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SOME ASPECTS OF THE CONTROL OF BLAST DISEASE OF PADDY

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Introductory.—The 'blast' of paddy is known in almost all the rice-growing countries of the world. It has been recorded from Italy, Russia, China, Japan, United States of America and India. In India, it has been known to occur in Bengal, Behar and several districts of Madras. It is the most important disease of the Paddy crop in South India and in bad years has been reported to cause losses up to seventy per cent of the yield. Rice being the staple food of the South Indian, paddy ranks first in importance among cultivated crops and the area under paddy in Madras runs to about 11½ million acres. The control of a disease of such destructive possibilities is therefore of profound importance from an economic view point.

The cause of the disease.—The disease is caused by a fungus (*Piricularia oryzae*, Cav.) which attacks almost every portion of the plant, viz., the leaves, leaf-sheaths, nodes, the neck of the ear, the branches of the panicle, the glumes and rarely the internodes. The disease generally makes its first appearance on the leaves in the form of tiny brown spots which develop into oval or elongated lesions provided with a narrow brown marginal ring and a grey centre (Plate I, Fig. 1) on these spots minute hyaline three-celled pear-shaped spores (conidia) are borne in profusion. Two or more adjacent spots may coalesce to form irregular patches of dead tissue which in large numbers cause the withering of leaves (Plate III,) and in extreme cases the complete death of the plant. On the culm the attack is conspicuous on the nodes, the neck and branches of the ear which are killed and turned black, often breaking the stalk at the point of attack (Plate I, Figs. 4, 5, 6 and 7). If the attack takes place at the time of the emergence of the ear, the head fails to emerge, and the crowded flowers take the infection and entirely fail to develop (Plate I, Fig. 3). When the neck of the ear is attacked before the grains pass the milk stage, the whole earhead is starved by the cessation in the ascent of sap and the glumes are chaffed in consequence. Individual branches of the panicle so attacked are killed and the flowers borne on them fail to develop (Plate I, Fig. 2).

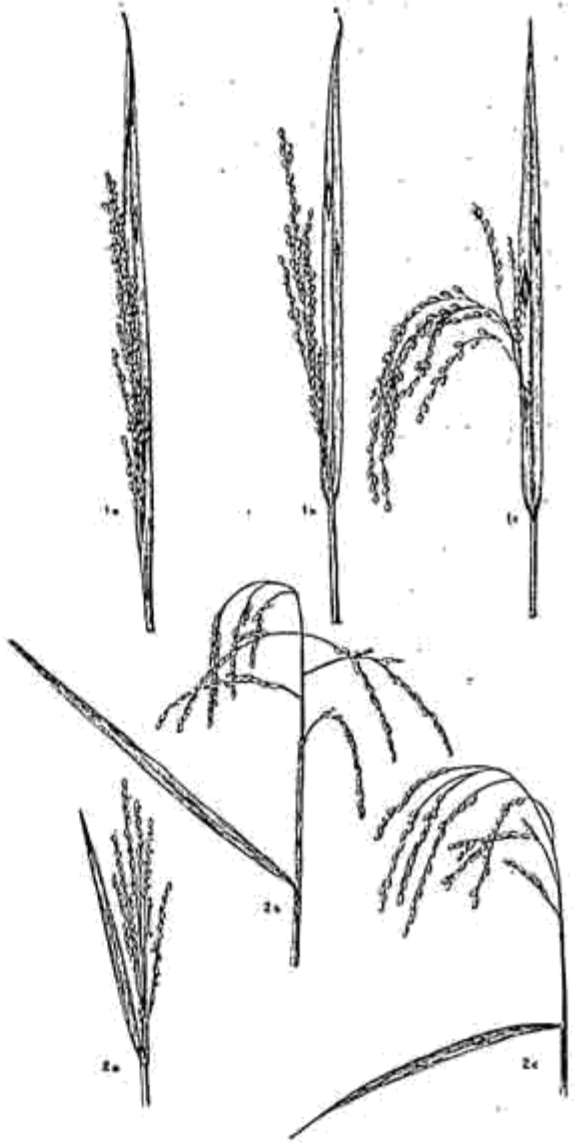
History of the disease.—Though Cavara recorded and described the disease in Italy as early as 1897, our knowledge of the disease has till recent years remained very meagre. The existence of the disease in South India was first recorded in 1918 when a serious outbreak in the Tanjore Delta brought it to the notice of the Madras Mycologist. The investigation of the disease was immediately taken up at Coimbatore and Dr. McRae[1]

[1] McRae, W., *Jour. Madras Agric. Stud. Union*, vol. vi, pp. 115-120 and *Agricul. Jour. India*, vol. xiv, pp. 65-70.

