Effect of Powdery Mildew on Net Photosynthesis, Dark Respiration, and Kernel Composition of Pecan

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ABSTRACT

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Pecan foliage and fruit were studied to determine the effect of powdery mildew on net photosynthesis, dark respiration, and kernel composition. Powdery mildew had no effect on net photosynthesis or dark respiration of pecan fruit or on leaf respiration. Net photosynthesis of foliage was reduced as much as 42% by high disease levels (about 54–76%). Powdery mildew covering 50% of the fruit surface area decreased percent kernel oil, protein, and free fatty acids by 3.8, 7.1, and 73.1%, respectively, and increased percent moisture by 3.4%. Heavy mildew (about 100% of the surface area infected) decreased percent kernel oil, protein, and free fatty acids by 8.6, 22.3, and 73.1%, respectively, and increased percent moisture by 13.6%.

Powdery mildew, caused by *Microsphaera penicillata* (Wallr.: Fr.) Lév. (syn. *Microsphaera alni* (Wallr.) Wint.), occurs on foliage and fruit of pecan, *Carya illinoensis* (Wang.) K. Koch. The disease usually appears by May or June in the southeastern United States, especially during seasons of relatively high rainfall and humidity (8,13). Powdery mildew can be especially conspicuous on nut shucks (involucres) of some genotypes (Fig. 1A). Contrary to early accounts (8), recent reports indicate that the disease causes yield and kernel reductions resulting from nut drop, reduced nut size, premature shuck split, shriveled kernels, and premature defoliation (6,13). In one study, however, no correlation was found between high mildew ratings and nutlet set the following season on trees of cultivar Schley (18).

The effect of powdery mildew on photosynthesis and respiration has been researched extensively for various crops, especially cereals, in which *Erysiphe graminis* DC. substantially decreased photosynthesis after chloroplast degradation and caused an increase in respiration (7,11,15,17). Although no reduction in leaf size of cereals infected by powdery mildew has been detected, the disease does retard leaf development and accelerate leaf senescence (5,12). Mildew also affects grain yield and quality by decreasing grain size and starch and protein content, causing significant yield losses (5,17).

Powdery mildew on walnut (*Juglans regia* L.) caused by *M. penicillata* appears to cause little damage. On various oak species, however, powdery mildew (*Microsphaera* spp.) leaf infections can halt shoot growth, distort leaves, reduce leaf size, and cause premature abscission (2).

Oil and free fatty acid content are traditionally used as indicators of pecan kernel quality (1,3,10,14). Kernel rancidity is associated with oxidation of unsaturated fatty acids that predominate in pecan oils (16). A reduction in unsaturated fatty acid content consequently reduces kernel quality. In healthy fruit, oil and protein contents are about 70 and 10%, respectively, although percent oil varies considerably among cultivars. Kernel quality is also affected by moisture content through its effect on crispness, texture, and storage stability (3,16).

The purpose of this study was to

Fig. 1.(A) Cluster of mature pecan fruit with 100% of involucre surfaces covered with powdery mildew (*Microsphaera penicillata*). **(B)** Leaf of greenhouse-grown pecan seedling with severe foliar mildew. Leaf is deformed because of stunting of areas in expanding leaf blade.

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quantify the effects of pecan powdery mildew at various disease intensity levels on net photosynthesis, dark respiration of leaves and fruits, and nut quality in an attempt to better understand the commercial importance of pecan mildew.

MATERIALS AND METHODS

All CO_2 measurements were done by the standard differential analysis method, measuring the flux in CO_2 entering and exiting a photosynthesis chamber with a Beckman 865 IR CO_2 analyzer (Beckman Instruments, Inc., 1790 Fourth St., Berkeley, CA 94710). The rectangular Plexiglas photosynthesis chamber (about 280 ml in volume) was sealed gastight with a rubber O-ring and an Ensolite foam gasket. Chambers were supplied with ambient air at a flow rate of 2 L min^{-1}. Energy was provided from a color-improved mercury-vapor lamp suspended perpendicular to the leaf surface. Photon density at the leaf or fruit surface was 300 $\mu E\ m^{-2}\ s^{-1}$ as measured by a LI-COR 185 quantum sensor (Li-Cor, Inc., Box 4425, Lincoln, NE 68504). Leaf temperature was maintained at 27 ± 1 C with a leaf thermistor. Dark respiration measurements were made after covering the chamber with an opaque shroud. Leaf area was measured with a LI-3100 leaf area meter (Li-Cor, Inc.). Surface area of pecan fruit was estimated by the formula for a prolate spheroid.

