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Resistance

Chemical Desiccation of Wheat Plants as a Simulator of Postanthesis Speckled Leaf Blotch Stress

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ABSTRACT

Zilberstein, M., Blum, A., and Eyal, Z. 1985. Chemical desiccation of wheat plants as a simulator of postanthesis speckled leaf blotch stress. Phytopathology 75:226-230.

Field trials were conducted over 2 yr to evaluate whether the postanthesis destruction of the photosynthetic source by chemical desiccation may be used to detect wheat cultivars that sustain kernel growth in the presence of speckled leaf blotch. Spring wheat cultivars of diverse origin were subjected to three treatments: inoculation with virulent isolates of *Septoria tritici* until an epidemic was initiated, postanthesis application of magnesium chlorate (4% a.i.) solution to destroy most of the plant's green tissues, and a control in which a fungicide was applied to protect against loss of green tissue. Grain yield components, kernel growth curves, and harvest index were determined. The progress of the pathogen on the four uppermost leaves was monitored at weekly intervals. For similar *Septoria* progress values (area under the disease progress curve), various cultivars manifested different rates of loss in kernel weight (as percent of the fungicide-treated

control), and harvest index. Cultivars differed in the rate of loss in kernel weight and harvest index when treated with the chemical desiccant. Significant correlations were revealed across the same five cultivars in losses in kernel weight between plants infected by *S. tritici* and those that had been chemically desiccated in 1 yr ($r = 0.925$) but not in the other ($r = 0.804$). Correlation between the two parameters was highly significant ($r = 0.626$) across 16 (out of 18) cultivars that had similar *Septoria* progress values. The correlations in losses in kernel weight between plants infected by *S. tritici* and those that had been mechanically defoliated (postanthesis) in the five cultivars in 1981-1982 were $r = 0.733$. The potential for utilizing postanthesis chemical desiccation as a measure for revealing wheat cultivars tolerant to speckled leaf blotch in the absence of infection by *S. tritici* is discussed.

Additional key words: tolerance, *Triticum aestivum*, yield components.

Speckled leaf blotch, which is caused in wheat by the fungus *Septoria tritici* Rob. ex Desm. (perfect state: *Mycosphaerella graminicola* (Fuckel) Schroeter), may impose severe limitations on crop yield. In certain environments and years the impact is more pronounced than in others (7).

Under certain environments, early buildup of infection by *S. tritici* on lower plant parts may adversely affect root biomass and plant development (19). Early infection of lower leaves also may reduce yield, especially by altering sink development (the number of tillers per plant, the number of spikes per plant, and the number of grains per spike) and consequently affect assimilate distribution (16,17,19).

Infection of the upper plant parts that are responsible for grain filling is considered to be the most significant factor contributing to losses in yield (18). Infection on upper plant parts usually affects kernel weight and grain number (6,9,22,24). The magnitude of reduction in yield components depends on the pre- and postanthesis level of disease-affected plant tissues, disease progress

relative to plant growth stage, and cultivar response to disease stress (1,5,18). Wheat cultivars of similar phenotypic characters may express differential loss in yield under similar apparent disease severity and disease progress (4,22-24). Wheat cultivars may vary in ability to endure (tolerate) severe *Septoria* epidemics without sustaining significant losses in yield when compared to vulnerable (nontolerant) cultivars (5). This endurance or the tolerance of plants to pathogen-generated stress (10,11,14), though widely mentioned, is poorly understood. One of the major obstacles in evaluating plant responses to disease stresses relates to the inherent difficulties in establishing equivalent disease stresses across cultivars and characterizing the nature and magnitude of the imposed stresses. Accumulating evidence suggests that wheat genotypes vary in capacity to utilize stored assimilates as a source for kernel growth in the absence of postanthesis photosynthesis (2,3,20,21). The differential capacity of wheat cultivars to sustain translocation-based kernel growth in the absence of transient photosynthesis was revealed (3) through postanthesis destruction of the photosynthetic source by chemical desiccation. Since the major effect of postanthesis infection by *S. tritici* is expressed by reduction in the photosynthetic source, it was hypothesized that postanthesis chemical desiccation of the wheat canopy may simulate a uniform disease stress in testing for tolerance. Tolerance is thus estimated as the plant's capacity to sustain appreciable

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kernel growth following destruction of the photosynthetic source by chemical desiccation or speckled leaf blotch of wheat.