Plate I

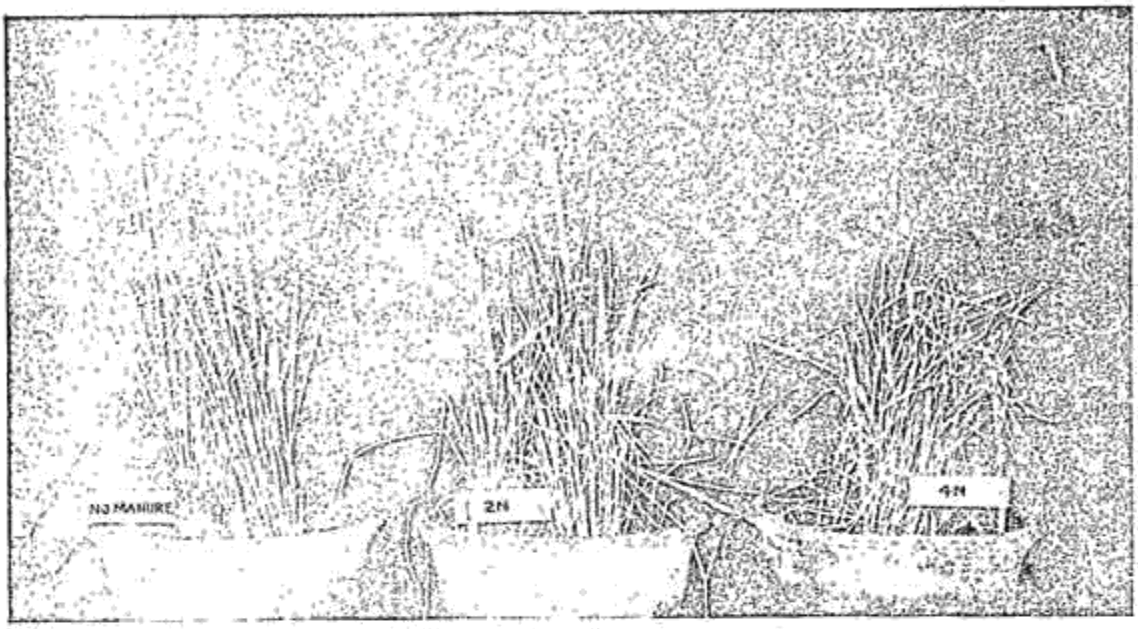
The effect of the ' blast disease ' on paddy. 1. Leaf showing spots and blackening of ' neck '. 2. A branch of the panicle broken at the point of attack. 3. The disease preventing emergence of the ear. 4, 5, 6. Attacked nodes. 7. An attacked neck.

