Yield Loss of Maize Caused by *Kabatiella zeae*

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ABSTRACT

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The effect of eyespot disease, caused by *Kabatiella zeae*, on yield of maize (*Zea mays*) and the relationship between yield and disease rating at different plant growth stages and inoculation frequencies were studied using inbred W64A (susceptible to *K. zeae*) in 1978 and inbreds W64A and Oh43 (resistant) and hybrids W64A × Oh43 and W64A × A632 in 1979 on a plowed field (PL) and on a field kept under minimum tillage, with debris on the surface (DB). In 1978, inoculations significantly decreased grain yields. Weekly inoculations reduced grain yields 44 and 33%, respectively, on PL and DB. Yields of uninoculated plants, however, were 20% lower on DB than on PL. In 1978 and again in 1979, reductions due to biweekly and monthly inoculations were similar. In 1979, average yield reduction for all inbreds and hybrids on both PL and DB, due to the natural occurrence of eyespot, was 9% lower than for fungicide-sprayed plants. Differences due to treatments and inbreds and hybrids on both PL and DB were highly significant, and the interaction of treatment by inbred or hybrid was highly significant on DB. Regressions of grain yields on disease ratings at late whorl, silk, or soft dough stages were highly significant for all inbreds and hybrids on both PL and DB. Silk was considered the best plant growth stage for eyespot evaluation, because ratings covered the range of the disease rating scale used. The destructive potential of *K. zeae* was considered similar to that of *Helminthosporium carbonum*.

Eyespot disease of maize (*Zea mays* L.), caused by *Kabatiella zeae* Narita & Y. Hiratsuka, was identified in the United States in 1968 (12). In Wisconsin, maize fields have had substantial yield reductions due to the disease (2). Boothroyd (3) reported 68–72% greater yield after conventional tillage than after no-plow tillage, eyespot being largely responsible for the low yield because of its carryover in maize debris. Within the no-plow plot with fungicide application, yield was 21% greater than the check yield. In France, losses up to 50% were observed in certain fields (4).

To assess the potential effect of eyespot on yield of maize and to study relationships between yield and disease rating at different periods and inoculation frequencies, experiments were conducted in 1978 and 1979 on fields with two different tillage practices. Maize inbred W64A, used in the production of approximately one-third of hybrids certified in Wisconsin (1), was included in both years' trials.

MATERIALS AND METHODS

The experiments were conducted at Arlington, WI, on two adjacent fields with equivalent fertility levels. Both fields had been planted with maize for the previous 10 yr. One was plowed and disked each year, and the other was kept under minimum tillage (stubble mulch tillage) with debris on the soil surface.

In 1978, in both fields, plants of the susceptible inbred W64A (10) were inoculated weekly, biweekly, or monthly and compared with uninoculated plants. However, some natural infection occurred in the control plot. A randomized complete block design was used, with four replications. Plots consisted of four rows, 90 cm apart, with 32 plants per row spaced 23 cm apart. The 40 plants in the center of the two central rows of each plot were harvested, and whole plant, stover, and ear fresh weights were determined. After drying, similar weights, as well as grain and 1,000-kernel weights, were determined.

In 1979, W64A, resistant inbred Oh43 (5,10), and hybrids W64A × Oh43 and W64A × A632 were inoculated as in 1978 and compared with uninoculated plants sprayed with water or fungicide in both fields. Benomyl (methyl (1-butylcarbamoyl)2-benzimidazolecarbamate), known to be effective against *K. zeae* (4), was applied at 1,000 ppm weekly throughout the season. A split-plot design was used, with fungicide treatments as main plots and maize inbreds and hybrids as subplots, with five replications. Plots were similar to those in 1978 but had 14 plants per row. The 20 ears in the two central rows of each subplot were harvested, and weights were determined for fresh ears, dry ears, dry grain, and 1,000 kernels. Inoculum, consisting of a conidial suspension, was prepared by growing the fungus (isolate 73A3) on *K. zeae* liquid medium for 5–6 days (11). A low-pressure hand sprayer was used to inoculate the plants with the suspension (approximately 10^6 conidia per milliliter), the plants being sprayed until runoff at sunset. Eight weekly inoculations were made in 1978, but only five in 1979, due to the delayed emergence of Oh43 plants.

