HILGARDIA

JOURNAL OF AGRICULTURAL SCIENCE PUBLISHED BY
HE CALIFORNIA AGRICULTURAL EXPERIMENT STATION

Volume 49, Number 4 • April 1981

Effects of Infection with *Rhynchosporium secalis* on some Components of Growth and Yield in Two Barley Cultivars

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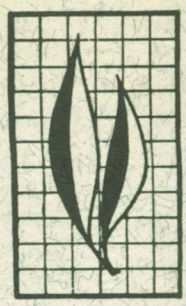

Two cultivars of barley, Numar and Briggs, differing in their susceptibility to *Rhynchosporium secalis,* but without any known vertical genes for disease resistance, were grown in replicate plots and either inoculated with race 74 of *R. secalis* or sprayed with Benlate for disease control. Measurements included height, numbers of various plant parts, leaf area, dry weight of plant parts, yield components and grain yield. Analysis of the data indicated the more resistant variety Briggs, outyielded the susceptible variety Numar, and differed in other growth components. Calculation of leaf life span indicated this was a key difference between varieties with respect to disease resistance. Further testing on the relationship between leaf life span and disease resistance is necessary, but measurement of leaf life span may be a useful tool in screening breeding material for a background level of horizontal resistance, as well as leading to better understanding of a mechanism of disease resistance.

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Effects of Infection with *Rhynchosporium secalis* on some Components of Growth and Yield in Two Barley Cultivars[1]

INTRODUCTION

Rhynchosporium secalis (Oud.) Davis, the causal agent of leaf scald, is a serious disease on barley in California, as well as other major barley-growing areas (Ali, Mayfield, and Clare, 1976; Jenkins, Melville, and Jemmett, 1972; Moseman, 1971). Losses as high as 35 percent (Schaller, 1951) have been reported in California. Attempts to control scald have stressed identification and incorporation of individual vertical resistance genes into cultivars. However, this has proved less than satisfactory, primarily because the great pathogenic variability of *R. secalis* (Ali, Mayfield, and Clare, 1976; Dyck and Schaller, 1961; Jackson and Webster, 1976a; Jackson and Webster, 1976b; Schein, 1958) enables it to overcome these vertical resistance factors rather quickly (Dyck and Schaller, 1961; Webster, Jackson, and Schaller, 1980). Because of the lack of success with the vertical resistance method, techniques aimed at identifying horizontal resistance should be examined. For this reason, experiments were conducted to determine if certain growth parameters could be used as indicators of horizontal resistance, and if so, whether they could be used to facilitate selection of cultivars with some level of horizontal resistance.

Two cultivars of barley were chosen for this introductory study based on their past response to *R. secalis* infection in the field. The cultivar Numar was selected, even though little is still grown commercially, because it contains no identified vertical resistance genes and is highly susceptible to known races in California. The other cultivar, Briggs, was chosen because it has a history of good performance under natural infection, although it contains no known vertical resistance genes. Briggs is used frequently as a genetic source for development of new commercial varieties, and is grown in California.

By examining the responses of some of the components of growth and yield of these two varieties, it may be possible to discern if there is a difference in growth and development between the two varieties that may contribute to their respective disease responses. The purpose of the experiments is to discover if Briggs and Numar respond differently under disease pressure from *R. secalis,* and if so, whether these differences may be due to differences in measured components of growth.

MATERIALS AND METHODS

An area of land 164 ft by 80 ft (50 m by 24.5 m) at the Plant Pathology field at Davis, California, was divided into 18 square plots of 24 ft (7.3 m) with 4 ft (1.2 m) alleys between them. The two cultivars, Numar and Briggs, were randomly assigned to eight

[1]Accepted for publication January 16, 1981.

plots in each half of the field, with the extra plot being assigned to Numar in one half and Briggs in the other. These extra plots were used to set planting equipment and to allow examination of plants between harvests, without disturbing the plants in sampling plots. Seed was drilled on October 19, 1978, into the prepared seedbed at a rate of 96 lb/acre (108 kg/ha) with an average distance between rows of 7 inches (178 mm). Sampling areas were selected when the barley reached the seedling stage. Areas were staked where there were eight to ten plants per 30 cm within the row and the adjacent rows were within 14 to 17 cm. This was done to minimize compensation associated with uneven plant spacing. Density of plants in sampled areas ranged from 220 to 270 plants per square meter[2].

Nine plots in the west half of the field were sprayed with 2 lb (0.91 kg) of Benlate (ai) at the rate of 20 gal/acre (187 l/ha) for disease control, on December 27, 1978, January 23, and March 5, 1979; the east half was inoculated with *R. secalis* race 74 on December 28, 1978, and February 1, 1979, to establish a uniform disease pressure. Both treatments were applied in the same manner, utilizing a hand-carried boom to spray the materials onto the plots. Ten plants from one randomly chosen sample area were taken from each plot on November 15 (harvest 1), December 11 (harvest 2), 1978, January 10 (harvest 3) and 23 (harvest 4), and February 12 (harvest 5), 1979. Six plant samples were taken on February 27 (harvest 6), March 15 (harvest 7), April 2 (harvest 8), and May 23 (harvest 9), 1979. Mechanical harvests of individual plots were completed on May 30, 1979.

Average height, percent cover, and approximate growth stage (Large, 1954) were measured before plants were removed. Plants were then harvested, removing them just at the crown (no root samples were taken). Plants from each plot were bulked, and measurements were based on the entire sample. The tillers, leaves by order of appearance, dead leaves, heads, florets, and seeds were counted. Leaf area was measured using an electronic leaf area meter. Diseased leaf area was measured on leaves that were still partially green, by tracing diseased area onto clear vinyl plastic which was then passed through the leaf area meter. Dry weights of leaves, stems, and heads were obtained after the plant material had been oven dried at 80 C (± 5) for about 48 hr.

