# Epidemiology of Powdery Mildew on Mango Blossoms

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**ABSTRACT**

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Conidia of *Oidium mangiferae*, the causal organism of powdery mildew on mango, were trapped in a mango orchard during the periods of flowering and fruit set from 1989–1991. Hourly aerial conidial concentrations were correlated positively with hourly temperature and negatively with hourly relative humidity, vapor pressure deficit, and leaf wetness. The number of trapped airborne conidia of *O. mangiferae* was characterized by a distinct diurnal periodicity. The greatest number of conidia were trapped between 1100 and 1600 hours. The first disease symptoms of powdery mildew occurred at approximately the same time each year. Inflorescences were susceptible beginning when the main axes changed color and ending at fruit set.

Powdery mildew caused by *Oidium mangiferae* Berthet is a serious disease of mango (*Mangiferae indica* L.) in South Africa, where crop losses of 80–90% have been reported (1,4,5). The fungus attacks the young tissue of all parts of the inflorescences, leaves, and fruit. No teleomorph of *O. mangiferae* has been found in South Africa (2,8). Under conditions unfavorable for infection, or when susceptible tissue is not available, the fungus presumably survives as mycelium on older leaves (8). A wide range of fungicides are registered for the control of powdery mildew (11) but losses due to the disease still occur.

Currently, fungicide applications commence when the first signs of the disease are observed, usually at the 50% flowering stage (11). More precise knowledge of when to expect the first appearance of the disease, based on weather conditions and the susceptibility of different developmental stages, would aid growers in the timing of fungicide applications.

This paper reports on studies of spore dispersal of powdery mildew in an unsprayed mango orchard and disease development in relation to the susceptibility of flowers during the course of their development.

## MATERIALS AND METHODS

**Conidial dispersal.** A spore trapping technique described by Ostry and Nicholls (7) was used to monitor airborne conidial concentrations in an unsprayed orchard (cv. Tommy Atkins) at Nelspruit from June 1989 to December 1991. The spore trap was composed of two slides held horizontally by clothes pegs with a layer of petroleum jelly applied to the uppermost side. Clothes pegs were attached to the ends of two metal strips fixed at right angles to one another on top of a 1-m-high, 50-mm-diameter wooden pole. A wire frame was placed above the slides to prevent birds from perching on the traps. A single spore trap was placed in the middle of the orchard.

Microscope slides were changed weekly and the exposed slides were stained with a drop of 0.1% trypan blue in 50% lactophenol. The number of conidia trapped on each slide was determined by counting the conidia at a 312× magnification in transects across the slide. Eight transects were read and the mean calculated. If less than 10 conidia were observed, an additional 22 transects were counted and the mean calculated. This was necessary to obtain an acceptable precision because of the extremely clumped distribution of spores on the slides (10). Conidial numbers as presented in the graphs are the means per transect.

During the exponential phase of the epidemic (20–27 August 1990), conidial concentration was monitored on an hourly basis by using a Burkard volumetric spore trap (Burkard Scientific Sales, Ltd., Rickmansworth, Hertfordshire, England). The spore trap was placed on the ground with the orifice approximately 40 cm above ground level. The trap was adjusted to sample 10 L of air per minute. The tape from the trap was cut into 48-mm sections corresponding to 24 h and mounted on microscope slides. Spores were stained as above and a single transect (0.70 mm field diameter) through the center of each hourly exposure was counted. Counts were normalized with the $\log(x + 1)$ transformation and correlation analyses were performed between meteorological variables and conidial concentrations. Temperature, relative humidity, and leaf wetness were monitored on an hourly basis with a general purpose data logger (MC Systems 120, Mike Cotton Systems Pty. Ltd., South Africa).

