Seeds and Sowing					
10 Madras measures of seed @ Re. 1 per measure			10	0	0
Sowing and covering	4		1	0	0
Irrigation.					
25 irrigations @ Rs. 2 per irrigation (1 pair and 2 men)			50	0	0
After-cultivation					
3 weedings		60	7	8	0
Harvesting					
Pulling, threshing and cleaning	4	20	3	8	0
Miscellaneous			1	0	0
			100	0	0
Gross income 6 kalams of 48 m. m. each @ Rs. 30			180	0	0

Net profit Rs. 80—0—0 per 60 cents (or Rs. 133 per acre).

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THE "FOOT-ROT" OF PADDY & ITS CONTROL

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In a previous paper the writer (1931) drew attention to the occurrence of a paddy disease new to the Madras Presidency and described its field symptoms as they were observed on *Garikasannavari* a popular variety grown in the Godavari delta. This disease has been named 'Foot-rot' which signifies the effect of the fungus on the host plant. The disease has since been observed on paddy in other parts of the Presidency also and has been recorded either sporadically or in artificial culture on over fifty varieties of paddy representing all the important paddy tracts of the province.

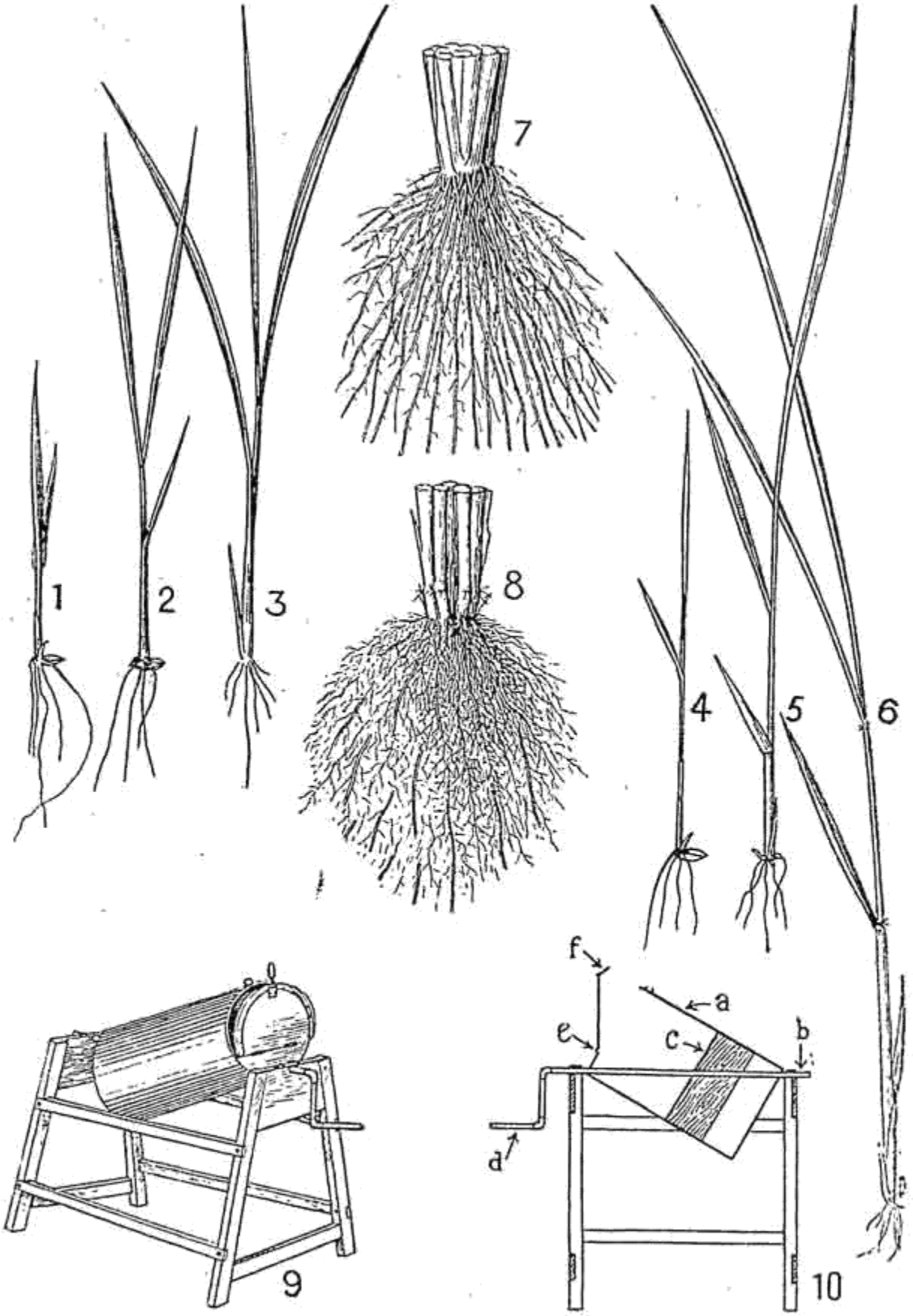
The symptoms of the disease recorded on *Garikasannavari* are essentially the same for all varieties though minor variations are met with in some. The most outstanding and at the same time the most easily detectable symptom of the disease is the appearance of pale, slender and abnormally elongated plants which ordinarily die out within a week of the first appearance of the diseased condition. Though the disease may become apparent in individual plants at all stages in the life of the crop, from as early as the sixth day after sowing to as late as the mature stage immediately prior to harvest, and is followed by wilting in whatever stage it occurs, the largest number of deaths occurs in the nursery stage ranging roughly from a fortnight to six weeks after sowing. This does not, however, account for a varying percentage of seeds which are killed during the period of germination before the plumule has elongated sufficiently to come out of the soil. Besides those described in the previous paper, another symptom which is conspicuous on well established plants is the fasciculation of the