Means and standard errors were calculated for each treatment group: Numar with fungicide (N-f), Briggs with fungicide (B-f), Numar inoculated with *R. secalis* (N-i), and Briggs inoculated with *R. secalis* (B-i). Means were calculated on a per-plant basis for most measurements, because the leaves of Briggs were smaller and the number of tillers was greater than for Numar, lending a bias to the leaf-area calculations. Measurements represented different proportions of the totals in Briggs and Numar, thus calculations were made on a per-plant basis to try to equalize the comparisons as much as possible. Comparisons among treatments were made using the largest of the four standard errors, which is the one given in the following tables and graphs.

RESULTS

General observations

Conditions during the growing season were favorable to both barley growth and disease development. Air temperatures ranged from 95 °F (35 °C) to 28 °F (– 7 °C), and average monthly high and low temperatures were about normal. Total seasonal rainfall was normal, well distributed within the barley growing season and of a frequency and duration to encourage development of *R. secalis*.

Although none of the fungicide-treated plots developed disease symptoms as early as the inoculated plots, disease was present by harvest 4, especially within the Numar plots. Final disease levels in the fungicide-treated plots were similar to inoculated plots for Numar, and nearly so for Briggs. Difference between the two treatments was in time-of-disease onset. In general, inoculated plots sustained a severe, early infection, while fungicide treated plots did not become severely infected until after fungicide applications were discontinued. There appeared to be a gradient of infection severity from fungicide-treated Briggs plots with the lowest disease level to inoculated Numar plots with the highest.

General crop development was about the same for both varieties, although Briggs was slightly later than Numar. All plots had reached 95 percent cover by harvest 5. After harvest 6, by which time all plots had reached 100 percent cover, there was a slight difference in percent cover due to differential senescence of leaves between treatments.

Plant heights were also similar if extended heights were used. Although Briggs appeared shorter than Numar in the field, this was because of the more open nature of the plants and less upright leaves of Briggs, and the fact that Briggs reached a given growth stage slightly later than Numar. Maximum height, reached at harvest 8, was between 118 cm and 124 cm for all plots.

Grain yield

Grain yield data gathered at harvest 9 and from the machine-harvested samples are shown in Table 1. These results illustrate the low yields associated with severe early infection. Highest yield was obtained from the fungicide-treated Briggs plots, which consistently had the lowest disease levels. The inoculated plots of Numar yielded the least grain; they were the plots with the earliest and highest disease levels. Number of kernels set per plant followed the same pattern: B-f plots produced the largest number of kernels per plant, while the N-i plots produced the lowest. Intermediately diseased plots, B-i and N-f, had intermediate numbers of kernels. Since the higher disease levels occurred earlier in the B-i plots than in the N-f plots, this may account for the slightly lower numbers of kernels in B-i than N-f. One hundred kernel weights are included as a measure of average kernel weight, which is a good indicator of fill.

TABLE 1

AVERAGE FINAL GRAIN YIELD FROM MACHINE HARVESTS OF BARLEY CULTIVARS NUMAR AND BRIGGS TREATED WITH FUNGICIDE COMPARED WITH THOSE INOCULATED WITH *R. SECALIS*

(HARVEST 9)

Treatment	Yield	100 seed wt	Seeds/plant
	kg/m²	*grams*	*number*
Numar-fungicide	1.62	3.53	216.5
Briggs-fungicide	1.88	3.86	295.0
Numar-inoculated	0.55	2.88	106.2
Briggs-inoculated	1.19	2.88	183.9
Largest standard error	0.05	0.14	31.2

Growth characteristics

Figure 1a shows the average number of tillers per plant for the four treatment combinations. It clearly shows that up to harvest 6 the variety Briggs tends to produce more tillers per plant than Numar. This agrees with the known characteristics of both varieties (C.W. Schaller, personal communication). However, by harvest 7, tiller numbers were similar between the two. Number of tillers for some treatments also decreased between harvests 6 and 9. All tillers were counted at each harvest, so there should have been at

