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Part B

ON RELATION OF SOIL MOISTURE TO DEVELOPMENT OF RICE BLAST DISEASE WITH SPECIAL REFERENCE TO RESULTS OF INOCULATION EXPERIMENTS ON SEEDLINGS AND PEDICELS OF SPIKES OF PLANTS GROWN IN SOILS DIFFERING IN TIME AND DURATION OF DRYING AND IRRIGATION

by

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I. INTRODUCTION

The relation between the irrigation and drainage of rice paddies and the generation of rice blast disease has been frequently discussed, based on the results of surveys of afflicted rice fields or on the results of experimental studies. Based on observation of the conditions following flooding in the Seijo region of Ehime Prefecture[22] and also considering the results of rice paddy drying experiments conducted by the Ehime Prefectural Agricultural Experimental Station[2], Yano reported that there was a widespread outbreak of rice blast disease accompanying extremely dry conditions in the rice paddies. Both the Nagano and the Ehime Prefectural Agricultural Experimental Stations reported that constant irrigation of the fields suppressed the disease, but that the incidence of the disease increased with increased dryness of the rice fields. Similarly, the Shiga Prefectural Agricultural Experimental Station reported a low incidence of the disease in irrigated rice fields[21]. Later, Urakura also mentioned in his report[1] that lack of irrigation water when the rice was about to flower often resulted in the occurrence of rice blast disease and that there was a widespread epidemic of rice blast disease of the pedicels of spikes in various parts of the country as a result of the drought in 1924.

All of these reports indicate that the drying-out of rice paddies promotes the development of rice blast disease while the disease tends to be suppressed by adequate irrigation. On the other hand, however, experiments performed at the Nagano Prefectural Agricultural Experimental Station under the auspices of the Ministry of Agriculture and Forestry produced cases in which dryness of the rice fields did not necessarily invite a breakout of the disease[9][13][14][15].

Itsumi[4][5] conducted some experiments on the relation between the development of rice blast disease and soil humidity, and he showed that irregardless of the stage of plant growth and also irregardless of whether the disease effected the plant leaf or the spike pedicel, there was a close relation between soil humidity and the development of the disease. He also showed that the susceptibility of the plant to the disease was proportional to the soil humidity and the length of the period of dryness, and that the susceptibility increased with increasing dryness. The author[19] experimented repeatedly with a number of different varieties of rice including "Aikoku" (disease resistant; beardless), "Jinryoku" (disease susceptible; improved variety), and "Obata" (dryland rice; rapid growing and regular varieties), testing for a relation between soil humidity and susceptibility of the variety to rice blast disease, and the results were found to corroborate those obtained previously by Itsumi[4][5]. The results were that, irrespective of the stage of growth of the plant, and also irrespective of whether the disease afflicted the leaf or the spike pedicel, in all three of the varieties tested, susceptibility to the disease was inversely proportional to the soil humidity, that is, there was less incidence of the disease with increasing soil humidity, or there was a higher incidence with increased dryness of the soil.

These results establish the fact that the susceptibility to rice blast disease is a function of soil humidity, and it can be assumed that the variation in susceptibility is due to physiological and morphological changes in the plant during its growth period. What is not known, however, is the degree of these changes and their effect on disease susceptibility during the different stages of growth of the plant. In order to clarify some of these points, the author performed inoculation tests on rice plants which were grown on soils differing in the conditions of humidity, that is in the duration of and the time of occurrence of a certain degree of humidity.

During the pursuit of this investigation, the author received considerable guidance and advice from Prof. Itsumi, to whom the author would like to express his gratitude.

