Reduction of Macadamia Nut Set by Botrytis cinerea

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Journal Series Paper No. 1474 of the Hawaii Agricultural Experiment Station, Honolulu.

The assistance of Yusuf N. Tamimi with the statistical analyses is gratefully acknowledged.

ABSTRACT

Macadamia racemes sprayed with a spore suspension of *Botrytis cinerea* immediately after anthesis produced very few nuts in comparison with racemes sprayed with water. Under conditions of natural inoculation in the field, racemes treated with benomyl to control Botrytis blight produced significantly (P = .01 level) more nuts than racemes treated with water. Significant negative correlation and regression values indicate that Botrytis blight is associated with a decrease in nut set on macadamia racemes.

Phytopathology 63:939-941.

Additional key word: benomyl.

Raceme blight of macadamia (*Macadamia integrifolia* Maiden & Betche) was first observed in 1960 on the Island of Hawaii. In 1963 it was reported by Holtzmann (2) to be caused by *Botrytis cinerea* Pers. ex Fr. The disease is presently referred to as Botrytis blight to distinguish it from Phytophthora blight, a disease of macadamia racemes recently reported by Hunter et al. (3). Botrytis blight occurs on blossoms only after anthesis or on senescent flower parts; flower buds and even very young nuts are not susceptible (2, 4). It is most serious during cool, moist periods; it is not, however, prevalent during periods of heavy tropical rainfall which may average 15-30 cm (6-12 inches) per week and sometimes exceeds 2.54 cm (1 inch) in 1-2 hr (4).

A causal relationship between Botrytis blight of macadamia flowers and subsequent reduction of nut set has not been established previously. Furthermore, prior to this report no correlation between control of *B. cinerea* and nut set has been noted in fungicide experiments (5). Cursory observations for reduced nut set following periods of Botrytis blight also have not consistently revealed any relationship. Moreover, other factors may obscure this relationship during periods of rainy weather. Shigeura et al (6), Urata (7), and Ito & Hunter (*unpublished*) have demonstrated by different methods an increase in nut set or yield as a result of cross-pollination of macadamia. Rain, which is common during Botrytis blight periods, may remove pollen from the air (1) or reduce honeybee activity and thereby also contribute to reduced nut set.

Because nut set may be reduced by Phytophthora blight, reduced cross-pollination, and other factors that may operate simultaneously with Botrytis blight, the cause and effect relationship between this disease and reduced yields has remained tenuous. This relationship is evinced in the experiments reported herein.

Inoculation experiments were conducted on racemes of macadamia cultivar '666' which were enclosed in plastic bags attached to the branches of the trees. Water was atomized onto the insides of the bags to provide a high humidity conducive to development of Botrytis blight. Ten racemes were inoculated by spraying a spore suspension of *B. cinerea* through the open base of the bag. Racemes treated similarly with water served as controls. Washed spore suspensions, prepared from pure cultures grown on potato-dextrose agar, were adjusted to a concentration of 100,000 spores per ml. Bags were closed

Fig. 1. Macadamia raceme being sprayed with water immediately after anthesis; an equal number were treated with benomyl. Racemes were tagged and Botrytis blight ratings made 1 week later; nut set counts were taken 3 weeks after the disease rating.

during the night to maintain a high humidity and opened and rolled-up during the day to expose the racemes to pollen. The racemes were sprayed with a spore suspension or water each night before the bags were closed; bags were removed after three nights. The experiment was repeated three times. In the third experiment, 10 racemes also were sprayed with a 1,000 ppm suspension of benomyl [methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate] before being inoculated. Previous studies have shown that benomyl provides excellent control of *B. cinerea* (5). Seven days after inoculation, the extent of sporulation on each raceme was rated as nil = 1, slight = 2, moderate = 3, or severe = 4. The average number of nuts per raceme was determined 3 weeks later.

Inoculated flowers turned brown and dropped from the rachis within a few days, except when they were protected with benomyl. Likewise, nut set was drastically reduced on inoculated racemes, unless they were treated with benomyl. For the three experiments, the average Botrytis blight rating for the inoculated and control racemes was 2.2 and 1.0, respectively. Inoculated racemes had an average of one nut per raceme compared to seven per raceme in the uninoculated controls. In the third experiment, where 10 racemes also were treated with benomyl before being inoculated, the Botrytis blight rating was 1.0, and the average nut set was 11.6 nuts per raceme.

To verify these results, a different experimental procedure was developed to compare nut set with *B. cinerea* incidence under conditions of natural inoculation in the field. Twenty-five pairs of racemes of cultivar '333' were selected immediately after anthesis. One raceme of each pair was sprayed with benomyl [454 g (1 lb) active/378.5 liters (100 gal) water containing 113.2 g (4 oz) Triton B-1956 spreader-sticker] and the other was sprayed with water (Fig. 1). The experiment was repeated six times at 3- to 4-day intervals. A Botrytis blight rating was taken approximately 1 week after treatment of the racemes with benomyl or water; nut-set data were collected approximately 3 weeks after the disease rating. The average diameter of the nuts was 7.5 mm when the counts were made.