roots caused by an abnormal branching of the main roots which gives the root system a woolly appearance. (Figs. 7 & 8).

The cause of the disease. The causal organism has been isolated and found to be a species of Fusarium. Since the perfect stage has not been obtained either in nature or in pure culture the exact identity of the fungus has not been determined. In several respects the disease resembles the 'bakanae' disease of rice recorded in Japan and which was attributed by Kurosawa (1926—7) to *Fusarium heterosporum*, later by the same author (1928) to *Lisea fujikuroi* Sawada, by Hemmi and Seto (1928—9) to *Fusarium sp.*, by Ito and Shimada (1931) to *Lisea fujikuroi*, by Ito and Kimura (1931) to *Gibberella fujikuroi* (Sawada) Wollenweber and by Nisikado (1931) to *Lisea fujikuroi*. It may be mentioned in this connection that some of the field symptoms observed in Madras e g., the production of adventitious roots from the upper nodes of grown up plants when they show infection and the fasciculation of the root system do not find mention by Japanese workers. Again, Ito and Kimura (1931) state that 38 per cent of the infected seedlings recover after transplanting, while in the writer's experience under South Indian conditions, out of several thousands of infected seedlings transplanted during several seasons, not one has so far survived transplanting. Some doubt, therefore exists whether the 'Foot-rot' of Madras is identical with the 'bakanae' of Japan. However, specimens of the disease and cultures of the fungus have been submitted to prominent Japanese workers for reciprocation and their valuable opinion. While the determination of the identity of fungus has to be deferred pending the receipt of cultures from Japan or the opinion of specialists in Japan and elsewhere, the writer felt justified in presenting the results of another aspect of his studies, viz., the methods of control, in the hope that some of the control measures which were found to be effective under laboratory and field conditions may be adopted by paddy growers and the heavy losses sustained on account of 'foot-rot' may be checked.

METHODS OF CONTROL.

