and the disease was first recognised in Japan even 200 years ago. Its existence in South India was not, however, recognised until 1918 when it appeared in an epidemic form in some portions of the Tanjore district causing over 60 to 80 per cent. loss of the crop in certain localities. The particular variety of rice, which was found attacked, *korangusamba,* had been grown for a long time in the eastern portion of the Cauvery delta in single crop lands. The trouble started only when it was taken to the western portion of the delta where people, because of its prolificacy, began to grow the variety in both single and double crop lands.

Dr. MacRae (1918) took up the study of this fungus and observed great variations in the occurrence of the disease among the different cultivated

varieties. Sundararaman (1921–1932) later continued the investigations on this disease in rice, other cereals like *ragi* (*Eleusine coracana*) and wheat and other grasses. Thomas (1930) carried out actual experiments to determine the relative resistance of several varieties of rice from the Paddy Specialist's collections to this disease. It was found that some varieties remained practically immune while others like *korangusamba* of Tanjore showed 70 to 80 per cent. infection. He also found that certain morphological characters like the size and inclination of the boot-leaf, the degree of emergence of the ear from the enclosing leaf sheath and the density of the earhead had some relationship to the incidence of the disease. His studies also showed that the disease varied in its intensity according to the environment, plots of high fertility showing greater incidence than comparatively poorer plots.

The fact that certain varieties of rice are resistant to the disease does not solve the problem as the same types cannot be grown everywhere because of the obvious differences in the requirements and conditions of rice-growing which vary from place to place, each tract having its own special set of varieties suited to its climatic and soil conditions. That this particular susceptible variety is still grown on an area of over 100,000 acres every year in Tanjore means that its yield and other agronomic qualities far outweigh the consideration of the risk due to loss caused by the disease when it does occur. Obviously the work resolved itself into one of building up by hybridisation a *korangusamba* type resistant to *piricularia*.

Scope of Work and Materials Used.—Breeders have sometimes obtained forms of crops resistant to diseases even by ordinary selections as in the case of Howard's wheats and Shaw's *rahar* (*Cajanus indicus*), but instances of resistant forms obtained by deliberate hybridisation between known parents are still rare in India. The possibilities of such work can be realised from the results recorded in this note.

Thomas's experiments had shown that two of the strains, GEB. 24 and Co. 4 evolved by the Paddy Specialist mainly for increased yields were highly resistant to *piricularia*. So these formed the parental material to be crossed with the susceptible variety, *korangusamba*. The cross between GEB. 24 and *korangusamba* was the first to be undertaken in 1926–27, and this will be dealt with in greater detail because of the conclusive and satisfactory results that have been obtained in this cross. The other cross Co. 4 × *korangusamba* was not taken up until three years later and the work has not yet advanced sufficiently.

Cross GEB. 24 × korangusamba.—86 F_1 plants were grown in 1927–28 and the descriptions of the parents and F_1s are given in Table I (Top).

TABLE I.

Cross GEB. 24 × korangusamba (1927–28).

	Average flowering duration (days)	Average height per plant Ft. in.	Average number of tillers per plant	Average emergence of earhead cms.	Average length of earhead cms.	Disposition of boot-leaf angle (degrees)	Percentage of unsetting	Remarks
T. 24 parent ..	107	3 10	54	6·0	26·8	65	9	* The unsetting here more refers to the usual spikelet sterility occurring in F_1s of certain crosses among rice varieties and not due to disease.
F_1 ..	118	4 5	73	4·1	26·8	34	70*	
Korangusamba parent ..	144	4 4	53	0·9	22·8	3	20	

Cross Co.4 × korangusamba (1930–31).