The present study was undertaken to test the possibility that chemical desiccation can be used as a simulator of postanthesis speckled leaf blotch infection in the detection of tolerance to the disease.

MATERIALS AND METHODS

The experiments were conducted at the Bet-Dagan Experimental Farm during the 1979-1980 and 1981-1982 growing seasons. Eight spring wheat (*Triticum aestivum* L.) cultivars (commercial and advanced lines) and 18 wheat cultivars, were tested in the first and the second year, respectively. All cultivars were of similar phenology and growth habit. Five wheat cultivars susceptible to *S. tritici* were included in both years: the early-maturing, dwarf (75-cm) cultivar Barkai (V238-8822-11/Miriam 2), the early-maturing semidwarfs (95-cm): Ceeon (Yaktana 65A³//Norin 10/Brevor), Hazera 337 (Inia "S" × Sonora 64-Tezanos Pentos Precoz/Yaqui 54), Miriam (Chapingo 53//Norin 10/Brevor/3/Yaqui 54/4/2 Merav), and the somewhat later-maturing (by 10 days) semidwarf cultivar Lakhish (Yaktana//Norin 10/Brevor/3/Florence Aurore). The experimental design was in split plots, with treatments in main plots and cultivars in subplots in four replications. Each subplot was 2 m wide and 12 m long. The plots were drill-seeded at a 30-cm row spacing. Three treatments were performed on all cultivars: fungicide-protected (three applications of Tilt-Propiconazole, CGA 64250) control, inoculation with *S. tritici*, and chemical desiccation. Speckled leaf blotch epidemics were incited by inoculating the plant canopy weekly with a suspension of 10⁷ spores per milliliter starting at the emergence of the flag-minus-2 leaf and finishing at the end of the milk stage. The suspension was prepared from a mixture of virulent isolates of *S. tritici*. Inoculation was performed during rainy days and/or dewy nights by using a low-volume low-pressure sprayer (Ulva 8-Micron Co., Bromyard, England). In the chemical desiccation treatment, magnesium chlorate was used as a commercial formulation (Machtshim Works, Ltd., Beer-Sheva, Israel) 18% active ingredient (a.i.) formulation routinely used for foliar defoliation in cotton (2). The desiccant was applied as a solution of 4% a.i. at a rate of 35 cm³/m². Each cultivar was sprayed once at 14 days after anthesis. The 30-cm row spacing allowed penetration of the spray into the canopy. Weekly assessment of percent disease coverage was initiated on the uppermost four leaves upon the emergence of the flag-minus-2 leaf in 15 randomly selected plants per treatment across cultivars in all replications (8). These plants were marked for disease assessment and later for yield components evaluation.

The five uppermost leaves in 15 randomly selected plants were mechanically defoliated 14 days after anthesis in the untreated

fungicide-protected control plots of the five cultivars in all replications (1981-1982 trial).

In the kernel growth studies, 15 main tillers were randomly sampled at weekly intervals between anthesis and the late dough stage, from a population of main tillers with a common anthesis date, in each plot. Disease blotch and kernel number were assessed for each plant separately. Kernel and shoot dry weights were determined for each main tiller after drying for 48 hr at 90 C. Harvest index was calculated as the dry weight ratio of grain to shoot.