(a) **Seed treatment.** Following the experimental evidence obtained in the laboratory that the disease is primarily seed-borne and that seedlings take infection at the period of germination, a preliminary field experiment was laid out in December 1930 at the Paddy Breeding Station, Maruter, to study the effect of seed treatment, seed-bed treatment and a combination of the two. Seed collected from an infected crop of *Garigasannavari* was used for the purpose. Seed treatment consisted in the steeping of the seed for 30 minutes in a 2 per cent solution of copper sulphate, while seed-bed treatment was done by the application just before sowing of 1 lb. of copper sulphate to 1 cent of nursery bed. The counts of diseased plants taken up to the time of transplanting showed an average of 0·15 per cent. in the



1, 2 & 3. Healthy paddy seedlings 10 days, 20 days & 30 days old; 4, 5 & 6. Diseased seedlings of the same age. 7. Root system of healthy plant 3 months old. 8. Root system of infected plant of the same age. 9. A seed disinfecting machine for mixing seed with fungicides in dry form. 10. Sectional view of the same (a) drum (b) pipe welded to drum, (c) mixing board screwed to drum (d) handle, (e) hinge (f) hasp for fasten[illegible]

case of seed treatment as against 0·11 in seed and seed bed treatment, 1·06 in seed bed treatment and 3·28 per cent in the control. Even after transplanting, plants raised from the seed treatment plots and the seed and seed bed treatment plots showed significantly better results than the controls.

During the next season (July 1931) a slightly more elaborate field experiment was laid out at Maruter to study the effects of four well known seed disinfectants viz., copper sulphate (2% solution for 30'), copper carbonate (2 gm. per lb. of seed), sulphur (2 gm. per lb. of seed) and hot water (55°C and 60°C for 15'). Provision was made in this experiment to study the incidence of disease in plump and light seeds and the use of chemicals six weeks in advance of sowing, immediately before soaking the seeds and immediately after soaking. Besides using seed collected from an infected crop of *Garigasannavari*, the seed was previously mixed with finely chopped spore-bearing straw collected from diseased plants. The results showed that copper sulphate gave a significant degree of freedom irrespective of the nature of the seed and the period of treatment. Hot water at both temperatures gave almost complete freedom from disease both with plumb and light seed. Copper carbonate gave a certain degree of freedom but not of sufficient value to recommend it as a preventive. Sulphur gave very disappointing results, showing little or no improvement over the controls.

Towards the latter half of 1931 a heavy outbreak of 'foot-rot' was found at Coimbatore involving several local varieties. A crop of *Gobi kar* showed a severe attack of the disease and the variety suggested itself as a suitable material for future experiments. The obvious limitations of conducting prolonged field experiments at a station about seven hundred miles away from headquarters were overcome and the avenue of further field experiments was transferred to Coimbatore. Taking advantage of a favourable second season, a field experiment was launched in January 1932 at the Central Farm, Coimbatore, to study the relative merits of copper sulphate, copper carbonate, formalin, sulphur and hot water. A pure line selection of *Gobi kar* was used for seed. The lay out of the plots and the *modus operandi* were the same as were employed at Maruter, but the counts of diseased plants were taken twice a week or oftener as the situation demanded. On a statistical analysis of the figures obtained it was found that formalin, hot water, copper sulphate, copper carbonate and sulphur took ranks in the order of their mention both in the nursery and post-nursery stages (Vide Tables I, II and III). There was no significant difference between the incidence of disease in the broad-cast and transplant plots.

In the light of the experience gained during the previous seasons, a more elaborate experiment was laid out at Coimbatore in July 1932. The

variety tried was *Gobi kar*. To minimise the element of chance, the seed was steeped in a spore suspension of the pure culture made in distilled water, then drained and air-dried before use. Twenty-three methods of seed treatment were tried. Unfortunately, seven treatments adversely affected the germination of seed under field conditions and were consequently discarded. The results of the remaining sixteen treatments are appended in Table IV.