	Average flowering duration (days)	Average emergence of earhead (cms.)	Average length of earhead (cms.)
Co. 4 parent	142	4·20	24·17
F_1	136	5·33	26·05
Korangusamba parent	138	1·65	25·17

The disease was present in the F_1 though in a much milder form than in the susceptible parent *korangusamba*. Only 16 F_2 families were grown in the following year which gave a population of 30,000 plants. Elaborate notes were taken of 8,000 plants individually with regard to the degree of disease incidence by the appearance of disease spots in the leaf, the stem, and the neck of the panicle. The plants were also examined for the morphological characters like the angle of the boot-leaf, hairiness on the leaf, degree of emergence of the panicle, etc., to see if there was any correlation between the appearance of the disease and the above characters. Most of the characters except the colour of the grain exhibited complicated inheritance, the figures being not analysable into simple ratios. As an example, the inheritance of flowering duration may be mentioned here. The parents were definitely different for duration, one being markedly earlier than the other. The F_1 was more like the early parent, but in the F_2, in the several thousands of plants studied there was none which either had the same duration as the later parent or exceeded it, though a number of types were obtained definitely earlier than the early parent. The inheritance of disease infection is dealt with later, but even here the classification was made complicated because of the variation in the appearance of the disease even on the

same family grown in different fields and in addition there was greater variation in the degree of disease incidence from season to season due to climatic factors. The only line pursued was to select a large number of plants which resembled *korangusamba* in their vegetative and grain characters but which were free from the disease as identified by the absence of disease spots in the leaf, stem and neck. The F_1 and F_2 had been grown at the Paddy Breeding Station, Coimbatore, but the F_3 and subsequent generations were grown in a separate area where the Mycologist had been carrying on his experiments with this disease in the Central Farm wet lands. The assured presence of the disease from year to year in this area, its virulence alone varying according to season, removed to a great extent, the difficulty of the want of uniformity in the occurrence of the disease in the area where the crop is grown.

Every family in the F_3s and subsequent generations was grown interspaced with the susceptible variety, which served the double purpose of providing infection and as a control to estimate the degree of disease incidence in the selections. Selection and elimination of types in later generations were guided firstly by their freedom from the disease, secondly by their apparent homozygosity for other characters and lastly by their yielding capacity. The results may be summarised as below :—

1929–30. F_3.—1,200 families under observation and 450 selections made mainly for absence of the disease.

1930–31. F_4.—Most of the 450 families did not show disease but were heterozygous for other characters. Only 40 apparent homozygous families selected.

1931–32. F_5.—Disease absent in all the 40 ; rough comparison of yield to eliminate obviously poor ones. Only 12 retained.

1932–33. F_6. All 12 families conspicuously free from disease which was very severe in the season. One eliminated as still heterozygous for flowering duration and 11 retained.

1933–34. F_7.—Regular yield trials with *korangusamba* as the control. All facilities were provided for the families to take the infection, firstly by trampling into the transplant fields the diseased straw of the previous season, and later by spraying on the plants, just before heading, a spore suspension of the fungus.

All 11 remained free, while the control suffered badly. Six gave higher yields than the control, the increase varying from 10 to 50 per cent. as shown below :—

Strain numbers	3725	10965	10998	11340	11348	11394	Control	Percentage standard error
Yield expressed as percentages of control.								
..	134	112	154	118	116	135	100	6·64

1934–35. F_8.—Repetition of yield trials with the six, both at Coimbatore and at the Agricultural Research Station, Aduturai. Adt. 10 an improved strain from the variety *korangusamba* was used as an additional control. Season was unfavourable for the disease and the control was also practically free from the disease. Still, 4 of the strains yielded over 10 per cent. bigger yield than the control. The results obtained are given below :—

Strain numbers	3725	10965	10998	11340	11348	11394	*Korangu-samba*	Adt. 10	Percentage standard error
Yield expressed as percentages of control.									
Coimbatore	95	97	113	102	114	95	90	100	2·88
Aduturai ..	98	99	111	113	100	100	..	100	2·24

It follows from what has been stated above that some of the strains are capable of giving phenomenally higher yields of 30 to 50 per cent. than *korangusamba* when the latter suffers from the disease, and reasonably heavier yields of 10 to 14 per cent. when the latter is free and yields normally. Extensive trials have now been undertaken with these two strains at a number of centres in the districts and if the results are favourable, as they are expected to be, judging from the two years' results, we would have achieved a big advance in the production of forms by hybridisation combining yield and disease resistance.