**Disease severity in relation to developmental stages.** Detailed records of flower and fruit development and disease severity on the inflorescences were kept through the course of the 1990 and 1991 seasons. Disease severity was monitored weekly and defined as the area of inflorescences covered with mycelium. At the same time, inflorescences were classified into a number of developmental stages (Figs. 1, 2A and B). These included: *(1)* bud-swell to bud-break stage; *(2)* mouse-ear stage—elongation of basal bracts and emergence of inflorescence; *(3)* protected stage—elongation of inflorescence still protected by bracts; *(4)* green-colored—further elongation of inflorescence and opening of secondary rachi, flowers still in bud stage; *(5)* red-colored—final elongation of inflorescence and reddening of rachi; *(6)* red-open—individual flowers start opening from base; *(7)* full-bloom—all individual flowers on inflorescence open; *(8)* fruit-set stage (Fig. 2A); and *(9)* pea-size fruit—approximately 8 mm in diameter (Fig. 2B).

In the 1990 season, 70 inflorescences at the bud-break stage were labeled at the beginning of June before conidia or disease symptoms were detected. In 1991, 100 inflorescences with normal flowering and 50 inflorescences already in the fruit-set stage were labeled. Inflorescences in the fruit-set stage were the result of an out-of-season flowering that occurred (early flowering).

As there was no certainty that all developmental stages would be present at the time when conidia were expected to be freely available, the technique of Mullins (6) was used to delay flowering in 300 additional inflorescences in the 1991 season. Inflorescences at bud-swell to bud-break stages were covered with paper bags at the beginning of the season to prevent powdery mildew infection. At fortnightly intervals, 30 of these were broken out, which had the effect of causing reflowering approximately 6 wk later.

All the bags were removed the first week of September when powdery mildew conidia were present at a high level in the orchard as evidenced by spore trap numbers. Inflorescences were inspected at 9, 18, and 37 days after exposure for disease severity on each development stage. On three occasions during the 1991 season (12 and 29

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August, 24 September), 50 uncovered inflorescences at each of six developmental stages were inspected for disease severity.

## RESULTS

**Conidial dispersal.** Conidia numbers trapped over three seasons are presented in Fig. 3. Generally, conidia were first detected in early July, reached a peak in early September, and were not detected after mid-October. The hourly conidial concentration monitored by the Burkard volumetric spore trap was positively correlated ($P = 0.01$) with hourly temperature and negatively correlated ($P = 0.01$) with hourly humidity, vapor pressure deficit, and leaf wetness. Conidial counts reached a peak between 1100 and 1600 hours, and few conidia were trapped between 2000 and 0700 hours (Fig. 4).

**Disease severity and development stages.** The severity of disease on inflorescences through the course of the 1990 and 1991 seasons is presented in Figs. 5 and 6 respectively.

During the 1990 season, the first symptoms could be observed at the end of July, approximately the same time as in 1989. The first symptoms were detected 2–3 wk after 20% of the inflorescences were between the red-colored and the fruit-set stages.

During the 1991 season, the first symptoms were observed the third week of July (Fig. 6). These symptoms were observed on the early flowering inflorescences (Fig. 6), which were all in the full-bloom to fruit-set stages. During this period, none of the normally flowering inflorescences were in the full-bloom stage or showed any disease symptoms. The first symptoms appeared on the latter inflorescences during the second week of August (Fig. 6), 4 wk after the early flowering inflorescences.

The first symptoms on normal flowering inflorescences were detected 2 wk after 20% of the inflorescences were between the red-colored and fruit-set stages (Table 1). All stages monitored were susceptible, except the protected stage. The green-colored and red-colored stages were only slightly susceptible. The full-bloom stage appeared to be the most susceptible stage.

Of the 300 inflorescences that were bagged at the end of May 1991, only 100 remained on the trees until the second week of September. Although some of the inflorescences and buds were broken out to ensure that all the different stages were present, most inflorescences were in the fruit-set stage. The mean percentage of disease severity of the inflorescences is presented in Table 2. Although equal numbers of the different developmental stages were not present, symptoms did not develop on any inflorescences in the bud-break, mouse-ear, protected, or green-colored stages. Only the red-colored, red-open, full-bloom, fruit-set, and pea-size stages showed symptoms and therefore only these stages were regarded as susceptible.