The last inoculations were made at tasseling. Growth stages were determined with a standard scale (6).

Plants were scored in 1978 at silking and in 1979 at late whorl, silking, and soft dough stages, on a 0–5 modified maize rust scale (8) for estimated percentage of leaf area covered with eyespot, excluding the uppermost three leaves. Ratings of 0–5 indicated eyespot covering 0, 1, 5, 10, 20, and more than 20% of the leaf surface, respectively.

Yield data were analyzed in 1978, and disease ratings and dry grain yield data were analyzed in 1979. Simple linear regression models were used to study the relationships among yields of the four genotypes and disease ratings at the three growth stages, on both fields.

RESULTS

1978 trials. *K. zeae* inoculations on the plowed field significantly decreased yields of inbred W64A (Table 1). Although there was an absolute decrease in yields with increased inoculation frequencies, yields for biweekly and monthly inoculations were statistically similar, except for plant and stover dry weights. Dry grain yields were reduced 44, 28, and 17% due to weekly, biweekly, and monthly inoculations, respectively. Yields of uninoculated plants were consistently lower on the minimum-tilled field (Table 1) than on the plowed field, dry grain yield being reduced approximately 20%. However, dry yields of plants inoculated weekly were similar to

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yields on the plowed field. In minimum tillage plots, dry grain yields were reduced 33, 20, and 8% due to weekly, biweekly, and monthly inoculations, but the frequency of inoculation did not have a significant effect on stover and 1,000-kernel weights. Disease ratings were similar for both plots (Table 1).

1979 trials. As in 1978, mean yields for the biweekly and monthly inoculations on both plots did not differ significantly, although yields were slightly higher with monthly than with biweekly inoculations (Table 2). Oh43 and W64A yields were reduced an average of 63 and 75%, respectively, considering data for both fields with weekly inoculations.

The water check, compared with the fungicide-sprayed plots, provided an estimate of yield reduction on both fields due to the natural occurrence of eyespot. Mean grain yields of all inbreds and hybrids sprayed with water were 9% lower than those of plants sprayed with fungicide, but this difference was not significant. However, yield of inbred W64A was reduced 20 and 34% on the plowed and minimum-tillage fields, respectively; the reduction in the minimum-tillage plot was significant.

The analysis of variance for grain dry weights showed highly significant differences due to both inoculation treatment and inbred or hybrid on both plots. The interaction of treatment by inbred or hybrid was highly significant on the minimum-tillage field.

Regression of grain yields on disease ratings at late whorl, silk, or soft dough stages was highly significant for all inbreds and hybrids in both fields. The regression analyses with the highest coefficients of determination (r^2) are reported in Table 3.

DISCUSSION

We believe the low yields of uninoculated W64A on the minimum-tillage field in 1978 and of the checks of all inbreds and hybrids on the same field in 1979 are due to subsoil compaction and other soil-related problems, since the area had not been plowed for a number of years. Abnormal ridging on the field increased the problem in 1978.

In both years, dry grain yield reductions due to biweekly and monthly inoculations did not differ significantly, except once in 1978. This indicates that biweekly inoculation may not be necessary to generate different eyespot severities. Further work involving single inoculations during the growing season at different plant growth stages would allow more complete assessment of crop loss due to eyespot.

Our results indicate that the destructive potential of *K. zeae* is similar to that of *Helminthosporium carbonum* (mean grain yield reduction of 6%), as reported by Fisher et al (7). Based on the comparison of water and fungicide applications, our estimate of mean grain yield reduction (9%) due to the natural occurrence of eyespot agrees with the range of 2–10% given by the Corn/Soybeans Study Team (9).