II. RICE SEEDLING INOCULATION TEST WITH VARYING PERIODS OF DIFFERENT SOIL HUMIDITY

The soil used for the experiment consisted of sandy soil fertilized with 107.25 kilograms of soya bean lees to the tan (= 0.245 acres), ammonium sulfate 35.63 kilograms, calcium superphosphate 28.88 kilograms, and wood ash 52.13 kilograms to the tan. This soil was put into 16 centimeter diameter unglazed pots and planted with seeds of a slow-growing "Asahi" variety developed by the Kyoto University farm. The seedlings were allowed to grow to a height of one centimeter before being subjected to fixed intervals of soil dryness and wetness at different stages of growth of the plants and simultaneously to the inoculation test. During the dry intervals, the soil was allowed to dry out to the limit at which the plant started to wilt, while during the wet intervals, the pot was left standing in water, so that water permeated into the soil from the hole in the bottom as well as through the walls of the pot and saturated the soil. The pots were divided into four groups. In one group, the soil was in a water-saturated condition throughout the period of growth of the rice seedling, while in another group, the soil was in a dry condition throughout the entire period of growth of the seedling. In one of the two remaining groups, the soil was wet during the first half and dry during the latter half of the growth period, while in the last group, this condition was reversed. The length of the experiment was 32 days in the first and the third series of experiments, and 28 days in the second series of experiments. The method of inoculation consisted of sprinkling the rice seedlings with a suspension of rice blast disease spores (Culture No. 9 stored in our laboratory), then placing the seedlings in a Kyoto University type constant temperature inoculation chamber maintained at a temperature of roughly 24°C for 24 hours, then finally removing the seedlings from this chamber and returning them to their shelves in the greenhouse, sprinkling water on the leaves from time to time. All of the experiments were conducted in the greenhouse, and the flowerpots used in each group numbered from three to six pots per group. An equivalent number of pots without inoculation with the disease were used for control. The results of these experiments are shown in Table 1.

Table 1. Results of Rice Seedling Inoculation Experiment with Differences in the Wet-Dry Condition of the Soil. (Period of experiment, June-July 1932.)

(1) 實驗回數	(5) 實驗區別		供試稻苗數 (12)	稻苗一個體當平均草丈 (13)	總病斑數 (14)	稻苗百個體當平均病斑數 (15)	發病比率 (16)	發病順位 (17)
(2) 第1回實驗	(2) 全期乾燥區	(10) 接種區	50	36.56	2507	5014.00	1.76	1
		(11) 標準區	38	36.22	0	0		
	(7) 全期濕潤區	(10) 接種區	40	37.88	1138	2845.00	1.00	4
		(11) 標準區	42	38.02	0	0		
	(8) 前半期乾燥後半期濕潤區	(10) 接種區	51	37.16	2484	4870.59	1.71	2
		(11) 標準區	45	37.50	0	0		
	(9) 前半期濕潤後半期乾燥區	(10) 接種區	50	38.03	2105	4210.00	1.48	3
		(11) 標準區	43	37.85	0	0		
(3) 第2回實驗	(5) 全期乾燥區	(10) 接種區	60	39.97	2334	3890.00	2.20	1
		(11) 標準區	63	40.05	0	0		
	(7) 全期濕潤區	(10) 接種區	72	46.23	1272	1766.67	1.00	4
		(11) 標準區	59	44.38	0	0		
	(8) 前半期乾燥後半期濕潤區	(10) 接種區	70	41.18	2349	3355.71	1.90	2
		(11) 標準區	63	40.08	0	0		
	(9) 前半期濕潤後半期乾燥區	(10) 接種區	72	36.61	1583	2198.61	1.24	3
		(11) 標準區	64	37.21	0	0		
(4) 第3回實驗	(5) 全期乾燥區	(10) 接種區	178	37.45	1580	887.64	1.82	1
		(11) 標準區	135	37.04	0	0		
	(7) 全期濕潤區	(10) 接種區	165	41.52	803	486.67	1.00	4
		(11) 標準區	126	42.05	0	0		
	(8) 前半期乾燥後半期濕潤區	(10) 接種區	240	39.06	1445	602.08	1.24	2
		(11) 標準區	168	38.89	0	0		
	(9) 前半期濕潤後半期乾燥區	(10) 接種區	200	37.97	1051	525.50	1.08	3
		(11) 標準區	150	38.05	0	0		

(1) No. of series of experiment; (2) First series; (3) Second series; (4) Third series; (5) Type of group; (6) Dry entire period; (7) Wet entire period; (8) 1st half dry, 2nd half wet; (9) 1st half wet, 2nd half dry; (10) Inoculated group; (11) Control group; (12) No. of rice seedlings used in test; (13) Average grass height of single rice seedling; (14) Total number of disease mottles; (15) Average number of disease mottles per hundred seedlings; (16) Rate of disease incidence; (17) Order of incidence.

The results clearly show that the incidence of rice blast disease was least in the group where the soil was wet during the entire period of growth; second least in the group where the soil was wet during the first half and dry during the second half of the growth period; more prevalent in the group where the soil was dry during the first half and wet during the second half; and most widespread in the group where the soil was kept dry during the entire period. It can be tentatively concluded that the incidence of the disease is roughly proportional to the length of the dry period, but at the same time the results indicate that for the same length of dry period, the occurrence of the dry period during the first half of the growth period has a more adverse effect than when the dry period occurs during the second half of growth. This latter phenomenum can be explained to some extent by assuming that when the wet period occurs during the first half of growth and that when it is followed by the dry period, time is required for the soil to dry; that is, there is residual moisture for some length of time such that the effective wet period is actually lengthened with a resulting lower incidence of the disease. One cannot rely on such an explanation alone however, and one must suspect the existance of other responsible factors such as, for instance, the dependence of susceptibility to the disease on the time of occurrence during the growth period of the wet-dry periods.