Though all the treatments show less disease than the untreated controls, formalin, hot water, copper sulphate, Ceresan brand Tillantin, Uspulun, Semesan (wet treatment) and Granosan have produced convincing results

Considering the applicability of these methods in practice, one has to consider their virtues and defects. Formalin is available in towns but requires correct dilution before use. In slight excess, it has the disadvantage of affecting germination. The use of hot water requires some scientific knowledge and the use of more elaborate equipment than what the average ryot can afford or safely handle. Mercuric chloride is a colourless poison dangerous in the hands of illiterate farmers. Uspulun, Ceresan brand Tillantin, Semesan and Granosan are proprietory preparations and though they are in extensive use in western countries, it would be difficult to induce the average villager to equip himself with any of them. Of these, Ceresan brand Tillantin and Granosan are used in dry form and have the advantage that even if the treatment is done before the period of sowing, they do not affect the germination of seed. Moreover, when treated in advance, the possibilities of reinfection through infected gunnies etc. are eliminated. But for treating large quantities, a seed-mixer of some type would be essential. Copper sulphate, though slightly inferior to these preparations in efficiency, has the advantage of availability in every Indian village. But it has one draw back viz., that it delays germination by 12 to 24 hours Attempts are now in progress to suitably modify the use of copper sulphate with a view to increase its efficiency. Even with its present defects, it would be easier to induce the Indian ryot to use it than other fungicides until such time as when better remedies are made available within his easy reach in suitable packets and at prices well within his means. The departmental agencies which distribute seed-paddy and big farmers may, however, resort to the dry treatments which are more efficient and fool-proof in large scale operations. The efficacy of the treatment depends on thorough mixing. An efficient and cheaply constructed dusting machine is illustrated in fig. 9. A design sketch after the design of the Pennsylvania State College Agricultural Experimental Station is given in fig. 10.

(b). **The utilisation of varietal resistance.** Field observations made at Maruteru station as early as 1930 showed that some varieties were more susceptible to the disease than others. Side by side with

the seed treatment trials, a field experiment was laid out in 1931 at Maruteru to estimate the relative resistance of 12 varieties of paddy grown at the station. The seeds were previously mixed with finely chopped spore-bearing straw collected from infected plants. Weekly counts were taken of diseased seedlings in the 12 varieties, each replicated four times. At the end of the experiment E. B. 24 showed complete freedom from disease. *Akkulu*, *Nallarlu*, *Atragada* and *Vankisannam* showed commendable degrees of resistance, but *Kuruvai* 18 (Adt. 4), *Swarnarlu*, *Kusuma*, *Konnamani*, *Garikasannavari* and *Basangi* showed varying degrees of susceptibility. Having thus established the existence of varietal differences in disease resistance, a more comprehensive experiment was laid at Coimbatore in 1932. Provision was made in this experiment to gauge the relative resistance of 41 varieties of paddy included in which were all the departmental strains and a number of pure line selections, representing the main paddy tracts of the province. As an improvement on the previous trial, the seeds of all the varieties were steeped in a spore suspension in distilled water made from pure cultures. Since all the varieties had equal opportunities of infection and the element of chance reduced to the minimum, it may be inferred that the percentages of disease recorded in this experiment (Table V) represent relatively their inherent susceptibility to the disease. The results show that none of the 41 varieties is absolutely immune, but varietal differences range at one extreme from the verge of complete resistance to almost total susceptibility at the other.

While considerations of yield, duration, suitability of soils and seasons, colour and size of grain, milling and cooking qualities etc. may not favour the growing of resistant varieties to the complete exclusion of susceptible ones, the experiment has brought to light one important avenue of disease control other than direct seed treatment. The reason why some varieties are more resistant than others is under investigation From the knowledge of the varieties experimented with, it is evident that the factors favouring resistance bear no correlation to the duration of the crop or the size and shape of grain.

Acknowledgments. The writer is indebted to M. R. Ry. S. Sundararaman, Avl., M.A., Government Mycologist for guidance. His thanks are due to the Paddy Specialist and the Superintendent of the Agricultural Research Station, Maruteru, for the supply of seeds of strains and pure line selections and for facilities for field experiments. Mr. S. Kalyanasubrahmanyam, Fieldman in Mycology, rendered invaluable help in the lay out of field experiments and recording of results.

Summary.

(1) Further symptoms of the 'Foot-rot' of paddy, a disease new to Madras, are recorded. The disease resembles 'Bakanae' of rice in Japan, but the identity of two has not been established.