Plate II

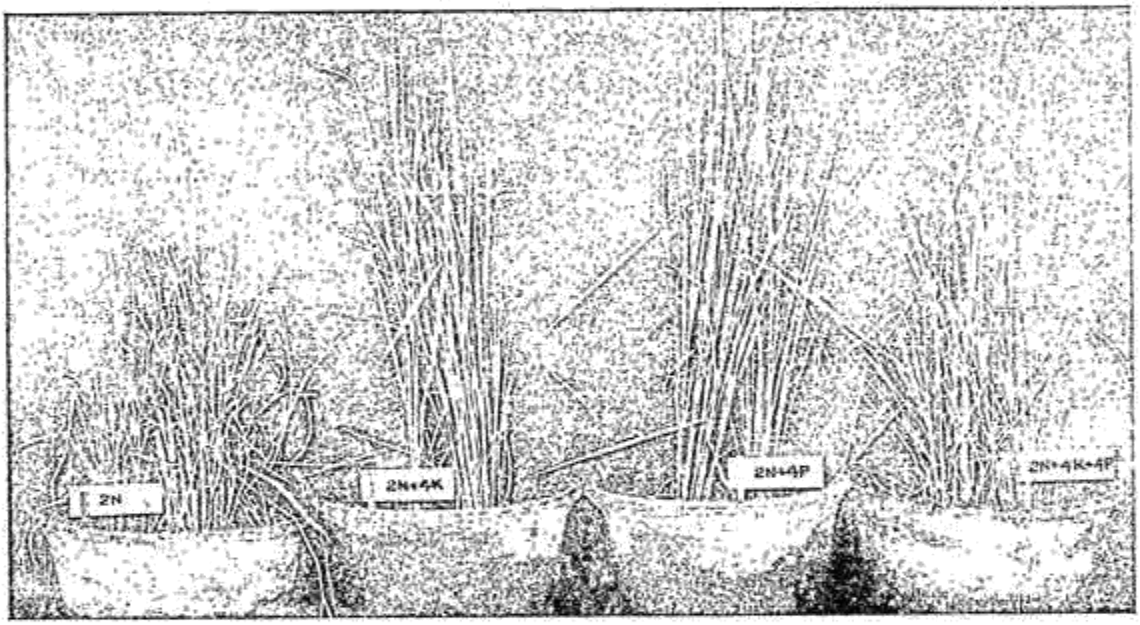


Above.—A variety susceptible to blast showing broad and erect 'flag ', short emergence and close panicle (3 stages).

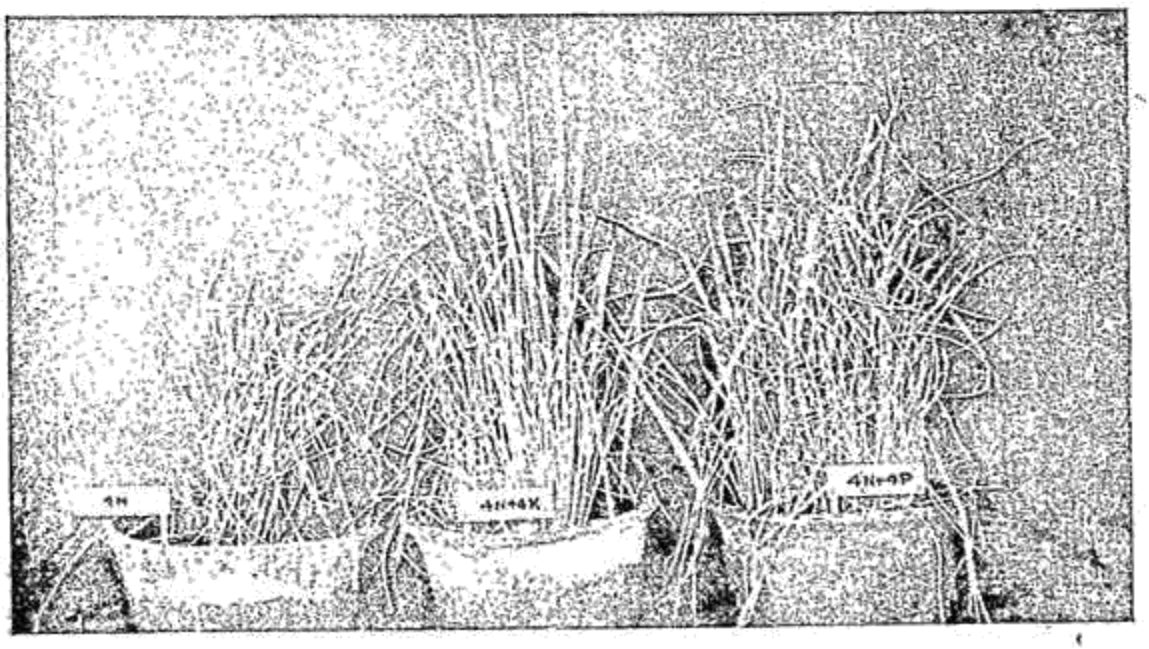
Below.—A resistant variety showing reclining ' flag ', long emergence and spreading panicle.



