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TOLERANCE LEVEL OF *ALTERNARIA SESAMI* AND THE EFFECT OF SEED INFECTION ON YIELD OF SESAME IN KENYA

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SUMMARY

Field plots of sesame (*Sesamum indicum*) with six different levels of seed infection with *Alternaria sesami* were monitored for *Alternaria* leaf spot severity at Kibwezi, eastern Kenya. The aim of the study was to determine the effect of seed transmission of the pathogen on yield and tolerance level of the fungus in sesame seed. Increase in percentage leaf area diseased and percentage defoliation fitted the Gompertz model more closely than the logistic model. Areas under disease progress curves (AUDPC), infection and defoliation rates varied among the six infection levels. Disease severity increased with increase in seed infection and was least and most severe in plots established with seeds with 0 and 8% infection levels respectively. Yields ranged from 234.9 to 300.1 kg ha^{-1} compared with 312.5 kg ha^{-1} for the control, and losses due to seed infection ranged from 4% to 25%. Disease severity was negatively correlated with seed yield, 1000-seed weight and seeds per capsule. Alternaria leaf spot severity had a major effect on the seed weight component of yield. Tolerance level of *A. sesami* in sesame seed was determined to be less than 2%.

INTRODUCTION

Sesame (*Sesamum indicum*) is considered to be a drought-resistant plant (Weiss, 1971) which can produce a crop with as little as 300 mm of rainfall. Among the most important diseases that affect yield of sesame in Kenya is alternaria leaf spot (Ayiecho and Nyabundi, 1995) caused by *Alternaria sesami* (Kawamura) (Mohanty and Behera, 1958). This seed-transmitted disease (Kolte, 1985) is distributed worldwide (Leppik and Sowell, 1964) and was first reported in Kenya by Gatumbi (1986).

The major constraint to the control of *Alternaria* leaf spot of sesame in Kenya is the lack of certified seeds for planting (Gichuki and Gethi, 1988) which have tolerable levels of *A. sesami*. In seed health testing, tolerance is established by correlation between infection levels based on seed health tests and disease ratings in fields planted with infected seed (Gabrielson, 1988). Rennie and Seaton (1975) reported a significant positive correlation between the proportion of barley embryos infected with *Ustilago nuda* and the field occurrence of loose smut of barley. This correlation is also referred to as the seed transmission: yield reduction ratio (Neergaard, 1979). Based on this ratio tolerance levels of several pathogens have been established. For instance, the tolerance level of *Alternaria* spp. in flax and linseed seed is 2% (Neergaard, 1979), and of *Cercospora kikuchii* in soyabean seed 4% (USDA–APHIS, 1986). Establishment of valid tolerance levels for local areas coupled with accurate seed health tests provides a powerful management tool for the control of many seed-borne diseases. Seed transmitted fungi that sporulate readily, such as *Alternaria* spp. are easily detectable in routine testing. Seed infection levels detected by such tests are fairly comparable. Therefore the objectives of the work in this paper were (1) to determine the effect of seed infection with *A. sesami* on alternaria leaf spot severity and (2) to define the tolerance levels of the fungus in sesame seed.

MATERIALS AND METHODS

Effect of seed infection on disease severity

Sesame plant accession SPS SIK 110 was used in this study. Seeds were obtained from the germplasm collection of the Sesame Improvement Project of the University of Nairobi. The seeds had been harvested in 1995 at two experimental sites in Siaya Farmer Training Center (FTC) in Nyanza Province and Mtwapa in Coast Province. Due to the high incidence of the disease in Siaya FTC, spraying was done using 0.1% zineb to control the disease. Seed infection was assessed using the agar plate method (Neergaard, 1979) and seeds were separated into six infection levels of 0, 2, 4, 5, 7 and 8%. The 0% infection level represented the control treatment, and no fungicides were applied in the control plots. Disease recorded on the control plants was assumed to be from outside sources and to affect uniformly all the treatments.

The seeds were planted in a randomized complete block design with three replicates at Kibwezi, Institute of Dryland Research Development and Utilisation (IDRDU) on 21 March and 29 October, 1996. Plots of each seed infection level consisted of five 4-m rows spaced 50 cm apart with plants 20 cm apart within rows. Plots were arranged perpendicular to the direction of the prevailing wind to reduce interplot interference, and were separated from each other at the ends and sides by 2-m strips of susceptible sesame accession SPS SIK 013.

