Vibrational Releases of Conidia by *Drechslera maydis* and *D. turcica* Related to Humidity and Red-Infrared Radiation

C. M. Leach

Professor, Department of Botany and Plant Pathology, Oregon State University, Corvallis 97331.

Technical Paper 5182 of the Oregon Agricultural Experiment Station; partially supported by National Science Foundation Grant DEB 76-14729.

Accepted for publication 5 September 1979.

ABSTRACT

LEACH, C. M. 1980. Vibrational release of conidia by *Drechslera maydis* and *D. turcica* related to humidity and red-infrared radiation. Phytopathology 70: 196-200.

Massive discharge of conidia was triggered by lightly vibrating sporulating leaf lesions infected with *Drechslera maydis* and *D. turcica.* Visual observation of vibrationally liberated conidia with special illumination revealed that the spores were violently discharged into the air perpendicular to the lesion surface. Vibrational release was markedly influenced by relative humidity (RH) and the presence or absence of red-infrared radiation (IR). These factors also were important in spontaneous spore liberation in the absence of vibrations. Vibrational release of conidia was most abundant from specimens exposed to IR at low RH and least from specimens held in darkness at RH 100%. There was a small, but significant, discharge when specimens were vibrated while exposed to IR during saturation. Vibrational release in darkness at lowered humidities ranged from neglible to moderate and was generally insignificant compared to liberation from irradiated specimens. Exposure to IR increased vibrational release during the following dark period.

Brief rain showers on diseased crops can trigger massive liberation of conidia by some foliar pathogens, such as *Botrytis squamosa* (21), *B. cinerea* (10), and *Drechslera turcica* (17). These are dry-spored fungi in contrast to foliar fungi such as *Colletotrichum* spp. and *Fusarium* spp. that produce slimy spores. This distinction is important because the effect of rain on dry-spored fungi (18) may be more complex than on the typical splash release of slimy-spored types (8).

While observing spore liberation by *Drechslera turcica* in the laboratory using special illumination (C. M. Leach, *unpublished*), I accidentally observed that slight vibration of sporulating maize lesions caused a massive, and violent spore discharge (Fig. 1). Violent liberation of conidia also occurs in the absence of vibration and this can be triggered by changes of atmospheric humidity and exposure to red-infrared radiation (11,16). Decreasing the relative humidity (RH), particularly below 50%, triggers major liberation of conidia, and raising the humidity also causes spores to be released (11,16). Although liberation of conidia in response to humidity changes may occur in darkness, spore release is greatly enhanced when these humidity changes occur in the presence of red-infrared radiation (11,16).

0031-949X/80/03019605/$03.00/0

The purpose of this research was to experimentally study vibrational release of conidia by *Drechslera maydis* (Nisik.) Subram. and Jain and *D. turcica* (Pass.) Subram. and Jain, two important foliar pathogens of maize. Because humidity and red-infrared radiation are important factors in nonvibrational spore releases (11,12,16,17), the interaction of these factors on vibrational liberation of conidia, was an integral part of this study.

MATERIALS AND METHODS

Field samples of lesions of northern and southern leaf blights of maize were collected, stored, and later incubated and induced to sporulate as previously described for *D. turcicum* (16). After incubation, the heavily sporulating lesions were transferred to the specimen chamber of a specially designed spore release apparatus (15) and subjected to different humidity and red-infrared light (unfiltered) regimes at constant temperature and air velocity (0.5 m/sec) as previously described (16). Temperature, light, and humidity conditions are shown in Fig. 1–5. Air temperature, relative humidity, light, and air velocity were measured as in earlier studies (15,16). Vibration of specimens involved an arbitrary, but standardized, procedure. A 50 g weight was dropped 5 cm onto a piece of hard cardboard placed on top of the Pyrex glass specimen chamber of the spore release apparatus (15).

RESULTS

Spore discharge in darkness and in the absence of vibration. Spore release was negligible under saturated conditions (96–100% RH) in darkness; only when the RH was lowered or raised were conidia discharged by *D. maydis* (Figs. 2 and 3) and *D. turcica* (Figs. 4 and 5). Conidia released in response to humidity changes were relatively few and only in a single experiment on *D. turcica* (Fig. 5A) in which there was a stepwise reduction and increase of relative humidity, was there a relatively large release of conidia. In this experiment, only when the relative humidity was decreased below 54% were conidia released in significant numbers; upon increasing relative humidity, the greatest release was from 27 to 78% and negligible during shifts from 78 to 100%.

Spore discharge from irradiated specimens. Exposure of specimens of *D. maydis* and *D. turcica* to red-infrared (IR) radiation when the RH was reduced, greatly enhanced spore discharge (Figs. 2–5). Only in one experiment on *D. turcica* (Fig. 4A) was there lack of an appreciable effect of IR. In this experiment the RH was decreased only to 57%, not low enough for optimal release as indicated by the results of the experiment shown in Fig. 5B. In this latter experiment the RH was decreased and increased in a stepwise manner and only at the lower RH levels was spore discharge significant.

Discharge of conidia from irradiated specimens of both *D. maydis* and *D. turcica* was bimodal with one major release associated with lowering the RH and another associated with raising the RH. This bimodal response is most clearly seen for *D. maydis* in Fig. 2A for the discharge occurring between 50 and 67 min and in Fig. 2B for the discharge between 6 and 22 min. The bimodal pattern of release of *D. turcica* in response to humidity changes can be seen in Figs. 4B and 5B.