1. The effect of varying doses of Nitrogen on a susceptible variety (*Korangu samba*) infected by Piricularia.



2 The inhibitory effect of Potash and Phosphate in the presence of Nitrogen.



3 The effects of Potash and Ph sphates are not felt when a heavy dose of nitrogen is applied.

made exhaustive studies on the symptoms of the disease and the morphological characters and parasitism of different strains of *Piricularia* isolated from a wide range of hosts, viz., Paddy, *Ragi* (Eleusine coracana), *Tenai* (Setaria italica), Wheat (Triticum vulgare), *Panicum repens* and *Digitaria sanguinalis*. About the same time Nishikado[1] in Japan made independent studies of some strains of the fungus collected in Japan. This paper does not attempt to review the work of these pioneers of Piricularia research or to recapitulate their observations, but is merely an effort to record what is really a sequel to Dr. McRae's valuable work on the subject.

Methods of propagation and distribution.—As far as our present knowledge goes, the fungus is propagated through its spores and mycelial threads. In a dry condition the spores of the fungus have been observed at Coimbatore to remain viable up to a period of seven months—a period sufficiently long to bridge the gulf between two successive paddy crops. Nishikado has recorded that the spores are known to live up to a period of eight months in Japan. The straw and stubbles of an infected crop have been observed to harbour the mycelium of the fungus and under favourable conditions of moisture are capable of producing new crops of spores. It is therefore evident that the fungus is capable of tiding over the off season and it is difficult of complete destruction once it has made its appearance in a field of paddy. Experience at Coimbatore goes to show that the disease recurs year after year in a previously infected field provided a variety of paddy susceptible to the disease is raised in it.

The fungus is spread from plant to plant through the agency of wind and rain. Infected straw and chaff are responsible for the dispersal of the fungus to much greater distances while infected grain distributed through human agency may carry it across all natural barriers.

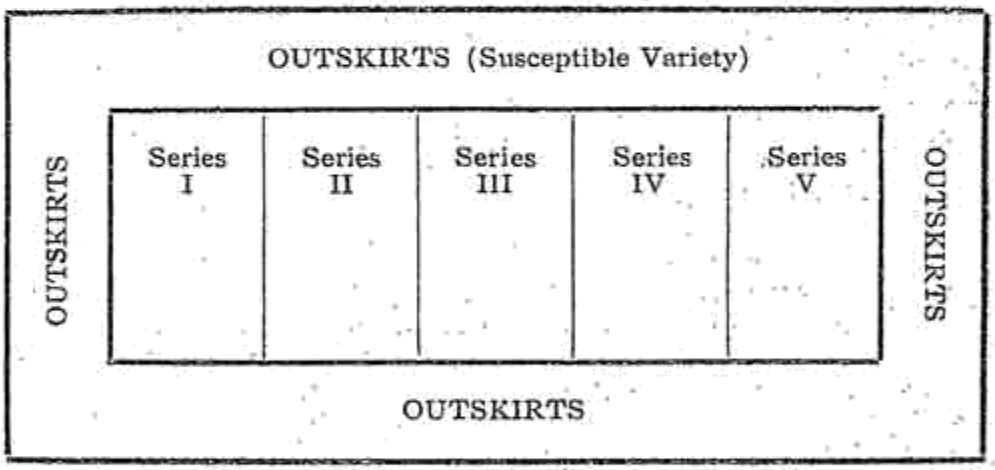
Limitations in the control of the disease.—Under South Indian conditions, the outbreak of *Piricularia* is closely linked with the weather prevailing during the paddy season. The sporadic nature of the outbreak and the rapidity of the spread of the disease do not admit of the usual measures of preventive and curative treatment feasible with ordinary crop diseases. Once the disease gets a foothold on the crop, it spreads like wild fire over extensive stretches of paddy fields, so that the problem of controlling the disease has baffled the best efforts of the plant pathologist.