Nut set counts for the six paired-treatment experiments were analyzed by Student's *t-test* method. The average number of nuts produced on racemes treated with benomyl or water was 3.7 and 1.5, respectively. This difference is significant at the 0.01 level (t = 5.80) (Table 1).

TABLE 1. Nut set of macadamia in relation to treatment of racemes with benomyl and water

Experiment[a]	Treatment[b] Benomyl	Water
1	6.1[c]	2.5[c]
2	2.2	0.8
3	2.5	0.5
4	4.8	2.6
5	4.6	1.4
6	2.2	0.9
Mean	3.7	1.5

t-test value = 5.80 (significant at the 0.01 level)

[a] Experiment repeated at 3- to 4-day intervals.

[b] For each experiment, 25 pairs of racemes were selected immediately following anthesis (onset of susceptible period); one member of each pair was sprayed with water and the other with benomyl [454 g (1 lb) active/378.5 liters (100 gal) water]. Nut-set counts were taken 4 weeks after treatment.

[c] Average number of nuts set per raceme.

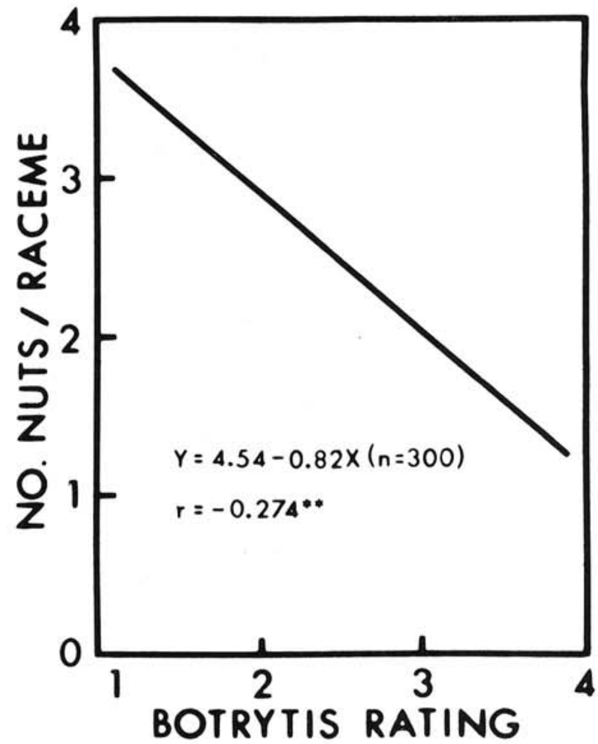

Fig. 2. Relationship between incidence of *Botrytis cinerea* and macadamia nut set. *B. cinerea* incidence was rated as nil = 1, slight = 2, moderate = 3, severe = 4. Nut set counts were made 3 weeks after the Botrytis blight rating.

The regression function between the incidence of *B. cinerea* and the number of nuts set per raceme was significant at the 0.01 level (Fig. 2). Negative correlation coefficients were obtained for the six experiments. These values were significant at the 0.01 level for four experiments and at the 0.05 level for two experiments. These significant negative correlation and regression values indicate that *B. cinerea* is associated with a decrease in nut set on macadamia racemes.

In previous studies, we were unable to demonstrate a relationship between Botrytis blight and reduced nut set. This led to speculation that *B. cinerea* develops only on senescent flower parts and therefore may give a false impression of not being a serious disease. This seemed plausible because there are approximately 300-400 flowers per macadamia raceme (Fig. 1) but only a few flowers produce nuts. The rest of the flowers rapidly become senescent and during ideal conditions serve as substrate for the development of massive amounts of *B. cinerea*. It was further speculated that reduction of nut set might be caused by other factors such as reduced cross-pollination during rainy periods.

Data obtained from these inoculation and fungicide experiments, however, show a causal relationship between incidence of *B. cinerea* and reduction of nut set. Failure to obtain this conclusion in previous studies probably can be attributed to several factors, including using an experimental design that may have led to inadvertent collection of data from racemes infected before the trees were sprayed with fungicides. Fortunately, the most recent experiments were conducted during a period when rainfall was adequate for development of Botrytis blight but undoubtedly was not heavy enough to reduce cross-pollination. The experiments were conducted in a mixed planting of cultivars, thus providing maximum opportunity for cross-pollination and nut set in racemes protected with benomyl.

Epidemics of economic significance probably will occur sporadically in Hawaii. The disease is prevalent during some blossom periods and very rare in other years. Application of fungicides on a commercial basis should increase yields during periods when Botrytis blight is common.

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