III. RELATION BETWEEN IRRIGATION, DRAINAGE, AND DEVELOPMENT OF RICE BLAST DISEASE OF THE SPIKE PEDICEL

In this part of the investigation, previously cultivated seedlings of the slow-growing "Asahi" variety of rice were transplanted into zinc containers roughly 18 centimeters in diameter and 26 centimeters high, containing dirt fertilized in the manner previously described. The soil in the cans was initially kept water-saturated, and after the transplants took root, the cans were divided into eight groups, each group being subjected to irrigation and drainage periods at different stages of growth of the plant. About the time of spike formation, a small wad of absorbent cotton was wrapped around the stem just below the spike pedicel articulation, and about 0.5 cc of a water suspension of the disease spore was titrated with a dropper onto the cotton wad. The can or cans were then kept for 36 hours in a humid room, after which they were returned to their shelves in the greenhouse, with frequent sprinkling of water on the leaves and stems. The eight different categories of tests performed were as follows:

Group I: Soil kept saturated with water during the entire period from transplant taking root to the occurrence of disease.

Group II: Soil kept wet from transplant taking root to flowering period, thereafter water allowed to drain and soil allowed to dry.

Group III: Soil kept wet from time of transplant taking root to flowering period; soil drained and dried from flowering period to inoculation period; soil wet again from inoculation period to time of occurrence of disease.

Group IV: Soil kept wet from time of transplant taking root to inoculation period; thereafter to time of occurrence of disease soil drained and dried.

Group V: Soil drained and dried for entire period from time transplant takes root to time of occurrence of disease.

Group VI: Soil drained and dried from time transplant takes root to flowering period; thereafter to time of occurrence of disease, soil kept wet.

Group VII: Soil drained and dried from time transplant takes root to inoculation period; thereafter to time of occurrence of disease, soil kept wet.

Group VIII: Soil drained and dried from time transplant takes root to flowering period; soil kept wet from flowering period to inoculation period; soil drained and dried from inoculation period to time of occurrence of disease.

The first and second series of experiments were performed in 1931. After the transplants took root, water was drained from the soil on 18 July, and the day the plants flowered was 29 August. The plants were inoculated on 11 September in the first series of experiments and on 13 September in the second series. The dates of examination of the plants for disease were 22 August for the first series and 25 August for the second series. The third series of experiments was conducted in 1932. In this case, water was drained on 23 July after the transplant took root, the irrigation or drainage during the flowering period was done on 2 September, the plants were inoculated with the disease on 3 September, and the plants were examined on 12 September. During the experiments, the plants were left outdoors until the flowering period, and then brought into the greenhouse for the remainder of the growth period. The strain of rice blast disease used in the experiments was the same as that used in the previous experiment, namely Culture No. 9 stored in our laboratory. The results of the experiments were as follows:

Table 2. Results of Experiment Concerning Relation Between Irrigation and Drainage and the Development of Rice Blast Disease of the Spike Pedicel

(1) 試験回数	(5) 試験区別		(16) 供試穂総数	(17) 発病穂頭数	(18) 百本当発病穂頭数	(19) 発病比率	(20) 発病順位
(2) 第1回実験	(6) 第 I 区	(14) 接種区	144	11	7.64	1.00	8
		(15) 標準区	120	0	0		
	(7) 第 II 区	(14) 接種区	124	29	23.39	3.06	3
		(15) 標準区	146	0	0		
	(8) 第 III 区	(14) 接種区	123	28	22.76	2.98	4
		(15) 標準区	140	0	0		
	(9) 第 IV 区	(14) 接種区	156	31	19.87	2.60	6
		(15) 標準区	108	0	0		
	(10) 第 V 区	(14) 接種区	88	42	47.73	6.25	1
		(15) 標準区	120	0	0		
	(11) 第 VI 区	(14) 接種区	106	18	16.98	2.22	7
		(15) 標準区	101	0	0		
	(12) 第 VII 区	(14) 接種区	71	27	38.03	4.98	2
		(15) 標準区	121	0	0		
	(13) 第 VIII 区	(14) 接種区	174	36	20.69	2.71	5
		(15) 標準区	131	0	0		
(3) 第	(6) 第 I 区	(14) 接種区	150	10	6.67	1.00	8
		(15) 標準区	83	0	0		
	(7) 第 II 区	(14) 接種区	76	25	32.89	4.93	3
		(15) 標準区	85	0	0		

Table 2 Continued.