Our data suggest that resistance shown by Oh43 would not be

TABLE 1. Effect of *Kabatiella zeae* inoculations on eyespot incidence and yields[x] of maize inbred W64A planted in 1978 on a plowed field and on a minimum-tilled field with debris

		Fresh weights (g)[z]			Dry weights (g)				
Treatment	Disease rating[y]	Plant	Stover	Ear	Plant	Stover	Ear	Grain	1,000 Kernel
Plowed									
Inoculation									
Weekly	5.0	8,528 a	5,216 a	3,311 a	3,040 a	1,457 a	1,582 a	1,244 a	148 a
Biweekly	3.2	10,070 b	5,942 b	4,128 b	3,596 b	1,575 b	2.021 b	1,584 b	156 b
Monthly	3.0	11,068 b	6,396 b	4,672 b	4,062 c	1,727 c	2,335 b	1,830 b	161 bc
Uninoculated	1.0	13,200 c	7,439 c	5,761 c	4,782 d	1,925 d	2,857 c	2,207 c	173 c
Debris									
Inoculation									
Weekly	5.0	7,530 a	4,218 a	3,311 a	2,934 a	1,430 a	1,504 a	1,177 a	146 a
Biweekly	3.5	8,165 a	4,400 a	3,765 a	3,301 a	1,515 a	1,786 a	1,398 b	149 a
Monthly	2.7	8,618 ab	4,309 a	4,309 b	3,690 b	1,597 a	2,092 b	1.613 c	140 a
Uninoculated	1.0	9.163 b	4,581 a	4,581 c	3,941 c	1,680 a	2,261 c	1,763 d	146 a

[x]Yields in grams per 40 plants.
[y]Averge of four replications, where 0 = 0, 1 = 1, 2 = 5, 3 = 10, 4 = 20, and 5 = >20% of the leaf surface, excluding the uppermost three leaves, covered with eyespot. Plants were rated at silking.
[z]Numbers followed by different letters within tillage treatments and columns differ significantly at $P = 0.05$, by Duncan's multiple range test.

TABLE 2. Effect of *Kabatiella zeae* inoculation on grain dry weights[a] of maize inbreds W64A and Oh43 and hybrids W64A × Oh43 and W64A × A632 planted in 1979 on a plowed field (PL) and on a minimum-tilled field with debris on the surface (DB)

	Grain dry weight (g) and disease rating[b]									
	W64A		Oh43		W64A × Oh43		W64A × A632		Mean	
Treatment	PL[c]	DB[d]	PL	DB	PL	DB	PL	DB	PL	DB
Inoculation										
Weekly	331 (4.0)[d]	428 (3.0)	428 (3.0)	524 (2.0)	1,490 (3.0)	1,503 (3.0)	2,082 (2.0)	1,879 (2.0)	1,083	1,084
Biweekly	602 (3.0)	556 (1.0)	736 (1.2)	845 (1.0)	2,078 (2.0)	2,046 (1.0)	2,362 (1.0)	2,221 (1.0)	1,444	1,417
Monthly	673 (1.2)	691 (1.0)	754 (1.0)	816 (1.0)	1,987 (1.0)	2,026 (1.2)	2,472 (1.0)	2,241 (1.0)	1,471	1,443
Check										
Water	1,310 (0.8)	956 (0.2)	1,186 (0.4)	1,186 (1.0)	3,093 (1.0)	3,001 (1.0)	3,090 (0.2)	2,948 (1.0)	2,170	2,073
Fungicide	1,627 (0.0)	1,449 (0.0)	1,368 (0.6)	1,252 (0.0)	3,338 (0.2)	2,978 (0.2)	3,328 (0.0)	3,253 (0.0)	2,352	2,233
Mean	909	816	894	925	2,346	2,311	2,667	2,508		

[a]Grain yields in grams per 20 plants.
[b]Average of five replications, where 0 = 0, 1 = 1, 2 = 5, 3 = 10, 4 = 20, and 5 = >20% of the leaf surface, excluding the uppermost three leaves, covered with eyespot. Ratings made at silking.
[c]LSD ($P = 0.05$) for PL: treatment means, 196; genotype means, 142; between genotypes within the same treatment, 317; within genotypes and between genotypes within different treatments, 337.
[d]LSD ($P = 0.05$) for DB: treatment means, 246; gentoype means, 116; between genotypes within the same treatment, 260; within genotypes and between genotypes within different treatments, 334.