Effects on fruit were determined by measuring CO_2 exchange of fruit with various degrees (0, 25, 50, 75, 100% of shuck surface area) of natural infection in mid-September. Fruit from two trees (USDA hybrid 40-9-266) were of mature size and about 70% filled. Fruits with midseason to late-season natural infections were used because of the scarcity of early-season infections and the difficulty of establishing the disease by inoculations. Shoots supporting sample fruits were cut in early morning; the shoot base was submerged immediately, recut under water, and kept in that state for a period not exceeding 1 hr until measurement. Fruit were immediately taken to the laboratory, and the aggregate CO_2 exchange of six fruits of each infection class was measured. Each class was replicated five times and measurements were made in random sequence. Fruit remained attached to the shoot until measured. Because all four faces of the fruit are capable of photosynthesis, radiation was provided to the underside of the fruit by mirrors.

The influence of powdery mildew on CO_2 exchange and leaf surface area of foliage was determined on attached, naturally infected, greenhouse-grown cultivar Curtis seedlings. Measurements were made on five replicates of fully expanded leaves at various levels of infection (0, 25, 50, and 75%). Each leaf used was the fifth simple leaf from the base of a 3-mo-old seedling. After CO_2 measurements, this leaf was removed for determination of surface area.

The effect of powdery mildew on pecan kernel quality was determined by using full-sized pecan fruit of cultivar Woodward collected in late October.

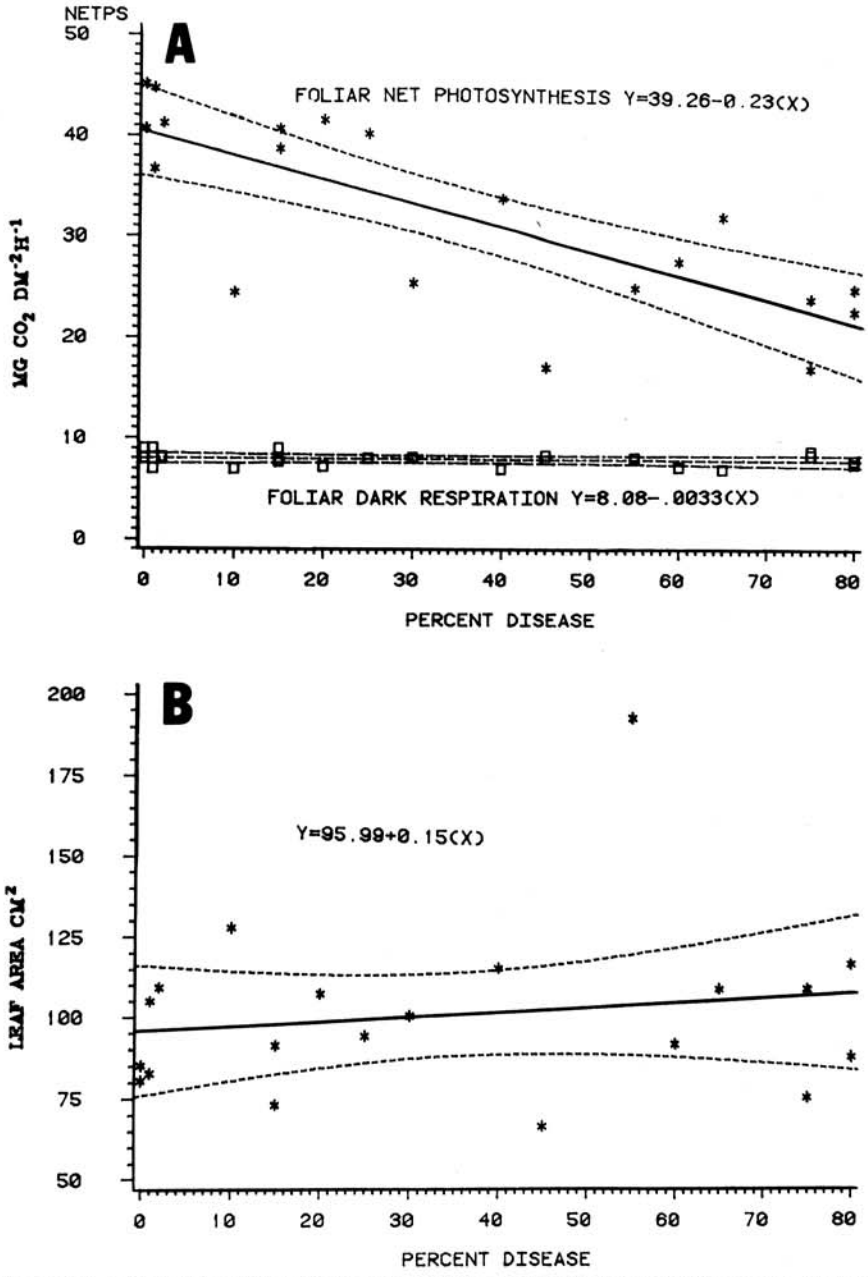

Fig. 2. Effect of powdery mildew on greenhouse-grown seedlings of pecan cultivar Curtis. **(A)** Net photosynthesis and dark respiration of foliage. **(B)** Effect on leaf area. Dashed lines indicate 95% confidence limits.