The mean percentages of disease severity on the uncovered inflorescences inspected on three occasions through the course of the 1991 season are presented in Table 3. The protected and green colored stages were only slightly susceptible, while the full-bloom and pea-size stages were highly susceptible. The red-colored and red-open stages were not differentiated in this trial. No symptoms were detected on the bud-break and mouse-ear stages, therefore these stages were not susceptible.

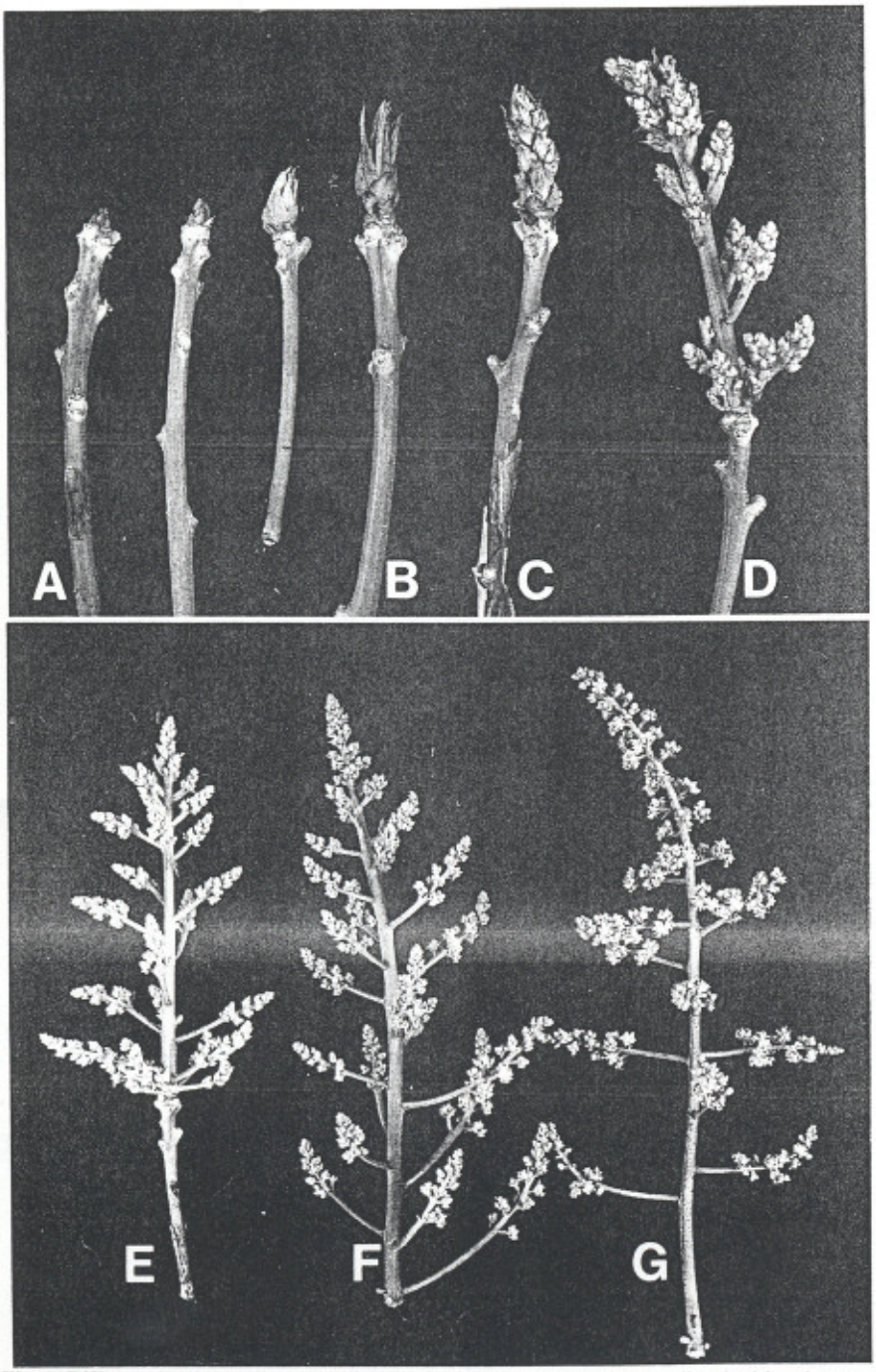


**Fig. 1.** Different development stages of mango inflorescences. (**A**) bud-swell to bud-break stage; (**B**) mouse-ear stage; (**C**) protected stage; (**D**) green-colored stage; (**E**) red-colored stage; (**F**) red-open stage; (**G**) full-bloom stage.