實驗回數	實驗區別		供試穗頸總數	發病穗頸數	百本當發病穗頸數	發病比率	發病順位
(3) 第2回實驗	(8) 第 III 區	(14) 接種區	111	27	24.32	3.65	4
		(15) 標準區	78	0	0		
	(9) 第 IV 區	(14) 接種區	109	13	11.93	1.79	6
		(15) 標準區	90	0	0		
	(10) 第 V 區	(14) 接種區	102	55	53.92	8.08	1
		(15) 標準區	85	0	0		
	(11) 第 VI 區	(14) 接種區	123	16	13.01	1.95	5
		(15) 標準區	96	0	0		
	(12) 第 VII 區	(14) 接種區	60	21	35.00	5.25	2
		(15) 標準區	103	0	0		
	(13) 第 VIII 區	(14) 接種區	164	16	9.76	1.46	7
		(15) 標準區	78	0	0		
(4) 第3回實驗	(6) 第 I 區	(14) 接種區	201	18	8.96	1.00	4
		(15) 標準區	52	0	0		
	(7) 第 II 區	(14) 接種區	138	32	23.19	2.59	2
		(15) 標準區	38	0	0		
	(10) 第 V 區	(14) 接種區	89	25	28.09	3.14	1
		(15) 標準區	43	0	0		
	(11) 第 VI 區	(14) 接種區	177	22	12.43	1.39	3
		(15) 標準區	28	0	0		

(1) No. of series of experiment; (2) First series; (3) Second series; (4) Third series; (5) No. of group of experiment; (6) Group I; (7) Group II; (8) Group III; (9) Group IV: (10) Group V; (11) Group VI; (12) Group VII; (13) Group VIII; (14) Inoculated group; (15) Control group; (16) No. of spike pedicels in experiment; (17) No. of spike pedicels infected with disease; (19) Percentage of spike pedicels infected with disease; (19) Rate of disease infection; (20) Order of disease incidence.

For the convenience of the reader, the results are also graphically presented in Figure 1.

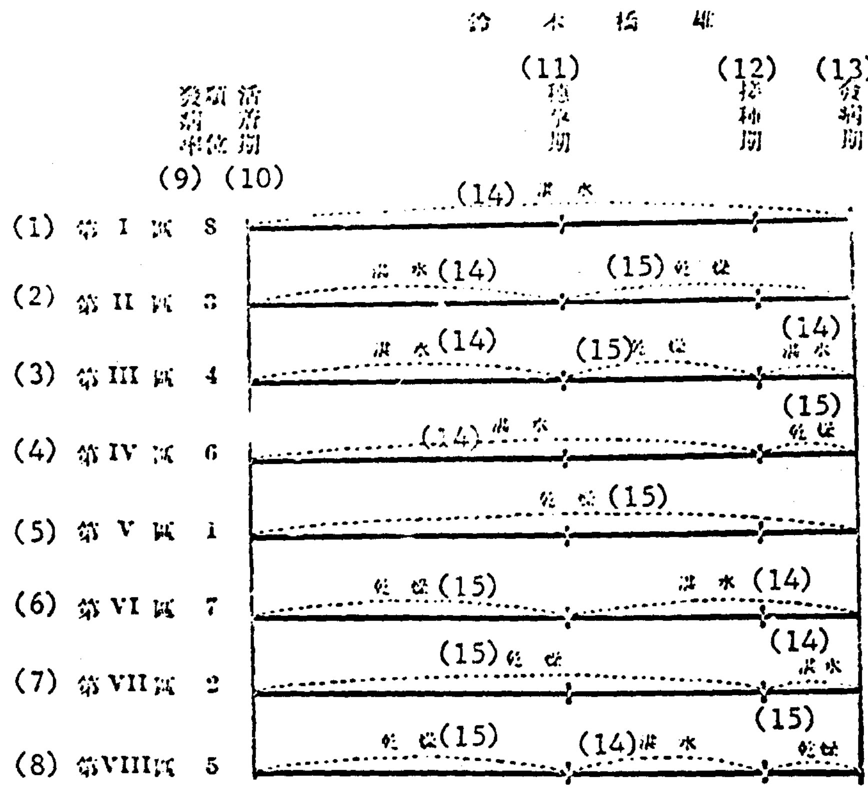


Figure 1. Graphic Summary of Relation Between Irrigation and Drainage and the Development of Rice Blast Disease of the Spike Pedicel.