(2) Methods of control found successful in South India consist in the use of seed disinfectants and the culture of resistant varieties. Formalin, hot water copper sulphate, Ceresan brand Tillantin, Uspulun, Semesan and Granosan have produced good results under field conditions. Forty-one varieties of paddy were tried under field conditions for the study of relative resistance. A wide range of variation was noticed among the varieties.

(3) Details of the seed treatment and varietal study experiments are furnished.

FOOT ROT OF PADDY. FIELD EXPERIMENTS

Table I. Incidence of Disease in Nursery. 1932

No.	Treatment.	Nature of Treatment.	Strength of fungicide and duration.	Mean percentage of disease.	Remarks.
1	Copper sulphate	wet	2 per cent. for 30'	14·37	Number of replications – 4
2	Copper carbonate	dry	2 gms. per lb. of seed	16·99	
3	Formalin	wet	2 per cent. for 15'	0·55	Size of plot – 10' × 3'
4	Sulphur	dry	2 gms. per lb.	43·51	
5	Hot water	wet	55°C for 15'	4·76	
6	Control	...	.....	49·03	

Analysis of Variance.

Variation due to.	Degrees of freedom.	Sum of Squares.	Mean Variance.	½ loge (M. V.)	Remarks.
Treatment	5	8127·56	1625·51	3·6966	The treatment differences are significant the Z being beyond the 1 per cent point, while the block effects are not. Differences between treatment mean percentages exceeding 6·58 may be considered real.
Blocks	3	14·22	4·74	0·7780	
Error	15	286·98	19·13	1·4756	

Table II. Incidence of disease in broadcast plots (Post-nursery stage).

No.	Treatment.	Strength of fungicide and duration of treatment.	Mean percentage of disease.	Remarks.
1	Copper sulphate	2% for 30'	12·95	No. of replications—4
2	Copper carbonate	2 gms per lb. of seed	15·95	Size of Plots 10' × 3'
3	Formalin	2% for 15'	3·14	
4	Sulphur	2 gms per lb. of seed	40·56	
5	Hot water	55°C for 15'	5·14	
6	Control		48·36	

Analysis of variance.

Variations due to	Degrees of freedom	Sum of squares.	Mean variance.	½ log$_e$ M. V.	Remarks.
Treatments	5	7168·66	1433·73	3·6337	The treatment differences are significant, while the block effect is not. Differences between mean percentages exceeding 4·98 may be considered real.
Blocks	3	25·73	8·58	1·0745	
Error	15	163·90	10·93	1·5957	

Table III.

Incidence of disease in transplant plots (transplanting to harvest) 1932.

No.	Treatment.	Nature of Treatment.	Strength of fungicide and duration.	Mean percentage of disease.	Remarks.
1	Copper sulphate	wet	2 per cent. for 30′	13·10	Number of replications – 4. Size of plots – 3′ × 10′
2	Copper carbonate	dry	2 gms. per lb. of seed	20·36	
3	Formalin	wet	2 per cent. for 15′	5·17	
4	Sulphur	dry	2 gms. per lb. of seed	43·48	
5	Hot water	wet	55°C for 15′	8·74	
6	Control	...	.....	49·32	

Analysis of Variance.

Variation due to.	Degrees of freedom.	Sum of Squares.	Mean Variance.	½ log$_e$ (M. V.)	Remarks.
Treatment	5	6949·81	1389·96	3·6185	The treatment effect is real, but not so the block effect. Differences between treatment mean percentages exceeding 7·11 may be considered real.
Blocks	3	3·17	1·06	0·0268	
Error	15	333·81	22·25	1·5513	

