AGRICULTURE

Intervarietal Mixtures of Rice and Incidence of Brown-spot Disease] (*Helminthosporium oryzae* Breda de Haan)

It has been demonstrated by Roy[1] that two varieties of rice, when grown in mixture, may influence the yield of each other, and that the effect is nearly as often favourable as unfavourable. Certain mixtures yield more than the means of the two components grown in monoculture, and occasionally even exceed the better components in yield.

The mixture effects of the rice varieties 36 *BK BR*7 and 498-2*A BR*8 (hereafter called *BK* and 2*A*, respectively) were studied critically, with adequate replicates, and under different ecological conditions over an adequate period. The general plan of the experiment was as follows: *BK* alone, 2*A* alone, intra-cluster mixture of *BK* and 2*A*, seed mixture of *BK* and 2*A* in equal proportions, alternate rows of *BK* and 2*A* and, finally, half-plots. Equal numbers of plants were transplanted in each plot. With

Table 1. Number of Grains infected by *Helminthosporium oryzae* and Percentage of Losses in Different Treatments of Two Rice Varieties

Variety	Treatment	Total No. of grains examined	No. of grains attacked by *H. oryzae*: Slight, Absolute	Slight, Relative (per cent)	Heavy, Absolute	Heavy, Relative (per cent)	Destructive, Absolute	Destructive, Relative (per cent)	Total	Percentage of loss
BK	Alone	32,350	9,190	28·5	3,340	10·3	973	3·0	13,503	8·0
BK	Alternate rows	32,520	4,150	12·8	1,021	3·1	322	1·0	5,493	2·7
BK	Seedling mixture	32,130	7,190	22·4	1,373	4·3	336	1·0	8,899	3·4
BK	Seed mixture	34,290	6,980	20·4	1,772	5·2	428	1·2	9,180	4·2
BK	Half-plots	37,930	11,190	29·5	2,452	6·5	302	0·8	13,944	4·6
2A	Alone	33,030			2,484	7·5	186	0·6	2,670	2·9
2A	Alternate rows	32,620			971	3·0	150	0·5	1,121	1·5
2A	Seedling mixture	34,270			1,811	5·3	195	0·6	2,006	2·6
2A	Seed mixture	33,830			1,949	5·8	214	0·6	2,163	2·4
2A	Half-plots	39,740			2,345	5·9	328	0·8	2,673	2·9

such a layout it was possible to compare the performances of different kinds of mixtures.

In 1 year, alternate rows gave an increased yield of 25·9 per cent more than the mean of the two components in pure stand, and 19·7 per cent more than the yield of the higher-yielding variety. Other kinds of mixtures gave smaller but significant increases.

Roy[1,2] has indicated that the factors involved in such intervarietal interactions are highly complex and that the final growth expressions of the components in a mixture are the results of the combined effects of a number of factors. Roy[2] also suspected that differential disease resistance of the component varieties might have beneficial effects in mixtures.

We are now in a position to test this hypothesis and to offer a partial explanation for the increased yield. In 1964 we observed that different plots suffered to varying degrees from brown-spot disease, which attacked leaves of rice plants in all stages of development. Later on, spots appeared on the glumes, and a part of the heavily infected grains remained sterile. The brown-spot is caused by a fungus *Helminthosporium oryzae* (Breda de Haan).

For detailed investigation, some ear-heads of rice were harvested from each plot at maturity, and the numbers of grains with slight incidence of the disease, heavy incidence and total destruction were counted. Owing to the red-brown colour of the glumes, slight attack could not clearly be detected in the variety *2A* and was left out of consideration. From the different plots of four replicates, 20 ear-heads of four different rows were cut and investigated. Altogether, 3,200 ear-heads with more than 300,000 grains were examined. The results are shown in Table 1.

To estimate the loss of weight caused by the fungus, the grains were sorted into the following four categories: healthy; slightly infected (light-brown spots on the surface of the glumes); heavily infected (dark-brown spots on the surfaces of the glumes and the fungus penetrating into deep layers); and totally destroyed. Weights of a thousand grains, with and without glumes, were recorded for both varieties and the results are shown in Table 2. Because of the red-brown colour of the glumes of *2A*, slightly infected grains could not be recorded separately.

The reduction in weight without glumes was used as a measure of the loss, since the glumes are of little economic value. The total losses were calculated and are shown in the last column of Table 1.

The superior performance of 'alternate rows' is clearly seen from Table 1. The results, however, show only the losses from attack on the ear-heads. Similar differences, especially between plots with pure varieties and plots with alternate rows, were seen in the attack of the fungus on the leaves and on the stem. The total losses through *H. oryzae* are, therefore, greater than indicated in Table 1, but the tendency shown in the figures should remain much the same.