Study of varietal differences in resistance to the disease.—In the light of the above observations, the chief avenue open to the pathologist is the exploitation of the possibilities of *indirect* methods of disease control. A casual survey of paddy crops in different tracts showed that while some varieties were bad victims to the disease, other varieties grown in the vicinity of infected fields and under apparently identical conditions did not suffer to the same extent, while some totally escaped the attack. But such observations were of limited value for immediate practical application so that

[1] Nishikado, Y. *Studies on the Rice blast disease, Berichte des Ohara Inst., Japan*, 1917, Band. I, Heft 2, pp. 171-218.

an attempt was made at Coimbatore to gauge in a scientific manner the relative resistance of several varieties of paddy to the disease, with a view to put the knowledge so acquired into practical application.

Lay out of the Experiment.—Sixteen varieties of paddy (types) grown at the Paddy Breeding Station, Coimbatore, were selected, special attention having been paid to include those which showed a wide range of variation in their duration and morphological characters. In order to grow these varieties under identical conditions of soil, climate, manuring, irrigation, exposure to spore-bombardment, etc., a rectangular block 120 feet by 60 feet was marked out in a plot in the Central Farm wetlands. Seedlings were raised in specially prepared strips and healthy single seedlings of each variety were planted in this block in equidistant rows running east to west, each row representing a variety. The distance between rows was one foot and the distance between plants in a row six inches. The series was replicated five times as in the adjoining plan. The outskirts of this rectangular block were planted 20 feet deep on all sides with *Poombalai* a variety in which the disease recurred every year. To make sure of the infection of the outskirts, pure cultures of the fungus were multiplied by inoculating the fungus on sterilized stalks and ears of paddy and the outskirts were sprayed before sunset with a spore suspension in distilled water at an opportune season when a spell of wet weather marked by cloudy days and drizzling rain prevailed during the month of September.



PLAN OF VARIETAL TRIALS

Method of observation.—In due course, the fungus spread rapidly through the outskirts and by the end of October the varieties were subject to a regular spore bombardment from the outskirts. It was noticed that there was considerable variation among the varieties in the number and size of spots on the leaves and the number of tillers affected per plant. Infection of the vegetative portions did not by any means give a correct indication of the loss to the crop as the latter almost entirely depended on the infection of the 'neck' and the nodes of the culm. A more correct method of estimating the loss was devised which consisted in the careful examination of the nodes, neck and panicles of every tiller and striking the percentage of infected tillers per each row of plants. The task was, no doubt, laborious

but the time and labour expended on it were amply rewarded. The following table summarizes the results of the experiment :—

TABLE I.—*Piricularia Experiments*, 1925-6. *Varietal Series.*

No.	Variety	Duration (from sowing to flowering) in days	Percentage of infection
1	*Safeda*	100	Nil.
2	*Elanikadan*	98	0·5
3	E. B. 24	111	0·1
4	P. S. 67	109	.14
5	Co 1	120	0·5
6	P. S. 65	125	2·0
7	E. B. 301	126	2·9
8	Co 2	128	23·1
9	Co 3	132	24·1
10	*Kattai Sambalai*	153	73·0
11	*Sadathilai*	153	75·3
12	Adt 1	152	73·1
13	Adt 2	151	78·2
14	*Korangu Samba*	153	73·5
15	*Nellore Samba*	155	13·0
16	*Sadai Samba*	147	24·2

It is seen from the above table that, within certain limits, the early maturing varieties show a relatively lower percentage of infection. It stands to reason that spore-infection increases in geometrical progression and since the early varieties come into flower at a period when the spores are comparatively less numerous, the spore bombardment is less intense. But the fact cannot be ignored that there is a wide range of variation among some varieties which are approximately of equal duration and which one should attribute to their inherent variation in disease resistance or special adaptation for disease avoidance.

The success of the above experiment in proving the existence of differences in varietal susceptibility to the disease, encouraged further trials on similar lines. With the experience gathered, the lay out of the experiment was slightly modified in subsequent years. The short duration

varieties were discarded in favour of long duration ones and departmental strains evolved from pure line selections replaced the types originally tried. *Korangu Samba* which was one of the most susceptible varieties replaced *Poombalai* for bulk planting in the outskirts and every varietal row was alternated with a row of *Korangu Samba*. The need for spraying spore suspensions on the growing crop was obviated by the use of the same piece of land for future experiments and the use of a highly susceptible variety like *Korangu Samba* in the outskirts and alternate rows. On the basis of grain development in the infected tillers, they were classified as 'lightly infected' and 'heavily infected.' The results of these trials were in general conformity with previous results as the following table shows :—