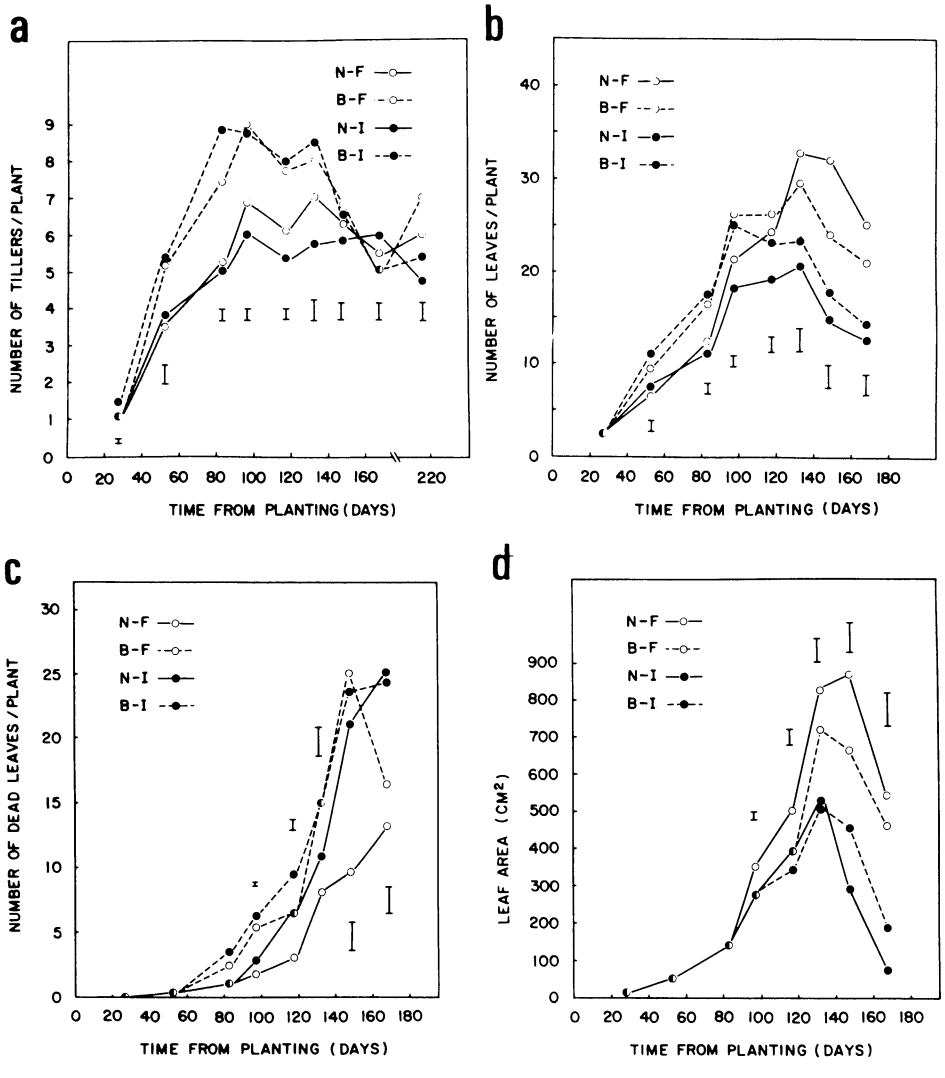


Fig. 1. Average number of a) tillers per plant, b) live leaves per plant, c) dead leaves per plant, and d) average total leaf area per plant: N-F, Numar-treated with the fungicide Benlate; B-F, Briggs treated with Benlate; N-I, Numar inoculated with race 74 of *Rhynchosporium secalis;* B-I, Briggs inoculated with race 74 of *R. secalis*. Each point represents the mean of 10 plants (harvests 1 thorough 5) or 6 plants (harvests 6 through 9) from four replicate plots of each treatment. Vertical bar represents the largest standard error at that sampling.

least as many present each time as at the maximum. Differences between plants sampled at successive harvests, as well as death of some of the small tillers may account for the discrepancy. At harvest 9, the final number of tillers was lower for B-i and N-i, unchanged for N-f, and still high for B-f.

Fig. 1b shows the average number of live leaves per plant, leaves which still have some healthy green area. Briggs, both -f and -i, had more lower leaves than did Numar until after harvest 4. As the season progressed, N-f maintained the most live leaves through the last measurement at harvest 8. All treatments had their maximum number of live leaves at harvest 6, except B-i, which showed a decrease after harvest 4. Figure 1c shows the average number of dead leaves per plant, essentially the inverse of Figure 1b.

Both B-f and B-i shed about the same number of leaves, regardless of disease level, until harvest 8, thus indicating that leaf shed was probably not due to disease level, at least not through this point in the season. However, dead leaf numbers for N-i and N-f were similar only until harvest 4, after which many more dead leaves were counted on the inoculated treatment. The number of dead leaves increased on fungicide-treated plants, but still remained low.

Average total leaf area (all but dead leaves) per plant for each treatment is shown in Figure 1d. The average leaf area was about the same for all treatment combinations until after harvest 4. After harvest 6, there were large differences, most notably between inoculated and fungicide-treated plots. Fungicide-treated plots of both Numar and Briggs maintained higher total leaf areas until harvest 7: total leaf areas of inoculated plots never equaled that of fungicide-treated, but B-i maintained its maximum leaf area until harvest 7, whereas N-i continued to decline after its earlier maximum reached at harvest 6.

Proportion of live leaf area by leaf class for harvests 6, 7, and 8 is shown in Figure 2. Leaf class indicates relative position of leaves. Leaves from each tiller were divided into groups based on location on the tiller. Leaves at the base of the tiller fell into the lower leaf class. The first leaf on a tiller that was distinctly above the base fell into leaf class 1. Leaves directly above those in leaf class 1 fell into leaf class 2, and so on. The highest leaf class, leaf class 6, contained the flag leaves. The main difference between the fungicide-treated and inoculated treatments was in perseverance of the lowest leaf classes. By harvest 6, the lower leaf class of N-i had already been greatly reduced, and leaf classes further up were also being reduced. Harvest 7 and 8 showed this trend to an even greater extent. By harvest 8, N-i had little leaf area in leaf class 4 and a greatly reduced leaf area in classes 5 and 6. B-i showed a similar trend in reduction, but did maintain larger leaf areas in more classes than did N-i. The difference between N-f and B-f was one of slightly less leaf area per class rather than a difference in perseverance of particular classes.

There were other differences between treatments with respect to leaf area. Figures 1d through 2c deal with total live leaf area, including both healthy and diseased leaf area in the totals. (Note: leaves had to have more than 10 percent of the lamina still green in order to be classified as live, if the remaining area was diseased.) Further divisions of leaf area into healthy and diseased were necessary. Figure 3 shows the average diseased leaf area per plant. Although inoculation occurred between harvests 2 and 3, there was no great difference between the treatments until after harvest 5. Subsequently, there was a dramatic increase in diseased leaf area of N-i, and a much smaller increase for B-i. The rise in diseased leaf area of B-i was not only smaller, but later as well.

Again, by dividing these averages into leaf classes in Figure 4, the diseased leaf area differences become clearer. The basic trends between -i and -f seemed to be: i) the fungicide treatments suffered much lower levels of disease, although by the last harvest these showed some disease in all leaf classes; ii) higher maximum leaf areas were reached

on the fungicide-treated plots; iii) the fungicide-treated plots had leaf area remaining in lower leaf classes.