RESULTS

Kernel weight. Most of the green tissues were dead within 2 days after the chemical desiccant was applied. Awns, glumes, leaf laminae, and parts of the spike-peduncle and leaf sheaths were bleached and killed. For all practical purposes, the desiccant-treated plants were devoid of photosynthetic source (3). During the 1981-1982 growing season disease progress was somewhat slower than the previous season (1979-1980), with consequent respective lower losses in 1,000-kernel weight (Table 1). Furthermore, the effect of the desiccant on kernel weight was somewhat higher in the 1979-1980 trial than in the 1981-1982 trial. Other than in Hazera 337 and Miriam, the response in kernel weight to speckled leaf blotch was the same for both years. Plants of cultivars Lakhish, Miriam (1981-1982 only), and Hazera 337 (1981-1982 only) sustained less losses in kernel weight due to speckled leaf blotch, chemical desiccation, and defoliation (1981-1982 only) than did cultivars Barkai and Ceeon (Table 1).

In both years, the mean effect of chemical desiccant on kernel weight was greater than the effect of Septoria, most probably due to a more drastic effect and a greater reduction in photosynthetic tissue in the former. Cultivars significantly differed in the rate of kernel weight loss due to chemical desiccation. These differences could be ascribed to differences in mobilization of plant reserves to the kernels (3). The correlation across the means of the five cultivars in percent kernel weight loss between Septoria-infected and chemically desiccated plants was significant in 1979-1980 ($r = 0.925$), but not in the 1981-1982 trial ($r = 0.804$). The relationship between kernel weight loss due to speckled leaf blotch and weight loss due to chemical desiccation across the 18 cultivars tested in 1981-1982 is presented in Fig. 1. The wheat cultivars Hazera 2218 and Hazera 2230 expressed almost a 1:1 loss ratio between Septoria and chemical desiccation under similar disease coverage. Their vulnerability to speckled leaf blotch was higher than that of the nontolerant cultivar Barkai (0.64 loss ratio—Septoria/desiccant). When data for these two cultivars were excluded from the analysis, the association presented in Fig. 1 became statistically stronger ($r = 0.626^{**}$), as compared to $r = 0.478^*$ for the 18 cultivars.

TABLE 1. The effect of speckled leaf blotch (caused by *Septoria tritici*), chemical desiccation (magnesium chlorate), and defoliation on 1,000-kernel weight in five spring bread wheat cultivars common to the two trials at Bet-Dagan, Israel in 1981-1982

Wheat cultivar	Septoria severity ^u (AUSPC × 10 ⁻²)		Loss in 1,000-kernel weight (%)				
	1979-1980	1981-1982	<i>S. tritici</i> ^v		desiccant ^w		defoliation ^x
			1979-1980	1981-1982	1979-1980	1981-1982	1981-1982
Barkai	44.7 a	43.0 a ^y	40.4 **	30.3 *	52.8 **	24.4 *	21.1 *
Ceeon	34.2 b	34.1 a	29.7 **	25.0 *	41.7 **	34.7 *	26.5 *
Hazera 337	33.5 b	22.0 b	31.6 **	9.0 ns	39.8 **	30.6 *	1.7 ns
Lakhish	28.7 b	20.8 b	2.3 ns ^z	13.7 ns	18.9 **	18.6 *	9.5 ns
Miriam	30.1 b	25.5 b	21.6 *	10.3 ns	44.3 **	19.0 *	15.6 ns
Mean ± SE	34.2 ± 2.8	29.1 ± 6.3	25.1 ± 6.4	17.7 ± 4.2	39.5 ± 5.6	25.5 ± 3.2	16.7 ± 4.1

^u Postanthesis Area Under Septoria Progress Curve × 10⁻² in the inoculated plants.

^v Percent loss = $\left\{ \frac{[(\text{kernel weight of fungicide protected}) - (\text{kernel weight of treated})]}{(\text{kernel weight of fungicide protected})} \right\} \times 100$.

^w Magnesium chlorate (4% a.i.) applied 14 days after anthesis.

^x Five uppermost leaves were mechanically defoliated 14 days after anthesis.

^y Means within columns with a common letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

^z The abbreviation ns = not significant, and the asterisks (*) and (**) indicate statistical significance $P = 0.05$ and 0.01, respectively, where treated plants were analyzed versus the untreated, fungicide protected control.

The correlation across the means of the five cultivars in percent kernel weight loss between Septoria-infected and defoliated (postanthesis) plants was not significant in 1981-1982 ($r = 0.733$).