(1) Group I; (2) Group II; (3) Group III; (4) Group IV; (5) Group V; (6) Group VI; (7) Group VII; (8) Group VIII; (9) Order of incidence of disease; (10) Period when transplants take root; (11) Flowering period; (12) Inoculation period; (13) Period when disease develops; (14) Irrigated; (15) Dry period.

According to the results given in Table 2, although there is some variation in the rate of infection with the disease from experiment to experiment, the rate was largest consistantly in Group V, followed by Groups VII, II, III, VIII, IV, and VI in descending order of disease incidence, with Group I having the smallest rate of disease infection. Group V with its largest rate of infection of the disease and Group I with its smallest rate prove that soil humidity effects the plant's susceptibility to rice blast disease for better or for worse during the entire growth period of the rice plant, and that dryness of the soil increases this susceptibility while wetness reduces the susceptibility.

Comparing Groups II and VI, it is seen that the soil humidity condition is changed at the flowering period, in Group II, the soil being wet before the flowering period and dry thereafter, while in the case of Group VI, the situation is reversed. In the author's experiments, the period of growth before flowering was longer than the period after flowering, and if we assumed that the susceptibility to the disease was proportional to the length of the dry period, the rate of infection of the disease should have been higher in Group VI than in Group II. The results turned out to be completely opposite to those expected, however, and it can be concluded that the susceptibility of the spike pedicel of the rice plant to blast disease as a result of the lack of soil humidity is closely related to the stage of growth of the host plant; that the enhancement of susceptibility due to soil dryness is more effective after flowering than before flowering; or that the reduction of susceptibility due to the wetness of the soil is more effective before flowering than after. That such a conclusion is justified can also be seen from the fact that the order of the rate of infection does not necessarily reflect the length of the dry period, and also from the fact that the rate of infection was always larger in Group III than in Group VIII.

The relation between soil humidity and disease infection between the times of inoculation and appearance of the disease can be established by comparing Groups I and IV and also Groups V and VII. Although in the author's experiments, the interval between inoculation and infection was rather short, the effect of soil humidity on susceptibility to the disease was also fairly strong during this stage of growth such that the rate of infection was higher in Group IV than in Group I, and similarly higher in Group V than in Group VII. As can be seen from these results, dryness of the soil during the interval from inoculation to infection tends to increase the incidence of blast disease of the spike pedicel of rice plants, and it could be similarly said that wetness of the soil during this same period of growth would tend to reduce infection.

IV. ANATOMICAL CHARACTERISTICS OF SPIKE PEDICELS OF RICE PLANTS GROWN IN SOILS UNDER DIFFERENT CONDITIONS OF IRRIGATION AND DRAINAGE

As a factor influencing the susceptibility of rice plant leaves and spike pedicels to the rice blast disease as a result of the dry or wet condition of the soil, one can also consider, in addition to physiological changes in the host plant, anatomical changes. A number of investigators have already reported that there is a relation between the resistance of a host plant to the disease caused by a parasitic micro-organism and the morphological characteristics of the host plant. Ikata[16] investigated the relation between resistance to rice blast disease and the thickness of the epidermus, and he found that the epidermus of the leaf was thicker in the disease resistant varieties than in the disease-susceptible strains, and that there was generally a positive correlation between thickness of the leaf epidermus and disease resistance. He also found on the other hand however, that the situation was reversed in the case of the epidermus of the spike pedicel such that a good correlation could not be established between disease resistance and epidermal thickness as well as the resilience of the epidermus to pressure.

The author grew three varieties of rice under conditions maintained as identical as possible with only the soil humidity being changed in the experiments[20]. The varieties were a disease-resistant beardless variety "Aikoku," a disease-susceptible improved variety "Jinryoku," and a dryland fast growing variety "Obata". Comparing the anatomical characteristics of the leaves and spike pedicels of these three varieties, it was found that in all of the varieties involved, the outer wall of the epidermal cells in both the leaves and spike pedicels were thicker in the plants grown in wet as compared to dry soil, there also tended to be larger epidermal cells and more cells with silica deposition, and the development of mechanical structure was more advanced in the wet-soil grown than in the dry-soil grown plants. These differences were found to occur in the disease-resistant as well as in the disease-susceptible strains.

If the relations described above, that is the relation between disease susceptibility and the thickness of the outer wall of the epidermal cells or the relation between the susceptibility and the degree of silica deposition in the epidermal cells, were real, they should also have occurred in the author's series of experiments. In order to investigate the existance of these conditions, the anatomical characteristics of from eight to ten samples from the control group of plants in the experiments described in the previous section of the report were studied.