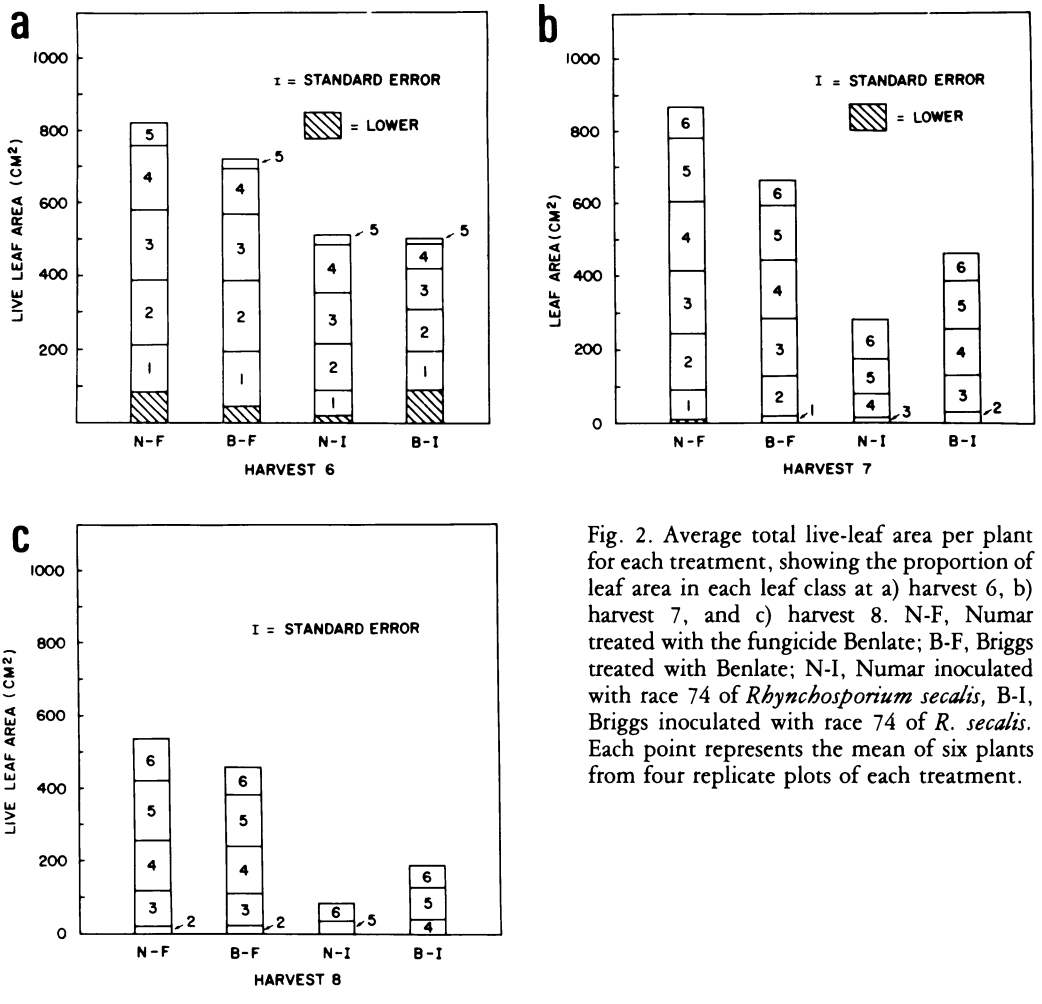


Fig. 2. Average total live-leaf area per plant for each treatment, showing the proportion of leaf area in each leaf class at a) harvest 6, b) harvest 7, and c) harvest 8. N-F, Numar treated with the fungicide Benlate; B-F, Briggs treated with Benlate; N-I, Numar inoculated with race 74 of *Rhynchosporium secalis*, B-I, Briggs inoculated with race 74 of *R. secalis*. Each point represents the mean of six plants from four replicate plots of each treatment.

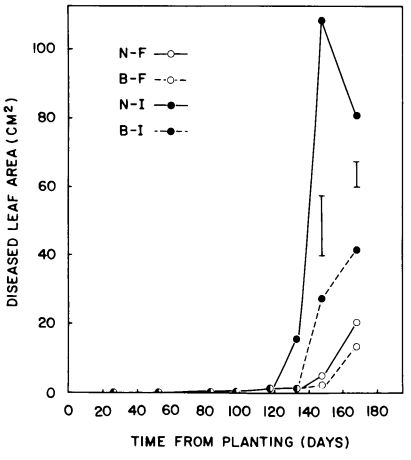


Fig. 3. Increase is average total diseased leaf area per plant for harvests 1 through 8: N-F, Numar treated with the fungicide Benlate; B-F, Briggs treated with Benlate; N-I, Numar inoculated with race 74 of *Rhynchosporium secalis;* B-I, Briggs inoculated with race 74 of *R. secalis*. Means are based on 10 plant samples (harvests 1 through 5) or six plant samples (harvests 6 through 9) from the four replicate plots of each treatment. Vertical bar represents the largest standard error at that sampling.