## DISCUSSION

For a powdery mildew epidemic to occur, weather conditions favorable for conidia release are necessary and susceptible tissue must be available at the same time. We found that certain developmental stages of inflorescences were resistant to infection. No stages before the protected stage were susceptible, even when disease levels had reached a peak on other inflorescences in the field. From the protected stage susceptibility increased with inflorescences development to the full-bloom stage. Weinhold (12)

studied the orchard development of peach powdery mildew caused by *Sphaerotheca pannosa* (Wallr.) Lév. var. *persicae* Woronichin and similarly found that only certain developmental stages were susceptible, infection only appearing 1 mo after flowering. Fruit were susceptible for the early stages of their development and were completely resistant 2 mo after flowering.

Flowering of the cv. Tommy Atkins during the 1989 and 1990 seasons occurred over the same period, although there was variation between and within trees. The first disease symptoms were observed at approximately the same time. Conidia were detected earlier in the 1989 season but counts remained low until the end of July after which the increase was similar to that of 1990.

During the 1991 season, an out-of-season flowering occurred in part of the orchard. Disease developed on these inflorescences earlier than expected when compared with the previous two seasons. At this stage these inflorescences were all in the full-bloom to fruit-set stage and therefore susceptible. Unfavorable weather conditions might explain why no disease developed on these inflorescences when they were in the susceptible red-colored to full-bloom stages. The later in-season flowering did not show any disease symp-