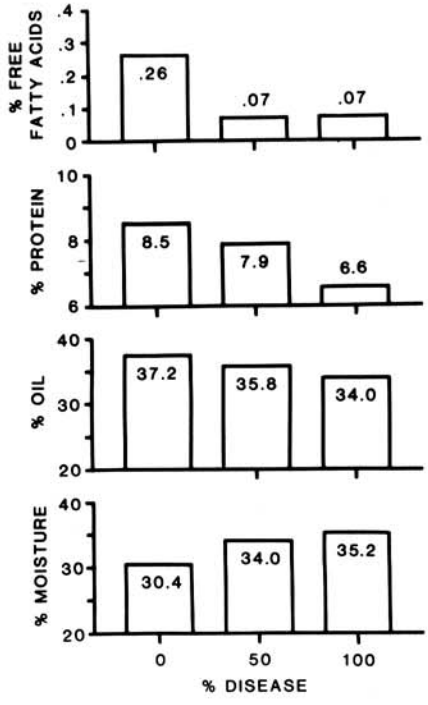

Fig. 3. Effect of pecan powdery mildew intensity vs. four parameters of pecan cultivar GraBohls' kernel quality. Each bar represents the average of three subsamples taken from a composite orchard sample at each disease intensity level.

Mildew had developed on these fruits between 19 July and 21 October. Fruits were graded into three levels of natural infection (0, 50, and 100), shelled, and composite samples from each disease grade collected. Kernel moisture, oil, protein, and free fatty acids were assayed by standard techniques used previously in studies of pecan kernel quality (4,9). Assays of composite samples were repeated three times, except for free fatty acids, which were only measured once because of limited sample material.

RESULTS AND DISCUSSION

Neither net photosynthesis nor dark respiration of full-sized pecan fruits was significantly affected by powdery mildew. Net photosynthesis of healthy shucks varied from 12.25 to 13.5 mg CO_2 dm^{-1} hr^{-1}, whereas that of shucks covered with mildew varied from 11.9 to 12.8 mg CO_2 dm^{-1} hr^{-1}. This was surprising because one would expect that fruits with 100% of their surface covered by mycelium would be sufficiently shaded to slightly reduce photosynthesis. Dark respiration of both healthy and mildewed shucks varied in the range of 11.0–11.9 mg CO_2 evolved per dm^{-1} hr^{-1} (Fig. 1A).

The effect of powdery mildew infection on seedling pecan foliage was more dramatic. Net photosynthesis was reduced 11, 38, and 42% by 25, 50, and 75% infection, respectively. Dark respiration, however, was unaffected by all levels of infection (Fig. 2A). Foliar mildew also caused deformation of expanding leaves (Fig. 1B). In this respect, pecan resembles *Quercus* sp., rather than the more closely related walnut (*Juglans* sp.), in sensitivity to mildew. Walnut appears to be only slightly affected by mildew (2). Unlike *Quercus* sp., however, pecan foliage was not stunted by this deformation, which appeared to have no effect on leaf surface area (Fig. 2B).

Photosynthesis and respiration were measured on intact, greenhouse-grown, seedling plants rather than excised foliage from the field. Foliar mildew is much less prevalent in the field than in a greenhouse environment. Occasional leaflet distortion from powdery mildew may occur in the field if leaflets are infected while very small and rapidly expanding (*unpublished*) but such early infections are rare. We have rarely seen foliar mildew, unlike fruit mildew, on pecan that was severe enough to warrant control efforts, and we have never seen foliar disease levels in the field as high as those found in this study. In addition, pecan powdery mildew generally does not show up until after mid-July. Mildew infection of pecan before July is rare, and the effect of early-season disease is not known.

Pecan powdery mildew was associated with decreases in percent kernel oil, protein, and free fatty acids and a small increase in moisture content (Fig. 3). Although most of these changes can be demonstrated consistently, they are relatively small and probably cause little decline in crop quality. Therefore, a reduction in either grade or selling price of pecan kernels is unlikely. This information, coupled with the small or negligible effect of powdery mildew on net photosynthesis and dark respiration of pecan fruit and its scarcity on foliage in the field, indicates that additional disease control for late-season powdery mildew beyond the normal pecan disease control program may be unnecessary.

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