Kernel growth. Typical kernel growth curves, as affected by treatments, in two representative cultivars (Miriam [tolerant] and Barkai [nontolerant]) of the same heading date, are presented in Fig. 2. Speckled leaf blotch caused a reduction in kernel growth rate in both cultivars. In Barkai, the pathogen also caused a reduction in kernel growth duration, as compared with Miriam. Chemical desiccation had a greater effect on kernel growth, as compared with Septoria-affected plants. It affected both kernel growth rate and growth duration in the two cultivars. The effect of the desiccant was greater in Barkai than in Miriam, especially in the earlier stages of grain development (at ~17-32 days after anthesis). The association across five cultivars between disease progress expressed as Area under Septoria Progress Curve ($\times 10^{-2}$) and losses in kernel growth rate (Area Under Grain Filling-Progress Curve [AUGFPC]) in plants affected by *S. tritici* was statistically not significant ($r = 0.621$). The lack of association indicates a differential cultivar response in kernel growth rate and growth duration, namely, some wheat cultivars (Lakhish, Hazera 337, and

Miriam) maintained high grain filling rate despite severe Septoria epidemics. The association between losses in kernel growth expressed as AUGFPC in Septoria-affected and chemical desiccation across the five cultivars was $r = 0.497$. This positive, nonsignificant correlation may be due to a differential cultivar loss response in kernel growth rate and growth duration.

Yield components and harvest index. Yield components are often used as indirect selection indices for a high yield potential in wheat breeding. The correlations across cultivars between percent loss in 1,000-kernel weight in Septoria-affected plants (as a measure of tolerance) and the potential number of kernels per spike, the potential kernel weight per spike, or the potential 1,000-kernel weight (as indicated by the uninoculated, protected control) were not statistically significant (Table 2). Therefore, tolerance to speckled leaf blotch of wheat in terms of sustained kernel growth in infected plants, appeared to be independent of yield potential or sink size.

Cultivars in the control treatment did not differ in harvest index (Table 3). Septoria and chemical desiccation reduced harvest index, by an average of 16.3 and 22.5%, respectively. For a very similar level of disease severity, the relative reduction in harvest index by the pathogen was less in the three more tolerant cultivars (Hazera 337, Lakhish, and Miriam) than in Barkai and Ceeon. While the relative reduction in harvest index by chemical

TABLE 2. Coefficients of correlation between potential yield components (uninoculated control) and tolerance to speckled leaf blotch (percent loss in 1,000-kernel weight) across cultivars (cvs) in 2 yr

Yield component	Correlation coefficient (r)			
	1979-1980 (8 cvs) ^y	1979-1980 (5 cvs)	1981-1982 (5 cvs)	1981-1982 (15 cvs)
Number of kernels per spike	0.202 ns ^z	-0.016 ns	-0.216 ns	-
Kernel weight per spike	-0.557 ns	-0.494 ns	-0.248 ns	-
1,000-kernel weight	-0.395 ns	-0.539 ns	-0.011 ns	0.007 ns

^yNumber of wheat cultivars tested.

^zAbbreviation ns = not significant $P = 0.05$.

TABLE 3. The effect of speckled leaf blotch (caused by *Septoria tritici*) and chemical desiccation on harvest index progress in five spring wheat cultivars, compared to fungicide-protected controls. Bet-Dagan Experiment Station, Israel, 1979-1980

Wheat cultivar	Disease severity (AUSPC $\times 10^2$)	Harvest index (control) ^w	Loss in harvest index (%) ^x	
			<i>S. tritici</i>	Desiccant
Barkai	44.7 a ^z	60.1 a	22.3 * ^y	25.9 *
Ceeon	34.2 b	57.0 a	23.5 *	31.9 *
Hazera 337	33.5 b	54.7 a	12.7 ns	16.9 ns
Lakhish	28.7 b	55.1 a	12.8 ns	22.0 *
Miriam	30.1 b	60.9 a	10.3 ns	15.6 ns
Mean \pm SE	34.2 \pm 2.8	57.6 \pm 2.2	16.3 \pm 3.1	22.5 \pm 2.8

^vPostanthesis Area Under Septoria Progress Curve $\times 10^{-2}$.