It is well known that *H. oryzae* forms a number of races[3,4]. Owing to the multi-nucleate cells and frequent saltations, however, the races do not always remain constant over long periods of time[5]. It was demonstrated

Table 2. Dry Weight (grams) of 1,000 Grains

Variety	Types of infection	Dry weight (g) of 1,000 grains: With glumes, Absolute	With glumes, Relative	Without glumes, Absolute	Without glumes, Relative
2A	Healthy	26·28	100	21·28	100
2A	Heavily infected	16·87	64	14·40	68
2A	Totally destroyed	3·53	13	0	0
BK	Healthy	25·42	100	20·62	100
BK	Slightly infected	23·76	93	19·76	96
BK	Heavily infected	14·97	59	12·78	62
BK	Totally destroyed	3·26	13	0	0

Table 3. The Influence of Non-emergence on the Attack of *H. oryzae*
Variety *BK*, 20 ear-heads each from non-lodging plants

Type of emergence	No. of grains	Attack of *H. oryzae*: Slight, Absolute	Slight, Relative (per cent)	Heavy, Absolute	Heavy, Relative (per cent)	Complete, Absolute	Complete, Relative (per cent)	Percentage of loss
Complete emergence	1,830	240	13·1	103	5·6	42	2·3	5·0
Slight non-emergence	1,840	510	27·7	343	18·6	303	16·5	24·5
Considerable non-emergence	1,720	300	17·4	462	26·9	414	24·1	68·5

Table 4. Four Winnowing Experiments with Infected Grains of Variety *BK*

Types of infected grains	Experiment No. I: Total No.	I: Winnowed out, Absolute	I: Winnowed out, Relative (%)	II: Total No.	II: Winnowed out, Absolute	II: Winnowed out, Relative (%)	III: Total No.	III: Winnowed out, Absolute	III: Winnowed out, Relative (%)	IV: Total No.	IV: Winnowed out, Absolute	IV: Winnowed out, Relative (%)	Total: Total No. of grains	Total: Winnowed out, Absolute	Total: Winnowed out, Relative (%)
Totally destroyed grains	8	8	100	5	5	100	11	11	100	9	9	100	33	33	100
Heavily infected grains	134	61	45·6	132	85	64·3	177	127	71·7	166	116	69·8	609	389	63·9
Empty 'grains'	26	8	31·0	72	60	83·3	84	84	100	98	98	100	280	250	89·3
Healthy grains	1,723	8	0·5	1,782	72	4·0	1,451	131	9·0	1,616	276	17·1	6,572	487	7·4
Total	1,891	85	4·5	1,991	222	11·1	1,723	353	20·5	1,889	490	26·4	7,494	1,159	15·5

by Das Gupta[6] that different varieties show a different resistance to the various strains of the fungus.

As a working hypothesis, we put forward the following explanation of our results. The yields of the different plots already described show a negative correlation with the incidence of *H. oryzae*. The superior performance of alternate rows, and the extremely small number of affected grains, can be explained by the isolating effect of the rows against the spread of the fungus. If the plants are arranged in a complete chess-board pattern, each plant in the plots with alternate rows is surrounded by two plants of the same variety and by six plants of a different variety. In all other arrangements, the number of neighbouring plants of the same variety is greater, and the isolating effect is therefore of less influence. The same should hold true for all pairs of varieties which are resistant to a common strain of *H. oryzae* but to different degrees. In the plots with intra-cluster mixtures of seeds the isolating effect is still important, although less so than in the alternate rows. It is to be expected that 'half-plots' of all kinds of mixtures will show the least influence.

The large number of grains infected by the fungus in the plots with pure varieties is to a certain extent due to the high degree of 'non-emergence'. As shown in Table 3, non-emergence results in a great number of totally destroyed grains, especially those remaining in the sheath of the top leaf under conditions of a high air humidity.

It is well known that mixtures are characterized by stability performance. While the causes of such stabilization are generally unknown, there does exist some fragmentary evidence on disease reaction in some crops. Suneson[7] has shown that the yield of a 3 : 1 mixture of two wheat varieties, respectively resistant and susceptible to the prevalent race of stem rust, was as great as the yield of the pure resistant variety, though plots of the pure susceptible were reduced to 58 per cent in yield. At maturity, susceptible plants in the mixed plots had only two-thirds the rust incidence of plants in the pure susceptible stands. In mixture, the attack had been slowed down sufficiently to allow the plants to yield a crop before succumbing. Suneson also reports comparable observations on oats[7]. The disease buffering effects of mixtures were considered as means of maintaining the temperate inbred cereals, wheat and oats, in equilibrium with their rusts until about 60 years ago, when 'boom and bust cycles'[7] were started by the adoption of pure line breeding[8].

This preliminary report suggests that further investigations are required. We suggest that this line of study be pursued in India and elsewhere. For such experiments, the component varieties should be chosen to have approximately the same duration. Separation becomes easy if the grains of the component varieties have different colours, shapes or sizes, or if the awns have different lengths. Dark grains are, however, unfavourable since the detection of infected grains is then more difficult.

Attention should also be given to another point. It is well known that the leaf-spot disease of rice is transmitted through infected seeds. Seed treatment with fungicides is not entirely successful, especially if seeds are heavily infected; in these cases, the fungus can penetrate into the deep layers of the glumes and sometimes as far as the embryo. It would, therefore, be of great help if the number of grains with heavy fungus attack could substantially be reduced before the seed treatment is carried out. As shown in Table 2, heavily attacked grains show a reduction in weight (not necessarily in length) of about 35–40 per cent. All totally destroyed grains are very light.

In many parts of India the cleaning of rice for seed purposes is done by rather primitive methods and with incomplete results, mostly by winnowing. It can, however, be demonstrated (see Table 4) that the winnowing-out of between 10 per cent and 25 per cent of the total number of grains results in a considerable reduction of heavy infection (about two-thirds) and a substantially complete eradication of totally destroyed and 'empty' grains from the seed remaining. Seed samples winnowed this way should, therefore, show a minimum transmission of the disease to the seed-bed after proper treatment with a fungicide and should remain largely free from the fungus during the early stages of growth.

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