TABLE II.—*Piricularia Experiments*, 1928-9. *Varietal Series*

No.	Variety	Duration (from sowing to flowering) in days	Total number of plants	Total number of tillers	No. of infected tillers	Percentage	No. of heavily infected tillers	Percentage
1	E. B. 24 ...	105	160	1816	33	1·8	Nil.	Nil.
2	Co 1 ...	108	160	1735	85	5·4	Nil.	Nil.
3	Co 2 ...	120	160	1991	832	41·6	569	28·5
4	Co 5 ...	122	160	2056	1508	73·3	1042	50·6
5	Co 7 ...	122	160	1914	908	47·4	393	15·1
6	Co 3 ...	126	160	1680	1395	83·0	652	38·7
7	Co 6 ...	132	160	1720	831	48·3	227	13·2
8	Adt 2 ...	143	160	1126	977	86·7	438	38·8
9	Adt 1 ...	146	160	1794	1490	83·0	550	30·6
10	Adt 5 ...	148	160	1821	1380	75·7	408	22·4
11	A. E. B. 3 ...	151	160	1438	1438	100·0	1165	81·0
12	Co 4 ...	152	160	1807	29	1·6	Nil.	Nil.

Note.—' Infected ' denotes the presence of infection on the leaf, node, neck, panicle or individual grains.

' Heavily infected ' denotes the condition in which the disease interferes (directly or indirectly) with the development of grain affecting the yield seriously.

Morphological characters in relation to the disease.—It is common knowledge that Paddy exhibits varietal differences in morphological characters, viz., size of leaf, inclination of the ' shot-blade ', spread of panicle, size of

grain, etc. Detailed observations on the incidence of the disease in the experimental plots suggested the existence of some relationship between morphological characters and the incidence of the disease. In the vast majority of infected tillers the loss to the crop was due to the infection of the lowest node of the panicle popularly known as the 'neck' of the earhead, for the simple reason that an attack of the neck involves the cessation of sap flow to the whole earhead (Plate I, Fig. 6). The preponderance of neck attack over other forms is attributable to two reasons. Firstly, the grooved nature of the internode immediately above the 'neck' which facilitates the conduction of spore-laden droplets of rain or dew down the ear and secondly, the existence of a fringe of short hairs borne at the telescopic ring of the node which functions as a convenient resting place and incubation ground for the spores deposited on it. It is therefore obvious that, at least to some extent, factors which aid the supply of a regular crop of spores to this vulnerable spot determine the capacity for infection. The chief factors to be considered under morphological characters are :—

(i) *Size and inclination of the shot-blade.*—Other conditions being equal, the larger the area of the leaf surface, the greater are the chances of air-borne spores lodging on the shot-blade or 'flag' and producing disease spots. Again, the inclination of the 'flag' to the horizon is a variable factor among paddy varieties. In some varieties like *Korangu Samba* the 'flag' stands vertical throughout the life of the plant while varieties like E. B. 24, Co 1 and E. B. 301 bend their flags soon after the emergence of the ear so that they stand almost horizontally (Plate II). An infected flag which stands erect is a constant menace to the ear it subtends, because the former functions in a three-fold capacity, (*a*) a nursery for the fungus which supplies an abundant and regular supply of spores ; (*b*) a channel for conducting the spores in drops of rain or dew to the base of the leaf-blade where they are collected by the ligular hairs and brought in contact with the panicle ; and (*c*) a convenient dissemination ground advantangeously situated by virtue of its altitude to command a wide area for spore dispersal through the agency of wind or through rain drops which spurt from it. (Plate II.)

(ii) *Emergence of the ear.*—The length of the flower stalk between the base of the shot-blade and the neck is again a varying quantity among different varieties. In E. B. 24 and Co 1 the emergence is 6—12 c.m. with the result that the spikelets are borne correspondingly higher than the 'flag'. In varieties like Co 2 and Co 3 the emergence in flower stage is hardly 1 to 2 c. m. Extreme cases are observed in some varieties like *Korangu Samba* where the emergence at flower stage is a negative quantity, the neck remaining within the sheath and the lowest spikelets caught up within the sheath. The neck being the most vulnerable point in the earhead it stands to reason that varieties with a short or negative emergence have greater chances of ear-infection by the spores washed down the erect flag.