1. Thickness of outer wall of epidermal cell of spike pedicel.

A slice was taken from a location about 0.5 cm below the spike pedicel articulation, and the thickness of the outer wall of the epidermal cell was measured, the results of the measurement being tabulated in Table 3.

Table 3. Results of Measurement of Thickness of Outer Wall of Epidermal Cell of Spike Pedicel. (Unit = 1.765 microns)

(1) 供試材料番號	(2) 第I區	(3) 第II區	(4) 第III區	(5) 第IV區	(6) 第V區	(7) 第VI區	(8) 第VII區	(9) 第VIII區
I	5.0—2.0	4.5—1.5	5.0—1.5	5.0—2.0	5.0—2.0	5.5—2.0	4.5—2.0	5.0—2.0
II	5.0—2.0	4.5—1.5	5.0—2.0	5.0—2.0	4.5—1.5	5.0—2.0	5.0—1.5	6.0—2.0
III	4.5—2.0	4.5—1.5	4.5—2.0	4.5—2.0	5.0—1.5	5.0—2.0	4.0—1.5	5.0—2.0
IV	5.0—1.5	4.5—1.5	5.0—2.0	5.5—2.0	4.5—1.0	5.0—2.0	5.0—2.0	5.0—2.0
V	5.0—2.0	4.5—2.0	5.0—1.5	5.0—2.0	4.5—2.0	5.0—2.0	5.0—1.5	5.0—2.0
VI	5.0—2.0	4.0—1.5	5.0—2.0	5.5—2.0	5.0—1.5	5.5—2.0	4.5—1.5	5.0—2.0
VII	5.0—2.0	4.5—1.0	4.5—2.0	5.0—2.0	5.0—2.0	5.5—2.0	4.5—1.5	5.0—2.0
VIII	5.0—2.0	4.5—1.5	4.5—2.0	5.0—2.0	4.5—2.0	5.0—2.0	4.5—1.5	4.0—2.0
IX	5.0—2.0	4.5—2.0	4.5—2.0	4.5—2.0	5.0—2.0	5.0—2.0	——	4.5—2.0
X	5.0—2.0	5.0—2.0	4.5—2.0	5.0—2.0	4.5—2.0	5.0—2.0	——	4.5—2.0
(10) 平均	4.95—1.95	4.50—1.60	4.75—1.90	5.00—2.00	4.75—1.75	5.15—2.00	4.63—1.44	4.90—2.00

(1) No. of sample; (2) Group I; (3) Group II; (4) Group III; (5) Group IV; (6) Group V; (7) Group VI; (8) Group VII; (9) Group VIII; (10) Average.

According to the results shown in the above table, the thickness of the outer wall of the epidermal cells of the spike pedicel was larger in Groups I, IV, VI, and VIII than in the other four groups, and except for a slight fluctuation, the order of thickness corresponded to the order of rate of infection previously determined. These results indicate the existance of a close relation between the thickness of the outer wall of the epidermal cells of the spike pedicel and the susceptibility of the spike pedicel to rice blast disease.

2. Number of silicated short cells (Kieselkurzzelle) in the epidermal tissue.

In the epidermal tissue of the spike pedicel, the epidermal tissue lacking stomata in between the bistomatal bands is elongated and it consists of epidermal cells with wavy cellular membrane. In between these cells and lying either next to cork cells or rarely existing singly are roughly square-shaped silicated short cells. These silicated short cells are characterized by the precipitation of a large amount of silica and they can be readily recognized by stripping epidermal tissue from the spike pedicel, soaking the specimen in phenol, and examining it under a microscope. In order to measure the amount of silicate in the epidermal cells, the number of silicated short cells distributed in a 0.4 mm distance along a single row of spike pedicel epidermal cells along the rachis longitudinal axis was counted. It was found that the number of silicated short cells was always larger in the spike pedicel epidermus of rice grown in wet soil than in dry soil, and also larger in the disease-resistant varieties than in the disease-susceptible strains, as previously reported by the author[20]. A similar study was made with respect to eight to ten samples of the control group of plants used in the previous experiment, with the results shown in Table 4, the figures given in the table representing an average of measurements taken at ten different sites.