Table IV. Incidence of disease in seed treatment plots 1932-'33

No.	Treatment	Nature of treatment	Strength of fungicide and duration	Mean percentage	Remarks
1	Formalin	wet	1 per cent for 15'	0·35	
2	Hot water	wet	55° C. for 30'	7·49	
3	Copper sulphate	wet	2 per cent for 30'	9·55	
4	Mer. chloride	wet	1 in 1000 for 30'	12·00	
5	Pot. permanganate	wet	3 per cent for 30'	49·51	
6	Ceresan brand Tillantin	dry	1 gm. per lb. of seed	9·25	Made by Bayer Products, Ltd., London. Indian Agents: Havero Trading Co., Calcutta.
7	Lime-sulphur	wet	1 in. 20 for 30'	22·46	
8	Germisan	wet	0·25 per cent for 30'	45 80	Ronsheim & Moore 11 a Wormwood Street, London E. C. 2.
9	Uspulun	wet	0·5 per cent for 30'	1 68	Made by I. G. Farbenindustrie A. G. (Havero Trading Co. Calcutta).
10	Semesan	wet	0·6 per cent for 30'	15·47	E. I. Du Pont de Nemours & Co., (Wilmington, Delaware) U.S.A. (Indian branch Sasoon buildings. Bombay.
11	Granosan	dry	1 gm. per lb. of seed	2·87	Do.
12	Tillantin	dry	1 gm. per lb. of seed	46·44	I. G. Farbenindustrie A.G. (Havero Trading Co., Calcutta.)
13	Sulphur	dry	2 gms. per lb. of seed	46·41	
14	Semesan	dry	1 gm. per lb. of seed	37·82	E. I. Du Pont de Nemours & Co., Sasoon buildings, Bombay.
15	Copper carbonate	dry	2 gms. per lb. of seed	49·57	
16	Semesan Jr.	dry	1½ gms. per lb. of seed	34 87	E. I. Du Pont de Nemours & Co. Sasoon buildings, Bombay.
17	Control	...	...	88·85	

Analysis of variance.

Variation due to	Degree of freedom	Sum of squares	Mean Variance	½ log$_e$ (M. V.)	Remarks.
Treatment	16	37654·45	2353·40	3 8818	Treatment differences are real but not the block differences. Differences between mean percentages exceeding 6·68 may be considered real.
Blocks	3	42·28	14·09	1·3226	
Error	48	1116·45	23·26	1·5734	

Table V. Incidence of disease in varieties.

No.	Variety.	Mean percentage of disease	Remarks.	No.	Variety.	Mean percentage of disease	Remarks.
1	Co 1	19·20	Coimbatore strain	21	Adt 8	66·61	Aduturai strain
2	Co 2	85·11	do.	22	*Poonkar*	77·78	Aduturai selection 615
3	Co 3	95·56	do.	23	A. E. B. 65	30 43	Aduturai selection
4	Co 4	79·36	do.	24	*Korangu samba*	50·33	Aduturai selection 954 B K
5	Co 5	82·45	do.	25	*Sornavari*	91·76	From Palur
6	Co 6	85·27	do.	26	*Garika sanna vari*	92·12	Maruter selection 925
7	Co 7	89·71	do.	27	*Basangi*	49·78	do. 614
8	G. E. B 24	4·83	do.	28	*Akkulu*	90·83	do 6
9	*Gobikar*	93·51	Coimbatore selection	29	*Wateribune*	1·13	American variety recently introduced at Maruter
10	*Gobi Ayyan Samba*	83·30	do.	30	*Vaukisonnam*	38·26	Maruter selection 3259
11	*Tinnevelly Kar*	30 00	do. 10375	31	*Krishnakatukulu*	15·51	do. 89
12	*Tinnevelly Anaikomban*	95·12	do. 7566	32	*Atragoda*	29·14	do. 1837
13	*Jeerka Samba*	19·83	do.	33	*Kusuma*	64 32	do. C
14	Adt 1	61 61	Aduturai strain	34	*Thavalakannan*	59·18	Pattambi selection 999 N
15	Adt 2	47·73	do.	35	*Koyama*	43·07	do. 558 N
16	Adt 3	72·63	do.	36	*Athikraya*	66·13	do. 907 N
17	Adt 4	84·89	do.	37	*Aryan*	1·85	do. 323 N
18	Adt 5	86·61	do	38	*Thekkanchéera*	53·18	do. 38 N
19	Adt 6	74·20	do.	39	*Jeerakasala*	70·31	do. 1181 N
20	Adt 7	76·92	do.	40	*Block Puttu*	13·88	Coimbatore selection glutinous variety
				41	*Chitrakali*	91·56	From Palur