Severity of *Alternaria* leaf spot was assessed as the percentage leaf area diseased and the percentage defoliation from April to June 1996 for the first season, and from November to February 1997 for the second season. Average diseased leaf areas of plants in the treatment plots were estimated using 10 plants selected at random on each sampling date. Leaf areas (one surface) were calculated by multiplying average width by length measurements for various linear proportions of the leaves with the triangular leaf apices calculated separately. Lesion counts and lesion areas were recorded every 10–14 d for the 10 plants that were tagged throughout the study for determination of disease progress. Mean percentage disease was calculated by lesion numbers multiplied by average lesion area divided by total leaf area. To determine percentage defoliation, each row within the plot was divided into 50-cm segments prior to each assessment date. One segment per row was randomly selected every 10–14 d in each plot and the number of nodes and missing leaves counted on each main stem. The percentage leaf area blighted and the percentage defoliation were used in separate determinations of the area under disease progress curve (AUDPC) as a result of leaf area blighted (AUDPC–DL) and defoliation (AUDPC–DF) using the formula of Shaner and Finney (1977):

$$\text{AUDPC} = \Sigma\,[(Y_{i+1} + Y_i)/2]\,(X_{i+1} - X_i)$$

where Y_i = disease severity per unit (leaf area blighted or defoliation) at the ith observation
X_i = date of ith observation in days after planting

Determination of tolerance level of A. sesami *in sesame seed*

Seed yield from each treatment plot was determined and converted to kg ha^{-1}. Yield components (number of capsules per plant, the 1000-seed weights and seeds per capsule) were recorded. Percentage yield loss in each treatment plot (PYLT) was calculated using the average yield (kg ha^{-1}) observed in the control plots using the formula:

$$\text{PYLT} = [(\text{CY} - \text{TY})/\text{CY}] \times 100$$

where CY = yield in control plot
TY = yield in treatment plot

Data analysis

Gompertz and logistic models were fitted to percentage blighted leaf areas and percentage defoliation data. Apparent rates of disease increase were obtained by regressing transformed disease data against time. The most suitable model for assessing infection and defoliation rates was determined using standardized residual plots, coefficients of determination (R^2) and additional statistics as described by Neter *et al.* (1983). After choosing the most suitable model, autocorrelation of the residual was calculated as described by Madden (1986) and the Student *t*-test was used to determine whether the autocorrelation was different from zero. Rates of increase were obtained by regressing Gompertz-transformed disease or defoliation data against time (days after planting) using the equation:

$$K = [\text{gompit}(\text{Ymax}) - \text{gompit}(\text{Ymin})]/(t_2 - t_1)$$

in which gompit = $-\ln[-\ln(Y)]$, (Ymin) and (Ymax) being the proportion of disease or defoliation observed at the beginning (t_1) and the end (t_2) (Luke and Berger, 1982). The Student *t*-test was carried out separately for AUDPC–DL, AUDPC–DF, infection and defoliation rates, and yields in the first and second seasons to determine the existence of differences between the two seasons. Within each season, AUDPC–DL, AUDPC–DF, infection and defoliation rates, and yield from each treatment were compared using analysis of variance. Significant differences were identified using Least Significant Difference (l.s.d.) (Steel and Torrie, 1980). Correlation analysis was carried out to establish the relationship between AUDPCs and yield and yield components. Seed infection level at which the yield was not significantly different from that of the control defined the tolerance level of *A. sesami*.

RESULTS

Effect of seed infection on disease severity

Area under disease progress curves for percentage leaf area diseased (AUDPC–DL) due to *A. sesami* seed infection were significantly larger during the first season than in the second season. Highly significant differences in AUDPC–DL were also observed among the six seed infection levels in both seasons, plants established from seed with 8% infection having the largest AUDPC–DL in both seasons. The other infection levels studied had significantly smaller AUDPC–DL except 5% and 7% infection levels in season one and 7% infection during the second season (Table 1). Area under disease progress curves for percentage defoliation (AUDPC–DF) due to seed infection were also significantly larger in the first season than in the second season. Plants established with seed from the 8% infection level had a significantly larger AUDPC–DF than did other infection levels tested, except the 4%, 5% and 7% levels during both seasons (Table 1).