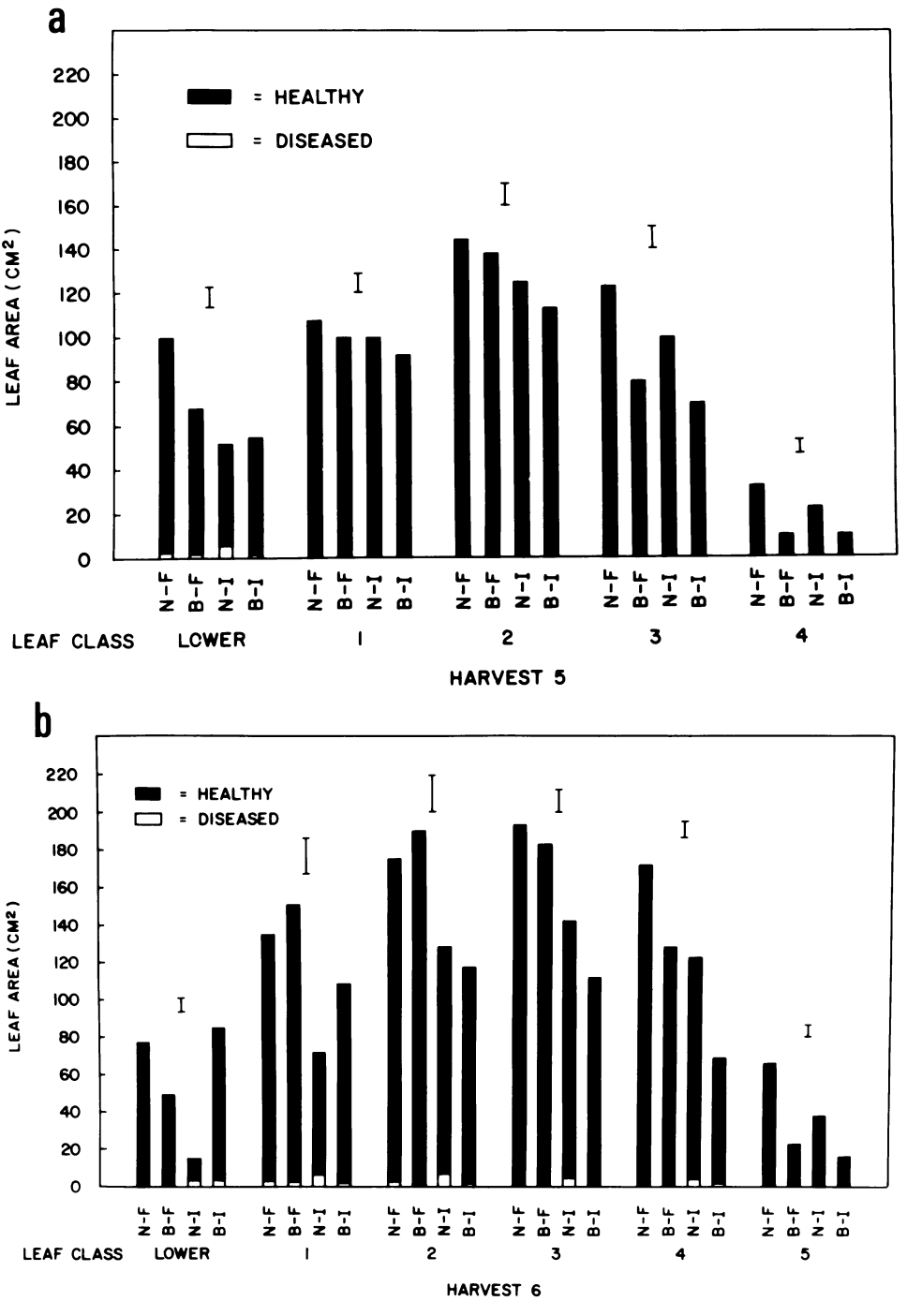
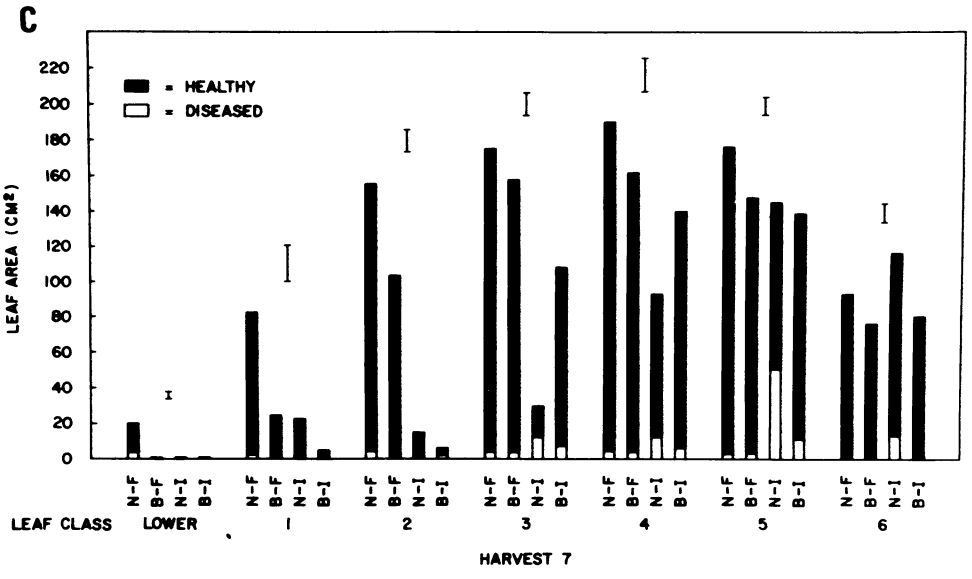


Fig. 4. Average leaf area by leaf class, showing the proportion of healthy and diseased leaf area for a) harvest 5, b) harvest 6, c) harvest 7, and d) harvest 8. Means are based on 10 plant samples (harvest 5) or 6 plant samples (harvest 6, 7, 8) from four replicate plots of each treatment. N-F, Numar treated with the fungicide Benlate; B-F, Briggs treated with Benlate; N-I, Numar inoculated with race 74 of *Rhynchosporium secalis;* B-I, Briggs inoculated with race 74 of *R. secalis.* Vertical line represents the largest standard error at that sampling.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= DISEASED
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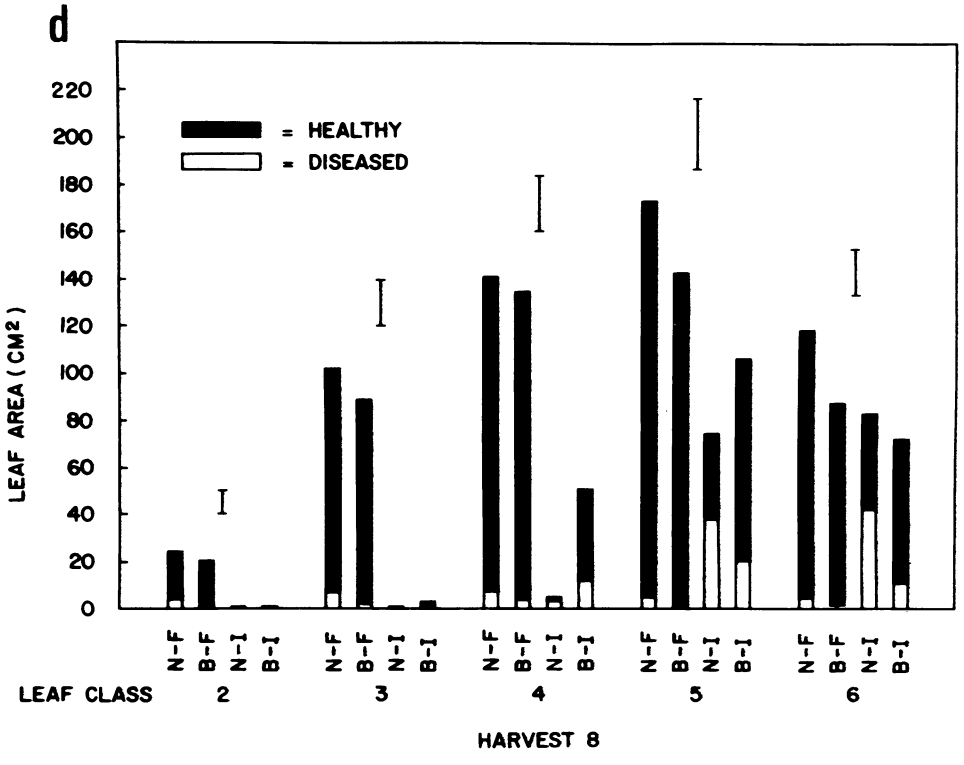
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LEAF CLASS 2 3 4 5 6
HARVEST 8