^wHarvest index = grain yield/shoot yield (Area Under Harvest Index Progress Curve $\times 10^{-2}$).

^xPercent loss in Harvest Index Progress Curve from anthesis to ripeness.

^yMeans within columns with a common letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

^zns and asterisk (*), not significant and significant, $P = 0.05$, respectively, where plants were analyzed versus the fungicide-protected control.

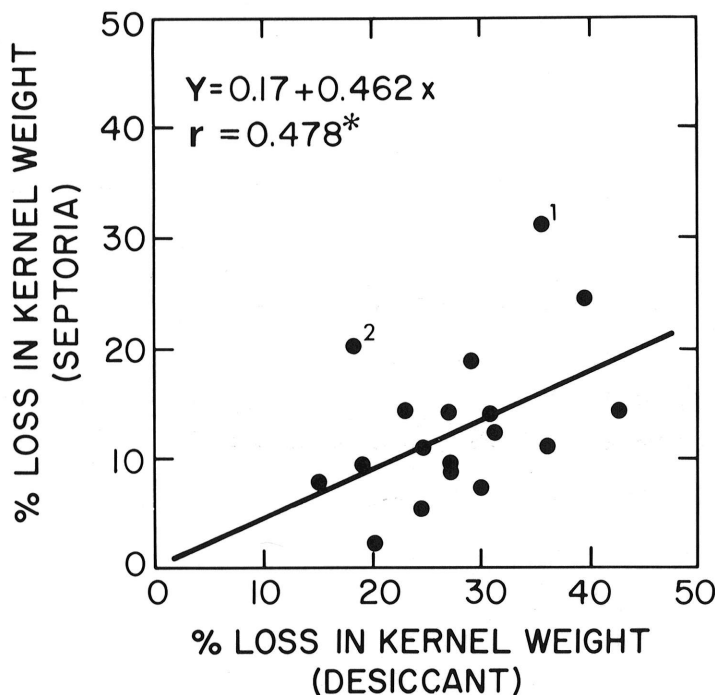


Fig. 1. The linear relationship between losses in 1,000-kernel weight of chemically desiccated and speckled leaf blotch-affected plots across 18 wheat cultivars. Bet-Dagan, Israel, 1981-1982. (1—Hazera 2218 and 2—Hazera 2230).

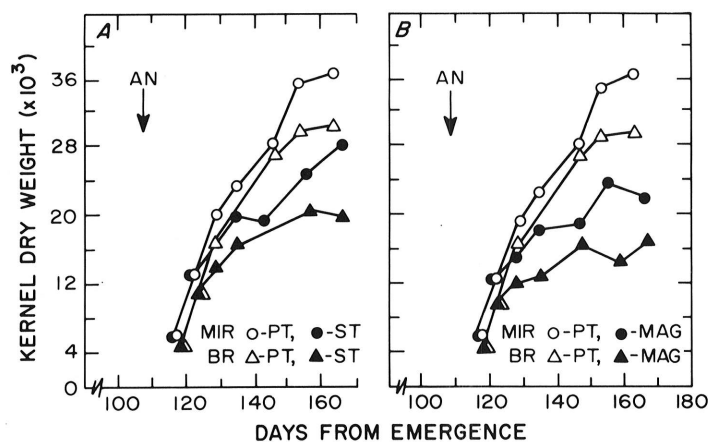


Fig. 2. Kernel growth rates for wheat cultivars Barkai (BR) and Miriam (MIR). A, Plants inoculated with *Septoria tritici* (ST) or protected by fungicide treatment (PT), and B, plants chemically desiccated with magnesium chloride (MAG) or protected by fungicide treatment. AN = anthesis.

desiccation was greater in Lakhish than in Hazera 337 and Miriam, the overall response of the five cultivars to chemical desiccation was similar in this respect to their response to Septoria. The correlation across cultivars between loss in harvest index due to disease and loss in harvest index due to chemical desiccation was statistically significant ($r = 0.926$). Thus, the relative capacity of speckled leaf blotch-tolerant cultivars to sustain the least reduction in harvest index was expressed quite well under chemical desiccation.