Cross Co. 4 × korangusamba.—It was pointed out earlier that none of the selections from the cross GEB. 24 × *korangusamba* approached *korangusamba* in duration. The selections actually under trial are about a week earlier than *korangusamba*. The inheritance studies in other families have given indications of the existence of a positive correlation between yield and duration making it possible that a strain of the same duration as *korangusamba* would be still better in yield. It was with this idea that the cross Co. 4 × *korangusamba* was undertaken, both of them being of the same duration. Unlike in the previous cross the disease resistance was absolutely dominant in the F_1. The characters of the F_1 and the parents

are given in Table I (bottom). This cross has now come to the F_6 stage. From the examination of the material, so far made, it would appear that there are possibilities of getting results here strikingly better than from the previous cross.

Inheritance of Piricularia *Resistance.*—As regards inheritance of disease resistance, the F_2 ratios obtained in the two sets of crosses may be examined.

F_2 ratios	Diseased	Disease-free	F_1
GEB. 24 × *korangusamba* ..	248	63	Intermediate
Co. 4 × *korangusamba* ..	161	311	Resistant

From the appearance of the F_1 and the F_2 ratios in the two crosses it may be said that the nature of inheritance is different in the two crosses. Though it has not been possible to pursue the inheritance studies beyond F_3, observations on the incidence of disease would appear to show that the resistance may be a simple recessive in the first cross and a little more complicated in the other. In the former cross, selections made in F_3 for freedom from the disease straightaway began to breed pure for this character. In the latter cross, however, a certain number of disease-free selections threw diseased progenies and the obtaining of pure-breeding disease-free selections has been a little more difficult. One parent has been common for both the crosses but still the inheritance is different in the two cases. Such differences in the inheritance behaviour of a character have been recorded by Ramiah (1933) previously for other characters in rice. The difference cannot possibly be due to the organisms causing the disease in the two crosses being different physiologically inasmuch as the susceptible variety was the same in both the crosses.

Though some tangible and valuable results have been obtained from the breeding work, there still remains a considerable gap in our fundamental knowledge about this disease-producing organism. A large amount of work has been done in this fungus in Japan where the disease was observed even 200 years ago. S. Konishi (1933) and Tadayosi Nose (1935) who have examined the fungus collected from the several localities of Corea, Formosa and Japan, first cultivating them and testing their pathogenetic activity in different types, have come to the conclusion that there are different physiologic forms of the fungus. Such a work yet remains to be done in India. But the mere discovery of physiological forms need not necessarily frighten the breeder though it only makes the work of breeding resistant forms more laborious and time-taking. The experience of breeding for

resistance to diseases in other cereals has shown that several of the physiological forms fall into groups and go together so that a type resistant to one form has been found to be equally resistant to a number of other forms as well. There are reasons to believe of a similar feature in rice also.

Apart from determining the physiological forms of the fungus we want more information about the relationship between the seasonal and climatic factors and the disease incidence. Our observations on this disease during the last 8 or 9 years both here and at Aduturai definitely show that the prevailing climatic conditions, of which rainfall may be one, have some influence on the appearance of the disease each year.

TABLE II.

Relation between incidence of disease and distribution of rainfall.

Year	Coimbatore		Aduturai	
	Rainfall	Incidence of disease	Rainfall	Incidence of disease
1927—28	Below average—dry weather during early vegetative growth as well as during and after flowering.	Very mild	North-east monsoon thorough failure.	Nil
1928—29	Fairly normal during the vegetative as well as flowering phases.	Severe	Very heavy during vegetative and flowering periods.	Mild
1929—30	Normal—well distributed.	Severe	Very heavy—right through the life of the crop.	Very severe
1930—31	Above average.	Fairly severe	Heavy rains during early vegetative growth—normal later on.	Mild
1931—32	Normal and well distributed.	Mild	Heavy rains during vegetative growth and flooded conditions at the flowering period.	Nil
1932—33	Normal and well distributed.	Fairly severe	Normal and well distributed	Nil, in spite of artificial infection
1933—34	Good rains during early vegetative growth. Bright weather during flowering.	Fairly severe	Fairly good rains during vegetative as well as flowering periods.	Nil
1934—35	Much below average—dry weather during vegetative as well as flowering periods.	Nil	Much below average—dry weather during vegetative as well as flowering periods.	Severe
1935—36	Very much below average. Fairly humid conditions during the shot-blade and flowering stages. Dry weather after flowering.	Extremely severe	Good rainfall in the early stages followed by too heavy a precipitation when the crop was in flower and grains were forming.	Severe