There was an inherent disease difference between the two varieties as well. Disease levels on Briggs were always less than those on Numar (within treatment groups). This is important, because for approximately equal total leaf areas, Briggs had a much larger effective (i.e., nondiseased) leaf area than did Numar.

Average leaf dry weight (Table 2) and dead leaf dry weight (Figure 5a) show several differences among treatments. Table 2 shows that leaf dry weight was approximately the same for the four treatments until harvest 4. After that time, N-f had higher leaf dry weights than other treatments, but B-f was not far below. At the final harvest, B-i showed a higher leaf dry weight than N-i, although up until that harvest, they had been about the same.

TABLE 2

AVERAGE TOTAL LIVE-LEAF DRY WEIGHT OF NUMAR AND BRIGGS BARLEY CULTIVARS SPRAYED WITH FUNGICIDE COMPARED WITH THOSE INOCULATED WITH *R. SECALIS**

Harvest	Numar-fungicide	Briggs-fungicide	Numar-inoculated	Briggs-inoculated	Largest standard error
			grams		
1	0.05	0.03	0.04	0.04	0.01
2	0.23	0.19	0.22	0.22	0.03
3	0.49	0.38	0.46	0.46	0.04
4	1.08	0.78	0.81	0.75	0.09
5	1.53	1.12	1.19	0.94	0.28
6	2.24	1.99	1.43	1.42	0.21
7	2.37	1.85	1.35	1.40	0.21
8	18.54	16.71	9.55	12.72	1.90
9 (senesced)	1.86	2.27	1.14	1.42	0.22

*Means are based on ten or six plant samples from the replicate plots of each treatment.

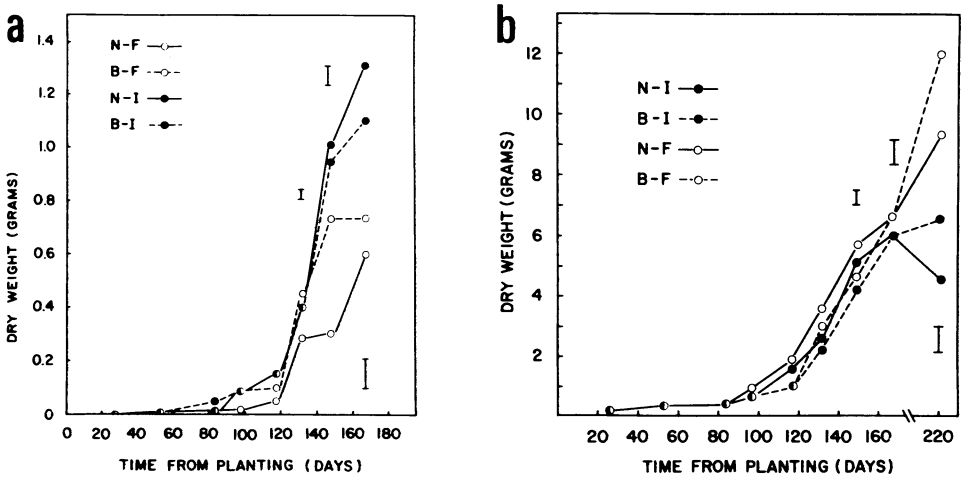

Fig. 5. Average dry weight of a) dead leaves and b) stems for N-F, Numar treated with the fungicide Benlate; B-F, Briggs treated with Benlate; N-I, Numar inoculated with race 74 of *Rhynchosporium secalis; B-I,* Briggs inoculated with race 74 of *R. secalis.* Means are based on 10 plant samples (harvests 1 through 5) or six plant samples (harvests 6 through 9) from four replicate plots of each treatment. Vertical line represents the largest standard error at that sampling.

Dead leaf dry weights indicated similarities, in reverse. N-f had consistently lower dead leaf dry weights, increasing, as they did for B-i and N-i, throughout. B-f had intermediate levels between N-f and B-i and N-i, but did not increase continually; the values held fairly constant from harvest 7 to harvest 8, an important time for grain development.

Stem dry weight, shown in Figure 5b, increased steadily with no consistent differences among treatments becoming apparent until the final harvest. For N-i, stem weight declined at harvest 9, whereas stem weight for B-i remained approximately the same. Both N-f and B-f showed large increases in stem weight, with B-f increasing more than N-f. Change in stem dry weight has been associated with the amount of available reserves for grain fill (Gallagher, Biscoe, and Scott, 1975; Rawson and Evans, 1971), and these data may indicate low reserves in N-i and possibly B-i as a result of early, severe infection.

DISCUSSION

As table 1 indicates, Briggs is able to outyield Numar under disease conditions. In both fungicide and inoculation treatments, disease development was less on Briggs than the comparable Numar treatment (Figures 3 through 4d). For the inoculated treatments, the yield increase was due to the greater number of kernels per plant. For the fungicide treatments the yield increase was due to more kernels per plant as well as to heavier kernels. Obviously, both yield components have important commercial implications.