DISCUSSION

The explanation of plant tolerance to speckled leaf blotch, in terms of sustained development of yield components, could not be derived from information obtained in studies on photosynthesis (16,17), and redistribution of ^{14}C (19). It is possible that the apparent storage of stem reserves in wheat and the capacity of the plant to translocate reserves to the growing kernel when the photosynthetic source is limited, may provide the explanation for postanthesis tolerance to Septoria.

Postanthesis chemical desiccation of the canopy causes stem reserve mobilization into the growing kernels (3). It was further shown (2) that in terms of the ability to sustain kernel growth in the absence of transient photosynthesis, plant response to chemical desiccation was similar to the response to postanthesis drought stress. The association across cultivars in the reduction in kernel growth between Septoria stress and chemical desiccation stress is not simple. While both stresses are apparently induced by (or do not interfere with) plant reserve mobilization to the growing kernel, Septoria stress is not as severe as chemical desiccation stress (Tables 1 and 3 and Fig. 1) and is not imposed abruptly at a given stage of kernel growth. While chemical desiccation destroys the plant's photosynthetic source almost totally, residual transient photosynthetic green area must still exist in plant parts that are unaffected by Septoria, such as the spike.

These differences between the two stresses may reduce the strength of the correlation across cultivars in the reduction of kernel growth between Septoria and chemical desiccation. Thus, for example, cultivars such as Lakhish (Table 3), that were relatively less affected by Septoria than by chemical desiccation may possess a surpassing capacity for ear photosynthesis. In spite of such complexities, significant associations were revealed in most of the tests between Septoria stress and chemical desiccation stress in the rate of loss in kernel growth and harvest index, across cultivars. As argued above, chemical desiccation of the canopy is not a perfect simulator of Septoria epiphytotic in that it does not result in the same pattern of foliar destruction (leaf laminae, sheaths, spike-peduncle, glumes, and awns). It is, however, a simulator of Septoria speckled leaf blotch stress in the sense that it reveals the genotypic capacity for translocation-based kernel growth when the photosynthetic source is severely affected.

The effect of mechanical defoliation on the supply of assimilates to the grain resembled that of speckled leaf blotch where sheath, spike-peduncle, glumes and awns are not as severely affected as chemically desiccated tissue. Differential response in kernel weight of wheat cultivars to defoliation of the upper leaves was also observed by Hendrix et al (12). Kernel weight of plants inoculated with stripe rust were more severely affected than of mechanically defoliated plants (12). While the removal of organs supplying photosynthetic assimilates to the grain may contribute to the understanding of the redistribution of plant reserves (15), it is difficult to employ as a rapid and simple screening technique for tolerance.

It is of interest to note that the cultivars Lakhish and Miriam, classified as tolerant to speckled leaf blotch in terms of kernel growth and harvest index, behaved similarly in a previous study (2,3) with respect to their response to chemical desiccation and postanthesis drought stress. It is, therefore, proposed that a superior capacity for translocation-based kernel growth is probably the common denominator for plant tolerance to various postanthesis stresses that affect the photosynthetic source, such as certain plant diseases or drought.

The question whether this mechanism of tolerance is associated with a reduced sink size and yield potential was raised (5,13) and addressed (2,24). It has been shown (2) that wheat cultivars that sustain the least reduction in kernel growth under conditions of postanthesis stress by drought or by chemical desiccation did not have a small sink size. Such cultivars tended to have a different sink geometry, in that they had a relatively larger number of kernels per spike and smaller kernels, relative to nontolerant cultivars. The results of this study also do not support an association between tolerance and small sink size (potential kernel number and kernel weight per spike) or low yield potential (13). Thus, the results obtained in this study, as well as those obtained previously (2,24), show that plant tolerance to postanthesis stress (either by speckled leaf blotch or by drought) in terms of translocation-based kernel growth, can be developed in high-yielding genotypes. Postanthesis chemical desiccation of the wheat canopy and the subsequent measurement of its effects on the relative reduction in kernel weight, may serve as a useful screening technique for tolerance to speckled leaf blotch of wheat.