Table 4. Results of Measurement of Number of Silicated Short Cells per Unit Distance in Epidermus of Spike Pedicel

(1) 供試材料番號	(2) 第 I 區	(3) 第 II 區	(4) 第 III 區	(5) 第 IV 區	(6) 第 V 區	(7) 第 VI 區	(8) 第 VII 區	(9) 第 VIII 區
I	4.5	4.1	4.6	4.9	4.2	4.7	3.8	5.0
II	4.2	3.8	4.5	5.3	4.4	4.6	3.5	4.5
III	4.5	4.5	4.5	4.6	4.0	4.7	3.8	4.9
IV	5.2	4.2	4.7	5.0	4.0	4.7	4.1	5.0
V	4.9	3.8	4.2	4.6	4.5	4.8	4.6	4.9
VI	4.7	4.2	4.6	5.2	3.4	5.0	4.0	5.0
VII	4.5	4.2	3.7	4.7	4.0	5.0	3.8	4.8
VIII	4.8	3.6	3.7	4.8	3.7	4.5	4.4	4.7
IX	5.7	4.5	4.5	4.7	4.0	4.9	—	4.7
X	5.4	3.9	4.0	4.5	3.8	5.0	—	4.9
(10) 平 均	4.84	4.08	4.30	4.83	4.05	4.79	4.00	4.84

(1) Number of sample; (2) Group I; (3) Group II; (4) Group III; (5) Group IV; (6) Group V; (7) Group VI; (8) Group VII; (9) Group VIII; (10) Average.

The results clearly show that the number of silicated short cells per unit distance along a single row of cells along the longitudinal axis of the rachis in the non-stomatal band of the epidermal tissue was larger in Groups I, IV, VI, and VIII compared to the four other groups, and that except for some minor fluctuations, the order of abundance of the silicated short cells corresponded to the order of the rate of infection. These results indicate that there is a close relation between the amount of silica precipitated in the epidermal tissue and the susceptibility of the spike pedicel to rice blast disease. Although it may seem somewhat rash to use the silicated short cell count per unit distance as a measure of the silica deposited in the epidermal tissue, the method used at least gives us one standard by which the degree of silica precipitated in the epidermal tissue can be judged.

The experiments described in this report have established that there are definite relations between the susceptibility of the rice plant to rice blast disease, the moisture content of the soil in which the plant is grown, the silica content of epidermal tissue, and also the thickness of the outer wall of epidermal cells.

V. DISCUSSION

The fact that the incidence of rice blast disease increases proportionally with the dryness of the soil and the length of time of dryness of the soil has been often reported by various investigators, but it apparently has never been clearly established as to whether this relation held uniformly for the entire period of growth of the plant or whether the effect of soil dryness and the length of the dryness varied with the stage of growth of the plant. In investigating this problem, the author studied separately the seedling and the later stage of growth following transplanting including the spike pedicel of the plant. It was found that at both stages of growth, the incidence of rice blast disease increased with the dryness of the soil and the period of dryness, but that at the same time, the effect varied with the stage of growth at which the dryness occurred. For instance, in the case of infection of the rice seedlings, the effect of soil dryness and the length of the dryness was more pronounced when these conditions occurred during the first half period of growth of the seedling rather than in the latter half period of growth, whereas with disease of the spike pedicel, the effect tended to be more pronounced when the dryness conditions occurred in the later stages of growth of the plant. In other words, the experimental results show that the effect of soil dryness on susceptibility to rice blast disease depends on the stage of growth at which the dryness conditions occur. The results also show that the effect of dryness on disease susceptibility arises through physiological and morphological changes in the rice plant resulting from the soil condition.

It has often been argued that there was a relation between disease caused by micro-organisms resulting in cuticular infection on one hand, and on the other hand, the thickness of the outer wall of the epidermus and the resistant to penetration of the wall in the host plant. The fact that the penetration of the parasite was due to cuticular infection in the case of rice blast disease was established by Matsuura[10], Ikata, Matsuura, and Taguchi[16], and others, while the relation between silica content and the resistance to[9] penetration was established by Onodera[17], Seki[18], Ito and Hayashi[7], Kawashima[8], Miyake and Ikeda[11], Miyake and Adachi[23], and others. Based on this result, it can be readily assumed that there is some relation between the nature of the epidermal tissue, which is directly connected with the penetration of rice blast disease micro-organisms, and the resistance of the plant to infection by the disease. The author and others[19][20] showed that in disease resistant strains grown in well irrigated soil, the anatomical features of the epidermal tissue were such as to increase tissue resistance to microbe penetration and infection, that is, the outer wall of the epidermal cells in the leaves as well as in the spike pedicel tended to be thicker and there tended to be more silicification of the epidermal cells when compared to disease-susceptible strains grown in dry soil. The same results were found to apply both to disease-resistant as well as disease-susceptible varieties. In the series of experiments in which the plants were subjected to different intervals of dryness and wetness of the soil at different stages of the growth of the plant, the results of inoculation showed that the order of the rate of disease infection corresponded very well with the order of thickness of the outer wall of the epidermal cells and the silicification of these cells. These results indicate that there is a close relation, within the range of the author's experiments at least, between the susceptibility of the rice plant to rice blast disease and the toughness of the epidermal tissue to infection.