Analysis of variance

Variation due to	Degree of freedom	Sum of squares	Mean variance	½ log$_e$ (M. V.)	Remarks.
Variety	40	139569·27	3489·232	6248·11	The varietal and block effects are real the Z's being beyond the 1% level. Differences between varietal mean percentages exceeding 6·21 may be considered significant.
Blocks	3	154·74	51·58	59·38	
Error	120	2421·00	20·18	23·23	

References.

1. *Fisher R. A. & Wishart* J. (1930). The arrangement of field experiments and the statistical reduction of results. *Imp. Bur. Soil. Sci. Tech. Comm.* No. 10.

2. *Hemmi, T. and Sato, F.* (1928). Experiments relating to the stimulative action by the causal fungus of the 'Bakanae' disease of Rice. *Proc. Imp. Acad. Japan* III 181—184. (Abstract in *Jap. Jour. Bot.* IV, p. 33.)

3. *Ito S. and Kimura J.* (1931). Studies on the 'Bakanae' disease of the rice plant (Japanese) with English summary. *Hokkaido Agri. Expt. Stn. Rep.* 27—99 pp. (Abstract in *Rev. Appl. Mycol.* XI. p. 398.)

4 *Ito S. and Shimada S.* (1931). On the nature of the growth-promoting substance excreted by the 'bakanae' fungus. *Ann. Phytopath Soc. Japan* II pp. 322—338 (Abstract in *Rev. Appl. Mycol.* X, p. 547.)

5. *Kurosawa, E.* (1926). Experimental studies on the secretion of *Fusarium heterosporum* on Rice plants (Japanese). *Jour. Nat. Hist. Soc. Formosa* XVI pp. 213—227. (English abstract in *Jap. Jour. Bot.* III, p. 91.)

6. *Kurosawa, E.* (1928). On the causal fungus of the 'Bakanae' disease of rice plants and the experiments of its isolation and infection (Japanese). *Rept. Nat. Hist. Soc. Formosa* XVIII 380—401. (English abstract in *Jap. Jour. Bot* IV p. 62.)

7. *Nisikado, Y.* (1931). Vergleichende untersuchungen uber die durch *Lisea fujikuroi* Saw. und *Gibberella moniliformis* Winel verursachten Gramineenkrankheiten. *Ber. des. Ohara Inst. fur land. Forsct.* V pp. 87—106.

8. *Sato, F.* (1928). Studies on the 'Bakanae' disease of Rice plant, I. A consideration of the occurrence of the 'Bakanae' disease and the 'Bakanae' phenomenon (Japanese with English resume). *Ann. Phyto Soc. Japan* II pp. 118—139. (English abstract in *Jap. Jour. Bot.* IV, p. 72.)

9. *Sato, F.* (1928). The reaction of rice seedlings to infection of the causal fungus of the 'Bakanae' disease and the filtrate of its culture. *Mem. Coll. Agri. Kyoto Imp. Univ.* No. 7.

10. *Thomas K. M.* (1931). A new paddy disease in Madras. *Madras Agri. Jour.* XIX, pp. 34—36.

Notes and Comments.

Honour to an Agricultural Officer. We congratulate Mr. N. S. Kolandaswami Pillai, our headquarters Deputy Director of Agriculture on the title of Rao Sahib recently conferred on him as a Birth-day honour. Mr. Pillai is one of our experienced and popular officers who was till lately the Deputy Director of Agriculture in the fifth circle. In that capacity he has done considerable work in helping the delta agriculturists in various ways and was recently deputed by Government to Ceylon on special duty to investigate the possibility of finding out some easy markets for Tanjore rice in Ceylon. We have no doubt that this is a well merited distinction and we wish Mr. Pillai many more honours in the future.