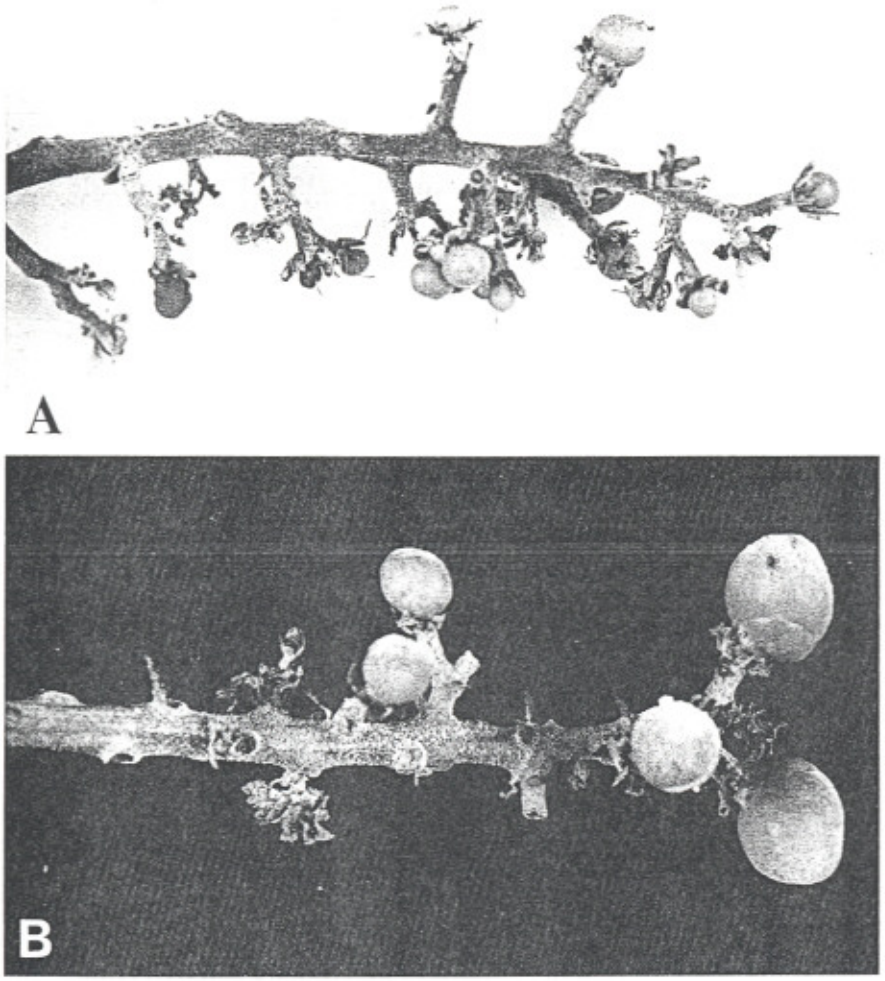


Fig. 2. Development stages of mango inflorescences. (A) An inflorescence in the fruit set stage. (B) An inflorescence in the pea-size stage.

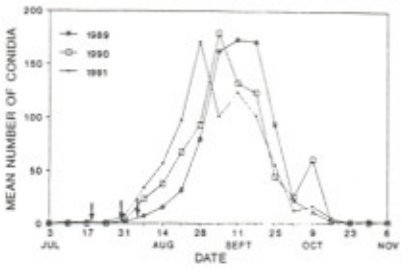


Fig. 3. The mean weekly number of conidia counted during 1989, 1990, and 1991 seasons and times the first disease symptoms were observed (↓).

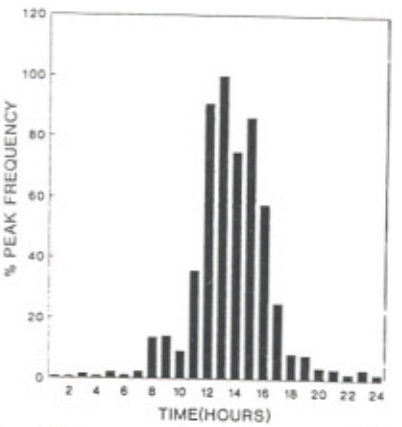


Fig. 4. Percentage of peak frequency of airborne conidia of *Oidium mangiferae* trapped in a Burkard volumetric spore trap during 1990.

**Table 1.** Mean powdery mildew severity on the normal flowering inflorescences monitored weekly over a 6-wk period during 1991 season in an unsprayed mango orchard at Nelspruit

| Stages of inflorescence development[a] | 13 Aug | | 20 Aug | | 28 Aug | | 3 Sept | | 10 Sept | | 17 Sept | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nr[b] | %[c] | Nr | % | Nr | % | Nr | % | Nr | % | Nr | % | Mean |
| Protected | 17 | 0 | 8 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Green-colored | 21 | 0.15 | 8 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 |
| Red-colored | 21 | 0.15 | 20 | 2.27 | 1 | 2.71 | 14 | 3.57 | 2 | 0 | 0 | 0 | 1.45 |
| Red-open | 28 | 0.11 | 37 | 4.10 | 3 | 6.60 | 16 | 19.14 | 13 | 13.70 | 2 | 4.69 | 8.06 |
| Full-bloom | 3 | 1.04 | 15 | 4.69 | 4 | 16.31 | 67 | 44.92 | 9 | 37.50 | 4 | 43.75 | 24.70 |
| Fruit-set | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 52 | 55.89 | 30 | 52.50 | 18.07 |
| Pea-size | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 64.71 | 53 | 44.51 | 18.20 |
| Mean % infection | | 0.21 | | 1.58 | | 3.66 | | 9.66 | | 24.54 | | 20.78 | |

[a] See Figs. 1 and 2 for photographs of stages.
[b] Number of inflorescences inspected.
[c] Area of inflorescence covered with mycelium.

toms at this stage since most of the inflorescences were in the nonsusceptible mouse-ear stage. These inflorescences reached the full bloom stage 3 wk later. The first symptoms appeared on these inflorescences 4 wk after symptoms were detected on the early inflorescences. Although the weather factors were favorable for conidia release and for infection to occur, symptoms developed only when inflorescences were in a susceptible stage.