(iii) *Spread of panicle.*—A panicle which possesses long branchlets has a tendency to spread out soon after the emergence of the ear from its sheath. Naturally enough, such spreading panicles permit a free play of sun and air through them so that their chances of spore infection are distinctly less than those of a crowded earhead.

The following table summarises the relationship between the morphological characters discussed above and the incidence of the disease.

TABLE III.—*Relationship between morphological characters and incidence of disease.*

No.	Variety.	Incidence of disease (per cent)	Area of flag.		Area of penultimate leaf.		Inclination of the flag in degrees.		Emergence of the ear.		Nature of panicle.
			Length c. m.	Breadth c. m.	Length c. m.	Breadth c. m.	Flower stage.	Ripe stage.	Flower stage.	Ripe stage.	
1	E. B. 24 ...	0·1	29·3	1·07	39·0	0·83	17·1	94·5	7·0	7·1	Spreading.
2	Co 1 ...	0·5	33·8	1·01	41·4	0·80	6·5	78·0	6·0	6·6	do.
3	E.B. 301 ...	2·9	32·3	1·82	48·3	1·68	73·0	93·5	2·1	4·3	Medium.
4	Co 2 ...	23·1	41·7	1·54	60·6	1·05	8·0	37·0	0·7	2·0	do.
5	Co 3 ...	24·1	37·0	1·39	57·5	1·05	4·5	30·5	1·3	8·2	do.
6	*Sadai samba* ...	24·2	34·9	1·19	46·5	1·00	15·5	52·0	3·5	7·1	do.
7	Adt 2 ...	78·2	35·5	1·17	50·7	0·97	11·5	15·0	-0·4	5·5	do.
8	Adt 1 ...	73·1	34·5	1·31	45·1	1·05	9·5	19·0	-0·6	6·3	do.
9	*Korangu samba.*	73·5	33·4	1·36	50·8	1·06	5·5	3·0	-2·75	4·0	Close.
10	*Nellore samba* ...	13·0	34·4	1·39	49·2	1·24	6·0	12·5	-1·2	1·0	Medium.

It is found that those varieties which possess a combination of the desirable qualities, viz., a reclining shotblade, a long emergence and a spreading panicle are the most resistant ones while those which combine the opposite qualities are easy to victims to the disease.

Susceptibility in relation to environment.—Apart from the inherent varietal variation in susceptibility, it is often observed that one and the same variety (raised from pure seed) behaves, to a certain extent, differently under different conditions of soil, manuring and irrigation. Portions of a field which show a rank vegetative growth suffer from the attack more than other portions. Patches in a field where manure heaps were dumped, portions immediately behind the inlets of irrigation channels and low-lying corners of fields are instances where heavy infection is found associated with heavy vegetative growth. Even the most resistant varieties have at times been known to suffer from the disease in such extraordinary situations. As a specific instance, it may be mentioned that a crop of E. B. 24—an almost immune variety—was grown in Field No. 59 of the Central Farm irrigated with the sullage water of the residential colony. The result was an extraordinary rank vegetative growth of the crop which suffered from an attack of *Piricularia* in a degree never observed in this strain before or since.

The Effect of vegetative growth.—An observation was conducted in 1926 which showed the effect of heavy vegetative growth on the disease. In the varietal trials conducted during that year the rows of plants were cut in the middle by a bund. The eastern portion was at a lower level than the

western, with the result that during a period of water scarcity, the former enjoyed better irrigation than the latter and there was a correspondingly better vegetative growth in it. At the time of harvest the plants in both halves were individually examined and separate records were kept for the two halves. The results are summarized in the table below :—