Environmental conditions also play a part. For instance in some seasons by planting the crop early, even by a week, serious incidence is avoided. Thomas (*loc. cit.*) had found that too high fertility of the field, usually reflected in rank vegetative growth of the plant, was a predisposing cause for the occurrence of the disease. Suzuki (1933) of Japan finds that the susceptibility is in inverse proportion to the water content of the soil in which the plant grows and resistance is definitely greater in plants in flooded soils than in dry soils. Several of these points require more careful study under the conditions obtaining in South India.

Regarding resistance to the disease brought about by external characters of the host plant, Thomas's observations regarding flag-leaf, emergence of panicle, etc., since confirmed by our studies, are at best only indications that could be utilised, in making selections in cross progenies. Very little work has yet been done here with regard to resistance and cellular structure of the host plant, though Suzuki (*loc. cit.*) finds a relationship between resistance and the thickness of the outer walls and of the silicated outermost layer of the epidermal cell. He has observed also greater resistance by applying soluble silica to the soil under flooded conditions.

The knowledge about the cell sap and resistance to *piricularia* is also very meagre. In our work at Coimbatore we tried to determine the pH value of the cell sap of the resistance variety Co. 4 and the susceptible variety *korangusamba*. Certain preliminary tests showed that the sap of the resistant type was slightly more acidic but whether this has anything to do with the resistance is not known. Moreover the pH determinations have not also been done on an extensive scale.

A comprehensive attack on the whole problem of resistance should require the application of advanced knowledge of plant physiology, plant pathology and genetics but it would be safe to assume that the breeder need not actually wait until the plant physiologist or the plant pathologist has made sufficient progress to find a satisfactory explanation for all the varied phenomena connected with resistance. That plant breeders were able to produce disease-resistant forms even long before the present advance in the knowledge concerning the physiology of the organisms was reached is a sure enough evidence for this assumption.

Recently the seeds of both the susceptible variety (*korangusamba*) and the resistant variety (Co. 4) have been subjected to X-ray treatment and they have produced several mutations in morphological characters. How these will behave with regard to the physiological character of resistance or susceptibility to *piricularia* is under study.

Summary.

The disease, *piricularia,* was first noticed in Madras when it appeared in an epidemic form attacking a particular variety of rice, *korangusamba,* in portions of the Tanjore district. The studies on the fungus by the Mycologist had shown that there was a wide range of susceptibility of rice varieties to the disease, some remaining practically immune while varieties like the Tanjore one showing 70 to 80 per cent. incidence.

Work of breeding forms resistant to *piricularia* was undertaken by the Paddy Specialist in 1926. Two of the strains evolved by him, GEB. 24 and Co. 4 which were determined to be highly resistant, were crossed with the susceptible variety from Tanjore. The inheritance of disease resistance appeared to be simple in the cross GEB. 24 × *korangusamba* and more complicated in the cross Co. 4 × *korangusamba.* In the former cross disease-free selections from F_3 onwards bred pure for freedom and two of these after two years' trial both at Coimbatore and Aduturai have been found to give a big increase in yield over the susceptible variety (10–50 per cent.), the increase being more or less according as the susceptible variety gets the infection or not. Selections from the other cross are still under study and appear even more promising than the first.

We are indebted to the Superintendent, Agricultural Research Station, Aduturai, for the figures of yield trials conducted there.

Postscript.

Since the above paper was written, the yield figures of another year's trial at Coimbatore and Aduturai have become available. The season was particularly favourable for the disease, especially at Coimbatore and consequently the susceptible variety suffered badly. From the data given below, the two strains Nos. 10998 and 11340 that did well in the two previous seasons have again come out very much better than the control.

Yield figures for 1935–36.

Strain Numbers	3725	10965	10998	11340	11348	11394	Adt. 10	Percentage standard error
Yield exprersed as percentages of control.								
Coimbatore ..	136	153	180	166	165	156	100	4·00
Aduturai ..	102	96	114	118	112	108	100	4·22