The number of airborne conidia of *O. mangiferae* trapped was characterized by a distinct diurnal periodicity. The greatest number of conidia were trapped between 1100 and 1600 hours when daytime temperatures were high and the humidity and vapor pressure deficit low. This is consistent with the findings of Gupta (3) with *O. mangiferae* on mango and Schnathorst (9) with *Erysiphe cichoracearum* DC. ex Mérat on lettuce. Schnathorst (9), in studies on powdery mildew on lettuce, observed that high wind velocity and low relative humidity appear to explain why the greatest numbers of conidia were trapped in the afternoon. Yarwood (13) found conidia of *Erysiphe polygoni* DC. were passively disseminated, depending on the maturity of the conidia, the dryness of plant and fungus surfaces, and wind. He suggested that liberation of conidia would be reduced at night, because of higher relative humidity and less wind. Schnathorst (9) observed that chains of conidia and individual conidia at high relative humidity (100%) adhered to one another. This prevented the detachment of chains of single conidia, whereas chains of conidia formed at lower humidities (50–60%) did not adhere to each other. These factors could possibly be responsible for the greater liberation of *O. mangiferae* conidia during daytime when humidities are low, temperatures high, and more wind occurs.

For the 1990 and 1991 seasons, the first disease symptoms were detected 2–3 wk after 20% of the inflorescences attained the red-colored to red-open stages. Fungicide application are therefore necessary before 50% of the inflorescences attain the full-bloom stage. The red-colored and red-open stages are well-defined stages in the mango cv. Tommy Atkins and make it easier for the grower to determine when spraying should start. A preventative spray during these stages would protect the crop adequately.

From this study it is recommended that growers monitor the development of the inflorescences and apply the first fungicidal spray as soon as axes of inflorescences change color. As most fungicides registered for the control of powdery mildew are effective for 3 wk, spraying at 3-wk intervals during the season will be necessary until susceptible tissue is unavailable. It is also important to ensure an even flowering period by removing out-of-season inflorescences.

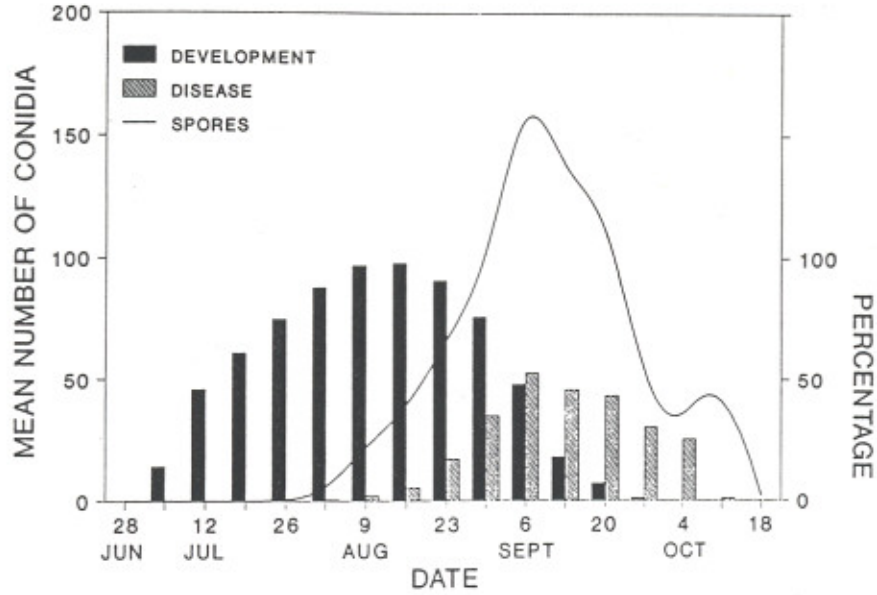


**Fig. 5.** The mean weekly number of conidia, the percentage of inflorescences in a susceptible development stage (red-colored to fruit-set), and mean percent disease incidence on labeled inflorescences during 1990.