TABLE 3. Regression analyses of grain dry weights, Y (grams per 20 ears), on eyespot ratings, X(0–5 scale), for maize inbreds W64A and Oh43 and hybrids W64A × Oh43 and W64A × A632 in a plowed and in a minimum-tilled field (debris)

Tillage and genotype	Growth stage[b]	Regression analysis[a]		
		Equation	$r^{2\,c}$	F^d
Plowed				
W64A	9.2	Y = 1,702 − 233X	0.85	36.5
Oh43	9.2	Y = 1,177 − 283X	0.64	43.1
W64A × Oh43	6	Y = 3,088 − 1,236X	0.70	57.4
W64A × A632	8	Y = 3,217 − 655X	0.81	105.4
Debris				
W64A	9.2	Y = 1,530 − 196X	0.76	75.4
Oh43	6	Y = 1,212 − 378X	0.49	23.7
W64A × Oh43	6	Y = 2,989 − 1,131X	0.72	63.7
W64A × A632	9.2	Y = 3,562 − 599X	0.75	71.9

[a] Only analyses with the highest coefficients of determination (r^2) for each inbred or hybrid are shown.
[b] Growth stages based on key by Chiarappa (6) in which 6 = late whorl, 8 = silk, and 9.2 = soft dough.
[c] Coefficients of determination adjusted for degrees of freedom.
[d] Each value in this column is significant at $P = 0.01$.

effective under severe epiphytotics, although Oh43's resistance is adequate if eyespot incidence is normal (5,10). The generally low yield of Oh43 may be related to its delayed emergence.

The rating scale we used may have lacked some resolution sensu Zadoks and Schein (13), which could have caused the regression analyses of grain yield on disease ratings to be highly significant at the scoring dates. At late whorl and soft dough stages, most ratings were grouped at only two values. At silking, however, ratings were spread throughout the scale, and we consider this to be the best growth stage for eyespot evaluation.

LITERATURE CITED

1. Anonymous. 1979. 1979 seed list. Wisc. Crop Improvement Assoc., Madison. 39 pp.
2. Arny, D. C., Smalley, E. B., Ullstrup, A. J., Worf, G. L., and Ahrens, R. W. 1971. Eyespot of maize, a disease new to North America. Phytopathology 61:54-57.
3. Boothroyd, C. W. 1977. *Kabatiella* eyespot in a comparison of no-plow and conventional tillage. Pages 6-8 in: Proc. of 32nd NE Corn Imp. Conf., New York, Feb. 11-12, 1977.
4. Cassini, R. 1971. *Helminthosporium maydis* race T et *Kabatiella zeae*, deux agents pathogenes du mais nouveaux en France. Bull. Tech. Inf. 264-265:1067-1072.
5. Cassini, R., and Gay, J. P. 1973. Comportment de quelques lignees pures et hybrids de mais vis a vis de *Kabatiella zeae* Narita et Hiratsuka. C. R. Eucarpia mais, Zagreb, Sept. 3-6, 1973. 6 pp.
6. Chiarappa, L. (ed.). 1971. Crop Loss Assessment Methods. Commonwealth Agric. Bur., Slough.
7. Fisher, D. E., Hooker, A. L., Lim, S. M., and Smith, D. R. 1976. Leaf infection and yield loss caused by four *Helminthosporium* leaf diseases of corn. Phytopathology 66:942-944.
8. Kim, S. K., and Brewbaker, J. L. 1977. Inheritance of general resistance in maize to *Puccinia sorghi* Schw. Crop Sci. 17:456-461.
9. National Academy of Sciences. 1975. Corn/Soybeans Pest Control. Natl. Acad. Sci., Washington, DC. 169 pp.
10. Reifschneider, F. J. B., and Arny, D. C. 1979. Inheritance of resistance to *Kabatiella zeae* Narita & Hiratsuka, the causal agent of eyespot of maize (*Zea mays* L.). (Abstr.) Phytopathology 69:542.
11. Reifschneider, F. J. B., and Arny, D. C. 1979. A liquid medium for the production of *Kabatiella zeae* conidia. Can. J. Microbiol. 25:1100-1102.
12. Ullstrup, A. J., Smalley, E. B., Worf, G. L., and Ahrens, R. W. 1969. Eyespot: A serious new disease of corn in the United States. (Abstr.) Phytopathology 59:1054.
13. Zadoks, J. C., and Schein, R. D. 1979. Epidemiology and Plant Disease Management. Oxford University Press, Inc., New York. 252 pp.