The Gompertz model generally produced higher coefficients of determination ($R^2 = 0.91$) than did the logistic model ($R^2 = 0.37$). Rates of increase in *Alternaria*

Table 1. Mean area under disease progress curves for percentage leaf area diseased (AUDPC–DL)† and percentage defoliation (AUDPC–DF) with six levels of seed infection by *A. sesami* for sesame grown at Kibwezi, eastern Kenya.

	Experimental season			
	First season		Second season	
Infection (%)	AUDPC–DL	AUDPC–DF	AUDPC–DL	AUDPC–DF
0	0.18	0.35	0.10	0.20
2	0.35	0.56	0.33	0.35
4	0.59	0.60	0.60	0.40
5	1.41	0.80	1.39	0.48
7	1.95	0.89	1.59	0.55
8	2.30	0.99	2.26	0.66
Mean	1.13	0.70	1.04	0.44
s.e.	0.36	0.10	0.34	0.07

†% disease per day, average of three replications in each season.

leaf spot were therefore estimated and compared using the Gompertz model. Goodness-of-fit of the models to disease progress data appeared to vary from one seed infection level to another. Rates of increase in percentage leaf area diseased (infection rates) due to *Alternaria* leaf spot were statistically similar in both experimental seasons. There were, however, highly significant differences in infection rates among the six levels of seed infection in both seasons. Maximum infection rates were observed in plots established with seeds of 8 and 7% infection levels in the first and second seasons respectively. The rates of increase in percentage leaf area diseased were significantly lower on the other seed infection levels tested except the 4, 5 and 7% levels in the first season, and 5% and 8% levels in the second season. The least rate of disease increase was observed in plots established from seed with a 0% infection level in the two seasons, though infection rates on plants with this infection level did not differ significantly from those of other infection levels studied except the 5, 7 and 8% levels in the first season and the 8% level in the second season.

Defoliation rates due to *Alternaria* leaf spot as a result of seed infection were significantly faster in the first season than in the second season. In both seasons the plants established from seed with 8% infection level had a significantly faster rate of defoliation than did other levels tested except the 5 and 7% levels in the first season and the 7% level in the second season. The slowest rate of increase in percentage defoliation was observed in plots established from seed with a 0% level, but the defoliation rate due to this infection level did not differ significantly from that due to other infection levels tested except the 7 and 8% levels in the first season, and the 8% level in the second season (Table 2).

Table 2. Rate of increase in percentage leaf area diseased† and percentage defoliation† with six levels of seed infection by *A. sesami*† for sesame grown at Kibwezi, eastern Kenya.

	Experimental season			
	First season		Second season	
Seed infection (%)	Infection rate	Defoliation rate	Infection rate	Defoliation rate
0	0.032	0.027	0.032	0.020
2	0.042	0.027	0.040	0.019
4	0.078	0.028	0.056	0.021
5	0.086	0.032	0.061	0.022
7	0.088	0.042	0.108	0.030
8	0.092	0.043	0.069	0.034
Mean	0.070	0.033	0.061	0.024
s.e.	0.010	0.003	0.011	0.002

†% disease per day, average of three replications in each season.

Table 3. Effect of leaf spot severity caused by seed infection by *A. sesami* on yield and yield components of sesame† grown at Kibwezi, eastern Kenya.

Seed infection (%)	Severity (AUDPC–DL)‡	Yield loss (%)	Yield (kg ha^{-1})	1000-seed weight (g)	Seeds per capsule	Capsultes per plant
0	0.14	0	312.50	3.97	60.5	42.8
2	0.34	4	300.10	3.82	58.8	38.6
4	0.60	7	290.60	3.71	55.1	39.4
5	1.40	10	283.70	2.70	51.1	40.3
7	1.77	18	255.10	2.20	50.7	37.8
8	2.28	25	234.90	2.10	45.4	39.4
Mean			279.50	3.10	53.6	39.7
s.e.			4.90	0.35	2.3	0.7
Correlation coefficient (r)§			−0.84*	−0.89**	−0.86*	−0.37
Correlation coefficient (r)¶			0.84*	0.80*	0.58	

†Yields were not significantly different in the two seasons and so yields and yield components are presented for combined data; ‡AUDPC–DL used for correlation are averages of both seasons; §correlation coefficients of severity against yield and yield components; * and ** are significant at $p = 0.01$ and $p = 0.001$ respectively.