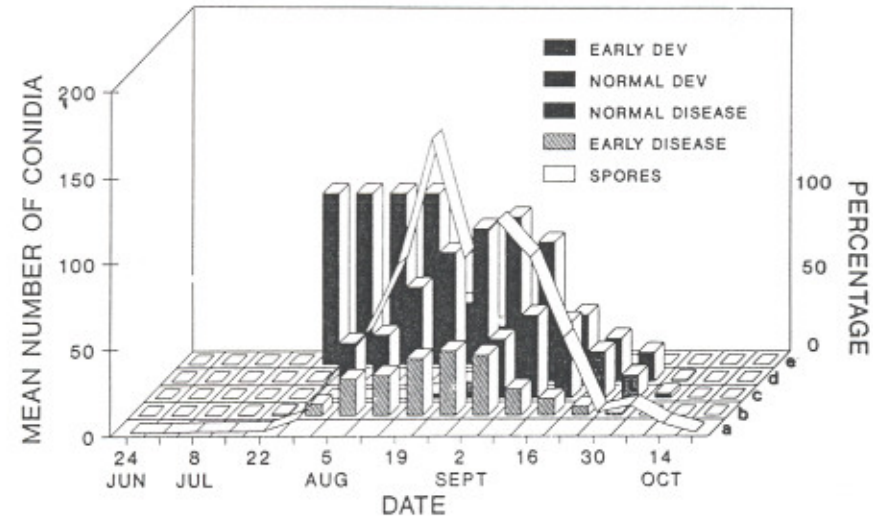


**Fig. 6.** The mean weekly number of conidia, percentage of inflorescences in susceptible development stages, and mean percent disease incidence on labeled inflorescences during 1991. *a:* Conidia numbers; *b:* Disease development on out-of-season inflorescences; *c:* Disease development on inflorescences during normal flowering period; *d:* Development of inflorescences during out-of-season flowering; *e:* Development of inflorescences during normal flowering period.

**Table 2.** Mean powdery mildew severity on 100 mango inflorescences bagged at beginning of 1991 season in an unsprayed mango orchard at Nelspruit

| | 11 Sept | | 20 Sept | | |
|---|---|---|---|---|---|
| Stage[a] | Number inspected | % infection | Number inspected | % infection | Mean % infection |
| Bud-break | 18 | 0[b] | 13 | 0 | 0 |
| Mouse-ears | 4 | 0 | 1 | 0 | 0 |
| Protected | 1 | 0 | 0 | 0 | 0 |
| Green-colored | 1 | 0 | 0 | 0 | 0 |
| Red-colored | 1 | 0 | 1 | 12.50 | 6.25 |
| Red-open | 1 | 0 | 2 | 15.63 | 7.81 |
| Full-bloom | 17 | 0.64 | 0 | ... | 0.64 |
| Fruit-set | 48 | 1.01 | 35 | 31.56 | 16.29 |
| Pea-size | 9 | 0.69 | 39 | 8.05 | 4.37 |
| Mean % infection | | 0.26 | | 7.53 | |

[a] See Figs. 1 and 2 for photographs of stages.
[b] Area of inflorescence covered with mycelium.

**Table 3.** Mean powdery mildew severity on uncovered inflorescences at six different developmental stages on three dates during 1991 season in an unsprayed mango orchard at Nelspruit

| Stage[a] | 12 Aug | | 29 Aug | | 24 Sept | | Mean infection (%) |
|---|---|---|---|---|---|---|---|
| | Number inspected | Infection (%) | Number inspected | Infection (%) | Number inspected | Infection (%) | |
| Bud-break | 50 | 0[b] | 17 | 0 | 0 | 0 | 0 |
| Mouse-ear | 30 | 0 | 15 | 0 | 0 | 0 | 0 |
| Protected | 50 | 0 | 31 | 0.40 | 0 | 0 | 0.13 |
| Green-colored | 50 | 0.406 | 46 | 1.87 | 0 | 0 | 0.76 |
| Full-bloom | 50 | 9.28 | 50 | 34.20 | 36 | 36.98 | 26.84 |
| Pea-size | 40 | 8.16 | 50 | 11.90 | 50 | 34.75 | 18.29 |
| Mean % infection | | 2.97 | | 8.08 | | 11.96 | |

[a]See Figs. 1 and 2 for photographs of stages.
[b]Area of inflorescence covered with mycelium.

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