The greater number of kernels from Briggs plants could be due to a greater number of fertile tillers (Figure 1a). By harvest 9, however, the differences in number of surviving tillers were very small among N-f, B-f, and B-i (Figure 6). It does partially explain the lower yield of N-i, since there were fewer fertile tillers in this treatment than the other three. The very early, severe disease on N-i may have been responsible, since decreases in tiller number have been noted for other foliar diseases early in the growing season (Brooks, 1972).

The difference between treatments in number of kernels per plant seems to be due to differences in number of kernels per head (Table 3). All treatments had produced

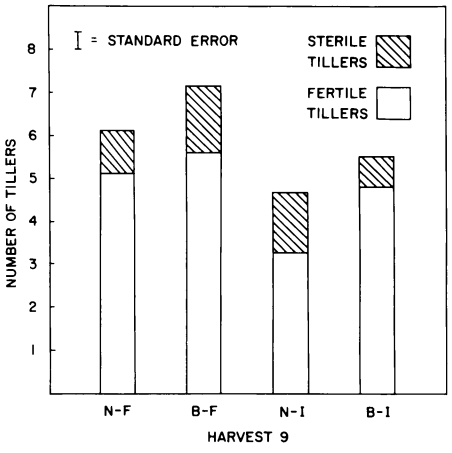

Fig. 6. Average total number of tillers, showing the proportions of fertile and sterile tillers at harvest 9: N-F, Numar treated with the fungicide Benlate; B-F, Briggs treated with Benlate; N-I, Numar inoculated with race 74 of *Rhynchosporium secalis;* B-I, Briggs inoculated with race 74 of *R. secalis*. Means are based on six plant samples from each treatment. Vertical line represents the largest standard error at that sampling.

TABLE 3
EFFECTS OF *R. SECALIS* INOCULATION VS. FUNGICIDE TREATMENT ON NUMBER OF FLORETS PER HEAD AND NUMBER OF SEEDS OF BARLEY CULTIVARS NUMAR AND BRIGGS*

Treatment	Number of seeds (harvest 9)	Number of florets/head	
		harvest 8	harvest 7
Numar-fungicide†	41.52	38.88	42.00
Briggs-fungicide	52.73	51.42	62.17
Numar-inoculated‡	30.60	33.46	40.50
Briggs-inoculated	38.35	44.63	48.88
Largest standard error	2.73	3.28	10.42

* Means based on six plant samples from the four replicate plots of each treatment.
† Plants treated with Benlate for scald disease control.
‡ Plants inoculated with race 74 of *Rhynchosporium secalis*.

roughly equal numbers of florets at harvest 7, but by harvest 8 B-f had the most and N-i the fewest florets. From kernel counts per head at harvest 9, it seems clear that B-f set the most kernels per head and N-i the fewest; N-f and B-i set about equal numbers. Thus, the yield difference between Numar and Briggs is probably due to both differences in number of grains set and, in the fungicide treatment, grain fill. It appears that disease pressure was early and severe enough in both -i and -f treatments to effect the number of florets set and grain filling, but why Briggs holds up generally better is not clear.

No doubt the better response of Briggs to disease pressure has to do with the amount and distribution of leaf area throughout the season, because the amount of assimilate determining numbers of grains, as well as extent of grain filling, has been closely linked with leaf area (Davidson, 1975; Evans and Wardlaw, 1976; Milthorpe and Ivins, 1965; Saghir, Khan, and Worzella, 1968; Willey and Holliday, 1971). In evaluating leaf area, accurate measurements of diseased leaf area are necessary. In this experiment, diseased leaf area was accurately estimated on leaves with some remaining green area (live leaves), but the total diseased leaf area was consistently underestimated, because diseased leaf area on dead leaves was not measured or estimated. Many leaves were classified as dead from disease infection. This was especially true of the Numar. Many dead leaves on Numar were obviously covered with lesions, but no accurate assessment could be made. On the other hand, dead leaves on Briggs were not usually covered with disease lesions, either in the B-f or B-i in most of the treatments, and looked very much like senescent leaves. Since functional leaf area is an important indicator in explaining yield in cereals (Davidson, 1965; Evans and Wardlaw, 1976; Saghir, Khan, and Worzella, 1968; Simpson, 1968), these faults in disease estimation could be serious.

Leaf area itself does not explain the entire result. Figure 1d shows N-f with the highest leaf area, and yet this treatment was not the highest yielding. B-i had almost the same leaf area as N-i and yet yielded better. Total leaf area certainly is affected by amount of disease, and it is the interaction of total leaf area, diseased leaf area, and time when the leaves become diseased that must affect the final yield—although other factors such as toxin sensitivity may be involved. As Figure 4 shows, it is through this interaction that Briggs gains the advantage over Numar.

In order to understand better the effects of leaf area on the final yield, it is necessary

to understand more fully what is happening to the leaves. Figure 7a shows the total number of leaves per plant and the number of dead leaves per plant. Using this graph and Ulrich's (1956) indirect graphical method, the leaf life span (Figure 7b) may be calculated. Ulrich's method involves measurement of the horizontal distance between curves for the total number of leaves per plant and the number of dead leaves per plant. The distance measured gives the time (here, in days) that the leaf will live. The leaf number is determined by reading the leaf number from the axis where the horizontal line is measured. A series of these measurements gives a curve like those shown in Figure 7b. When this is examined, certain differences in the pattern of response between Numar and Briggs can be seen. In general, the graph can be divided into two periods: that segment before the appearance of leaf seven and the period following the appearance of leaf seven.

In the first part of the graph, we see a basic difference between Briggs and Numar. While the leaf life span of Numar is long during this period, it is short for Briggs. This difference has important implications for disease development. The Briggs leaves are senescing earlier, allowing less time for *R. secalis* spores to establish, eliminating the sporulation base necessary for spread of disease up the plants. The leaves are colonized and used by the fungus in Numar. The Briggs plants have more time to establish themselves before the disease becomes severe. Numar leaves, on the other hand, have a longer time in which colonization and sporulation can occur, establishing a large source of secondary inoculum that can spread rapidly through the plants when conditions are favorable.