Tolerance level of A. sesami *in sesame seed*

Alternaria leaf spot significantly reduced seed yields with losses ranging from 4% to 25% (Table 3). Highly significant differences in yield were observed among the seed infection levels though yields were statistically similar in both seasons. The greatest yield loss of 25% occurred in plots established from seed with an 8% infection level, and seed yields decreased with increase in seed infection. The highest yield of 321.5 kg ha^{-1} obtained in the control plots established from seed with 0% infection did not differ significantly from yields obtained from seed with 2, 4 and 5% infection levels. The lowest seed yield of 234.9 kg ha^{-1} obtained in plots established from seed with an 8% infection level was significantly lower than yields from the other infection levels studied except the 7% level (Table 3).

Disease severity was significantly negatively correlated with seed yields ($r = -0.84$, $p = 0.01$), 1000-seed weight ($r = -0.89$, $p = 0.001$) and seed per capsule ($r = -0.86$, $p = 0.01$) but had only a weak negative correlation with capsules per plant ($r = -0.37$, $p = 0.01$). Seed yield was significantly positively correlated with 1000-seed weight ($r = 0.84$, $p = 0.01$) and seed per capsule ($r = 0.80$, $p = 0.01$) but had a weak positive correlation with capsules per plant ($r = 0.58$, $p = 0.01$) (Table 3).

DISCUSSION

The Gompertz model was superior compared with the logistic model in linearizing the alternaria leaf spot progress due to seed infection. Coefficients of determination of Gompertz-transformed disease data varied across the infection levels, though the Gompertz model provided statistically significant fits to disease progress data. This problem could have been avoided by using more mathematically explicit models such as the Wiebull model (Pennypecker *et al*., 1980), but such models often involve too complex computations to use especially when evaluating more than just a few infection levels.

Apart from making it possible to avoid problems associated with imperfect fits of disease data and being relatively easy to calculate, AUDPCs also appeared to be better descriptors of *Alternaria* leaf spot severity due to seed transmission compared with estimates of infection or defoliation rates. To the extent that the disease data did not fall on a straight line, the apparent infection and defoliation rates obscured some of the true variation in the rate of disease development. Rates of disease increase were averages over the entire season, while AUDPCs were calculated from averages of disease over 10–14 d intervals. AUDPCs may, therefore, reflect timing of disease more accurately than rates of disease increase. Johnson *et al*., (1986) also made similar conclusions while studying the early leaf spot of groundnut caused by *Cercospora arachidicola*. However, as defoliation due to greater severity can be confounded with effects of plant senescence or environmental stress, AUDPC–DF is a less reliable tool than AUDPC–DL.

Yield losses of up to 25% due to an infection level of only 8% indicate that higher yield losses may be realized as a result of higher levels of seed infection. Similar findings were made by Barboza *et al.* (1966) on sesame artificially infected by *Alternaria* spp. Alternaria leaf spot had a major effect on the seed weight component of yield. Yield losses in this study, therefore, were mostly attributed to decreases in the seed weights. Reduced seed weight was also reported to contribute greatly to yield losses in sunflower infected by *A. helianthi* (Carson, 1985). The high correlation coefficients obtained in this study indicated that much of the variance between yield and yield components due to seed infection was explained by and was due to *Alternaria* leaf spot severity.

The principal factors to consider when setting up disease tolerances in seed health testing is the effect of seed infection on yield (Gabrielson, 1988) and the seeding rate (Neergaard, 1979). This study showed that seed yields with 2, 4 and 5% levels of seed infection were not significantly different from that of the control. In this case, therefore, the tolerance level of *A. sesami* in sesame seed can be set at 2–5%. However, considering the spacing of 50 cm by 20 cm, the sesame plant population per hectare would be about 100 000 plants. With infection levels of 2, 4 and 5% there would be approximately 2000, 4000 and 5000 infected plants per hectare, respectively, assuming that all infected seeds germinate and seeds which germinate give rise to infected plants. Two thousand infected plants randomly distributed could bring about a severe epidemic leading to severe yield losses under favourable environmental conditions. Taking into consideration the above factors and given the importance of *Alternaria* leaf spot in sesame production, a seed infection level of less than 2% would be the most appropriate tolerance level of *A. sesami* in seed health tests.

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