VI. SUMMARY

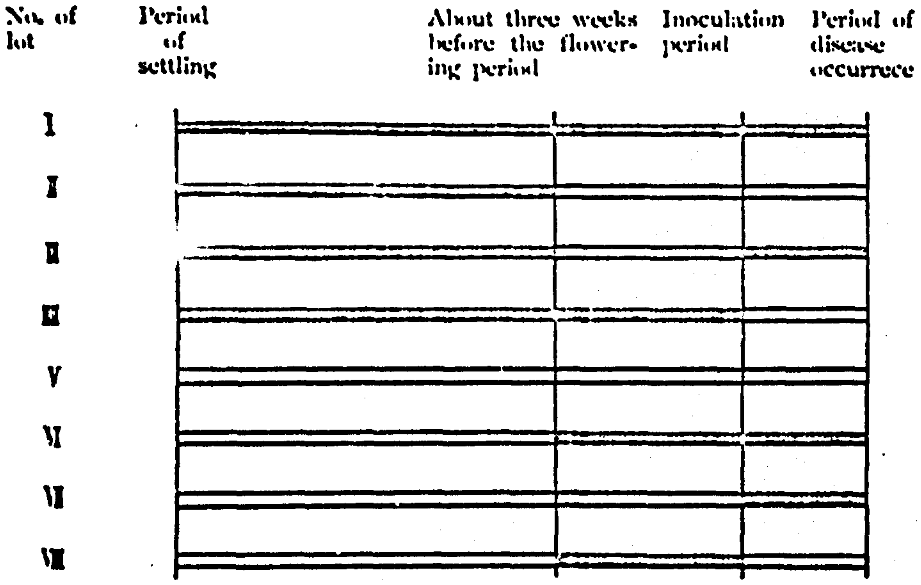
1. The present paper deals with the results of inoculation experiments on seedlings and spike pedicels of rice plants grown on soils differing in moisture for the same or different duration of time during different stages of growth of the plant.

2. It was found that the susceptibility of the seedlings as well as the spike pedicels of the rice plant to the blast disease increased proportionally with the length of duration of a dry condition, and that it decreased similarly with a humid state of the soil. The rate of increase or decrease of susceptibility to the disease seemed to vary with the stage of growth of the host plant at which a certain condition occurred.

3. The results of inoculation experiments on seedlings showed that the highest percentage of infection occurred in the lot in which the soil was continuously dry throughout the entire growth period. This was followed in percentage by the lot in which the soil was dry during the first half of the growth and well irrigated during the latter half of the growth period. The lot in which the soil was irrigated for the first half and allowed to dry out for the second half was third in rate of infection, while there was least infection in the lot which was constantly irrigated throughout the entire period of growth.

From the fact that the percentage of infection was greater in the lot dry during the first half of the growth period than in the lot dry for the second half, it can be concluded that the effect of soil dryness on susceptibility to the disease was greater during the early half of the growth period than during the latter half of the growth period.

4. The inoculation experiments on the spike pedicels were repeated several times with the plants divided into eight lots, the lots differing from one another with respect to the time and duration of the periods of dryness or wetness according to the following schedule:



Black line: Irrigated   White line: Dried

The experiments resulted in the conclusion that lot V had the highest percentage of infection, which lot was followed by lots VII, II, III, VIII, IV, VI, and I in descending order of percentage of infection.

5. From the results of the inoculation experiments, it was recognized that a difference in soil moisture might affect the susceptibility of the spike pedicels to the blast disease at any stage of the growth period of the rice plant. It was also found that this effect might be somewhat greater before the flowering period of the host plant than after this period.

6. The thickness of the outer wall of the epidermal cells as well as the number of silicated short cells (Kieselkurzzellen), spreading to a definite distance on a row of epidermal cells alined along the longitudinal axis of the rachis, of which a non-stomatal band consisted, were measured. The results of these measurements were almost in accord with the order of

percentage of infection obtained in the inoculation experiments. Accordingly, the existance of a correlation between susceptibility to the blast disease on one hand, and on the other hand the thickness of the outer wall or the amount of silica in the epidermal cells should be recognized.

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