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Resistance

Quantitative Comparison of the Resistance to *Phytophthora* Root Rot in Three Avocado Rootstocks

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ABSTRACT

Kellam, M. K., and Coffey, M. D. 1985. Quantitative comparison of the resistance to *Phytophthora* root rot in three avocado rootstocks. *Phytopathology* 75:230-234.

The resistance of three avocado (*Persea americana* var. *drymifolia*) rootstocks to *Phytophthora* root rot was compared quantitatively in greenhouse experiments. Susceptible seedlings of rootstocks Topa Topa and resistant cuttings of rootstocks Duke 7 and G6 were planted in avocado field soil naturally infested with *Phytophthora cinnamomi* at 0.3-3.1 propagules per gram (ppg) of dry soil. Soil populations of *P. cinnamomi*, percent of roots infected per plant, and shoot and root weights were determined after 8, 15, and 20 wk. At 20 wk, root infection was 55, 27, and 11% in Topa Topa, Duke 7, and G6, respectively. Soil populations after 20

wk were 55, 42, and 14 ppg for Topa Topa, Duke 7, and G6, respectively. Compared to uninfected controls, significant reductions in root weights of infected plants occurred with each rootstock, but the percent reduction was greater with Topa Topa than with Duke 7 or G6. Generally, more propagules were recovered on dilution plates from detached roots infected in culture with zoospores than from attached roots infected in the greenhouse while growing in infested soil. In the absence of *P. cinnamomi*, Duke 7 and G6 had a significantly greater capacity for root regeneration than the susceptible rootstocks Walter Hole and Topa Topa.

Additional key words: root growth potential.

Avocado root rot, caused by *Phytophthora cinnamomi* Rands, is a soilborne disease that seriously affects production of avocado (*Persea americana* Mill.) (15,17). An important approach to control of root rot has been the development of rootstocks with field resistance to *P. cinnamomi* (15). More than 3,000 selections of different *Persea* spp. have been screened for root rot resistance with qualitative methods that include hydroponic tank tests, greenhouse pot tests with infested soil, and long-term field plots in infested sites (16,17). As a result of this screening program, two Mexican avocado selections with some field resistance to avocado root rot, Duke 7 and G6, are available commercially as rooted cuttings. The resistance of Duke 7 and G6 to *P. cinnamomi* has been described by Zentmyer as "moderate horizontal resistance or tolerance" (15). There are, however, no quantitative data on the biological basis of this resistance or on the comparative levels of resistance in these rootstocks.

Component analysis of the disease cycle has been used to evaluate general resistance in several *Phytophthora*-host systems (14), but this quantitative approach to evaluating resistance has not been attempted in the interaction of *P. cinnamomi* and avocado.

The purpose of the work reported here was to develop methods of quantitatively comparing the levels of resistance in various avocado selections by analyzing components of the disease cycle.

MATERIALS AND METHODS

Sources of plants, soil, and inoculum. Four to 6-mo-old, root-rot-resistant cultivars Duke 7 and G6, and susceptible cultivars Topa Topa and Walter Hole of avocado [*Persea americana* Mill. var. *drymifolia* (Schlect. and Chamb.) Blake] were evaluated in various experiments. Seedlings of Topa Topa were raised in greenhouses at the University of California, Riverside. Rooted cuttings of Duke 7 and G6, and seedlings of Walter Hole were obtained from either Brokaw Nursery, Saticoy, CA or C and M Nursery, Nipomo, CA. All material was initially propagated in 7 × 27-cm plastic sleeves in a greenhouse potting mix of peat and Perlite® (60:40, w/w). Experiments were conducted with a sandy loam avocado field soil (Fallbrook series) collected in San Diego County 2-4 days prior to use. Soil infested with *P. cinnamomi* came

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