In the second part of the graph, Numar and Briggs again show differences. The leaf life span of Briggs peaks and begins to fall in both -i and -f treatments, as plants approach maturity. For Numar, there is a difference between -i and -f treatments. In N-i, leaf life span drops quickly to a low level, no doubt because disease spreads quickly and many leaves become totally covered by disease lesions (Figure 1c) and are removed as dead. Thus, effective leaf area is small, both because of leaf death, and because the remaining leaf area is decreased by disease (Figures 4c and 4d).

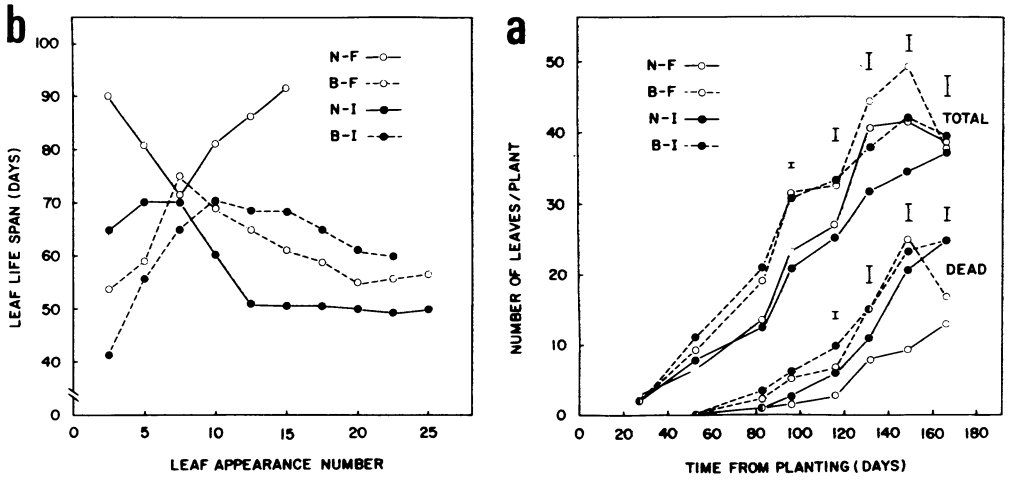

Fig. 7. a) Average total number of leaves per plant and average number of dead leaves per plant, and b) leaf life span, determined from Fig. 7a): N-F, Numar treated with fungicide Benlate; B-F, Briggs treated with Benlate; N-I, Numar inoculated with race 74 of *Rhynchosporium secalis;* B-I, Briggs inoculated with race 74 of *R. secalis.*

The curve for N-f is more difficult to interpret, because it is rather unusual in shape. The second rise in leaf life span may be due in part to effects of low levels of disease on leaf senescence: the presence of lesions on the leaves may keep them from senescing as rapidly as nondiseased leaves. It is apparent from Figure 1c that leaves continued to die but in lower numbers than other treatments.

In addition, the leaf appearance rate (Figure 8a) and the leaf death rate (Figure 8b) were examined. These graphs turned out to be of little importance because of the erratic nature of the curves. However, they confirm the basic difference between Numar and Briggs early in the season. The leaf death rate is roughly higher for Briggs early in the season. The leaves were eliminated progressively up the stem, eliminating leaves most likely to be infected. The leaf appearance rate for Briggs was roughly higher as well, indicating the presence of new leaves to replace those that were lost, augmenting the remaining leaf area. Numar, on the other hand, increased leaf area through slower addition and longer maintenance.

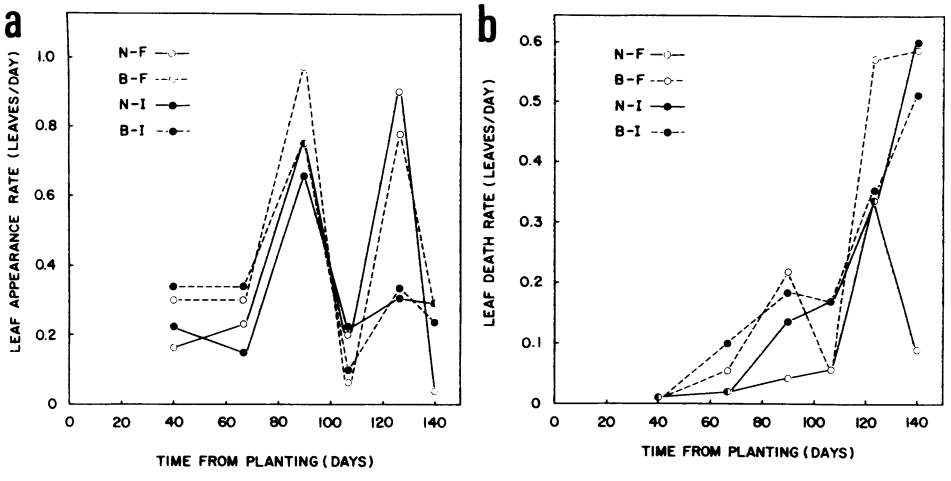

Fig. 8. a) Leaf appearance rate and b) leaf death rate determined from Fig. 7b. N-F, Numar treated with the fungicide Benlate; B-F, Briggs treated with Benlate; N-I, Numar inoculated with race 74 of *Rhynochosporium secalis;* B-I, Briggs inoculated with race 74 of *R. secalis.*

In summary, this experiment has demonstrated a difference between Numar and Briggs in relative ability to yield under disease pressure from *R. secalis.* It has also been suggested and evidence has been presented to show that one of the contributing factors to differences in disease response in these two cultivars is that of leaf life span. This is a significant step in understanding differences in resistance between Numar and Briggs. The suggested mechanism agrees with epidemiological data on how diseases develop and why this pattern of growth should result in less disease (van der Plank, 1963, 1975).

Since leaf life span can be measured relatively easily, this may result in a good basic screening technique. It would result in selection of a good genetic background to superimpose vertical resistance genes, because it would give a measure of basic background resistance (a horizontal type) from which to start. Finally, further work in this area may lead to a better understanding of resistance mechanisms and disease control.

Acknowledgment

The authors thank Don Phillips for the use of his leaf area meter, and Jeffrey Vieira for technical assistance.

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3m-4, '81 (PAD/ME)