TABLE IV.—*Incidence of Piricularia attack in relation to vegetative growth.*

No.	Variety	Average height of plant in inches		Average number of tillers		Percentage of ear and node infection	
		Low level	High level	Low level	High level	Low level	High level
1	Co 2	52·8	45·6	24·3	12·5	34·9	11·5
2	Co 3	57·6	48·8	23·0	10·6	34·8	14·9
3	*Kattai sambalai* ...	52·8	46·4	18·0	10·9	83·9	67·1
4	*Sadathilai*	52·0	49·6	17·9	13·3	85·8	60·8
5	Adt 1	55·2	47·2	18·2	9·9	87·0	56·1
6	Adt 2	54·4	49·6	13·0	12·5	88·6	70·2
7	*Korangu samba* ...	56·8	48·0	15·7	11·6	73·2	73·8
8	*Nellore samba*	54·4	49·6	13·2	12·0	18·9	8·1
9	*Sadai samba*	56·8	52·8	17·0	15·3	34·5	13·7

The figures in the above table show that, other conditions being equal, one and the same variety produces marked differences in susceptibility brought about by differences in environment. Whether this difference is due entirely to the difference in vegetative growth is a point yet to be determined. It clearly proves that there are factors other than climatic conditions and the inherent disease resisting quality of a plant that determine the extent to which a paddy crop is susceptible to disease.

The effect of manures on the disease.—The observations recorded in the foregoing para suggested the lay out of an experiment to test the effect of different doses of nitrogen, potash, phosphoric acid and their combinations on the disease. Carefully controlled pot-cultures of a moderately susceptible variety were raised in specially prepared soil to which known quantities of the manurial ingredients were added in the form of ammonium sulphate, potassium sulphate and super-phosphate. The experiments have shown that nitrogen induces susceptibility to the disease, and in the event of favourable weather, the plants which received very heavy doses were killed outright by the fungus. In the presence of nitrogen, potash and phosphoric acid have exhibited a slight inhibitory effect on the disease, but it was evident that the higher the inherent natural resistance of the variety, the better it withstands the disease even under the influence of nitrogen. Since the tillering of a paddy plant is largely dependent on the available nitrogen supply and the yield proportionate, within certain limits, to its tilling, it is impossible to ignore nitrogenous ingredients in a scheme of paddy manuring. It is therefore a safer course to grow varieties high enough in the resistance cadre than to depend on manurial applications calculated to inhibit the disease in a highly susceptible variety.

Limitations in the adoption of blast-resistant varieties.—The choice of paddy varieties for different tracts of the presidency depends on several factors, e.g., the duration of the crop, the suitability of the soil, yield, colour and size of grain, milling qualities, cooking qualities, etc. Each tract has a partiality for its old varieties and as such what is suitable for one tract happens to be unsuitable for another. For instance the Tanjore ryot has a partiality for the *Sirumany* (Adt 1 and Adt 2) and *Korangu samba* types of grains but all these varieties are highly susceptible to 'blast.' Resistant varieties like E. B. 24, Co 1 and Co 4 though greatly appreciated in some tracts cannot find general favour with the Tanjore ryot. It is therefore necessary either to discover for him a resistant variety which satisfies his exacting demands or to infuse into his favourites the disease-resistant blood from others. The latter course falls legitimately within the province of the Plant Breeder.

Acknowledgments.—The writer has great pleasure to acknowledge his indebtedness to M.R.Ry. S. Sundararaman Avl., M.A., Government Mycologist, Coimbatore, for guidance and to Mr. P. S. Surinarayana Ayyar, Sub-Assistant in Mycology, for ungrudging help rendered during the course of the above investigations.

Summary

1. 'Blast' is the most important disease of paddy (rice) in Madras and of great economic importance in the presidency. The cause of the disease and the methods of spread are outlined.

2. Not being amenable to direct treatment, an attempt was made to study the degree of resistance in several varieties of paddy. The plan of the experiment and the method of recording results are briefly described.

3. The varieties tried exhibited a wide range of variation in disease resistance. The incidence of disease was within certain limits, found associated with morphological characters, viz., size and inclination of the shot-blade, emergence of the ear and spread of the panicle. These factors are discussed.

4. In one and the same variety, differences in environment produced remarkable differences in disease incidence. Greater vegetative growth was found to favour greater susceptibility.

5. The effects of different manurial ingredients are briefly described.

6. The possible lines of utilizing the knowledge on blast-resistance are foreshadowed.