Spore liberation did not occur when *D. maydis* was irradiated during a period of atmospheric saturation (Fig. 2B, second exposure to IR). This also was true of *D. turcica* in earlier studies (11,16).

Spore discharge by *Drechslera* spp. in response to vibration in darkness. Release of conidia attributable to vibrations was negligible for both *D. maydis* and *D. turcica* when specimens were vibrated in darkness. Virtually no spores were liberated by vibration at saturation and only few more were discharged at decreased relative humidities. This is evident from the results of an experiment on *D. maydis* (Fig. 3) in which the specimen was vibrated on six occasions during the first 40 min, and for *D. turcica* (Fig. 4B) for the vibrations during the first 85 min of the experiment. An exception was a major release of conidia of *D. turcica* (Fig. 4A) at 57% RH when this specimen was vibrated in darkness at 72 min.

When specimens were vibrated in darkness following a period of exposure to IR, there seemed to be a carryover effect of the IR which enhanced spore discharge. This effect was observed for both *D. maydis* and *D. turcica* during periods of saturation as well as a lowered RH. In *D. maydis* during saturation in Fig. 2A which shows enhanced spore release for the three vibrations after 110 min, and in Fig. 3 for the three vibrations between 65 and 80 min. *D. turcica* shows this same IR carryover effect in Fig. 4B for the two vibrations after 118 min, and in Fig. 5 for the single vibration at 90 min.

The IR carryover effect in darkness was greater at decreased

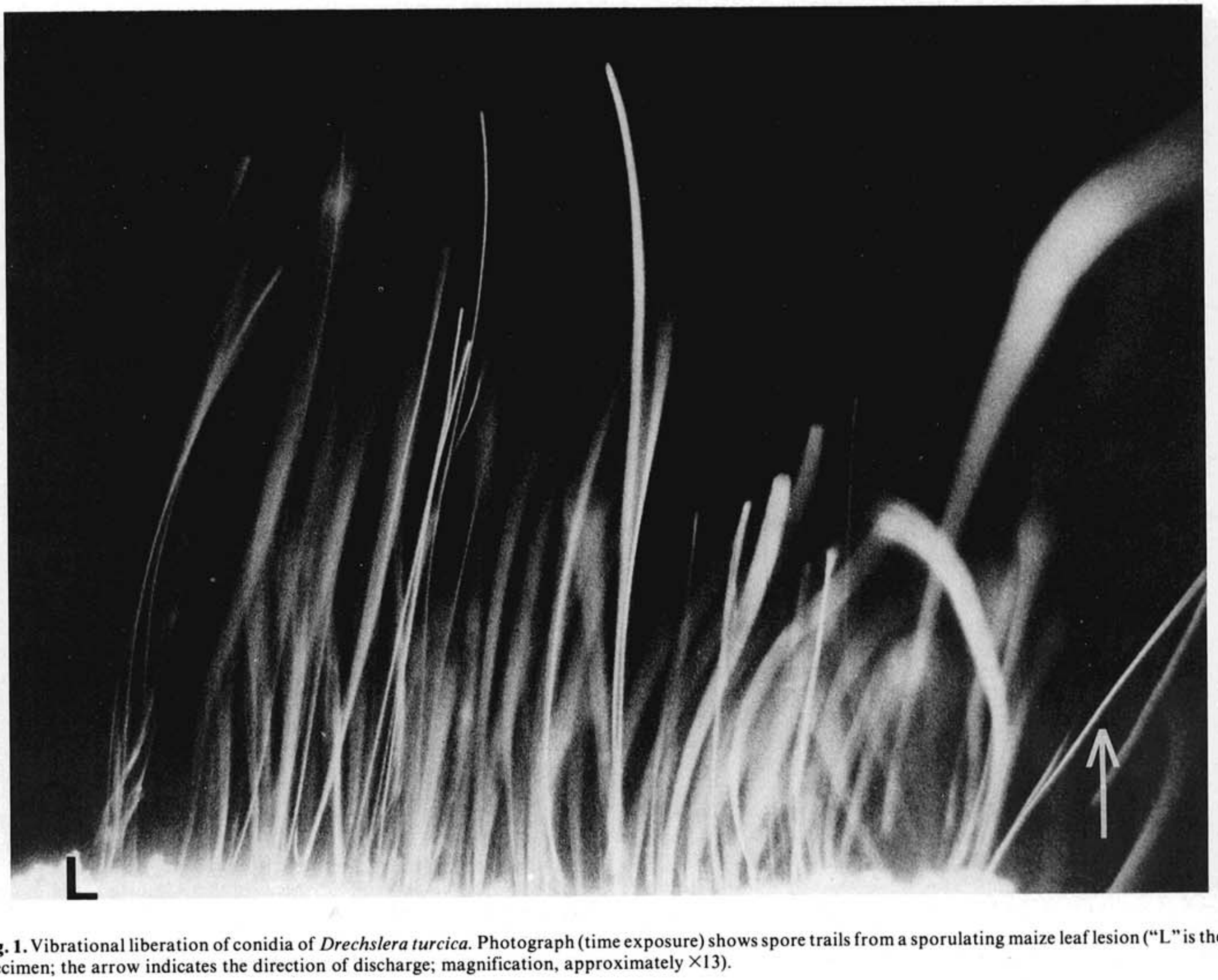

Fig. 1. Vibrational liberation of conidia of *Drechslera turcica*. Photograph (time exposure) shows spore trails from a sporulating maize leaf lesion ("L" is the specimen; the arrow indicates the direction of discharge; magnification, approximately ×13).

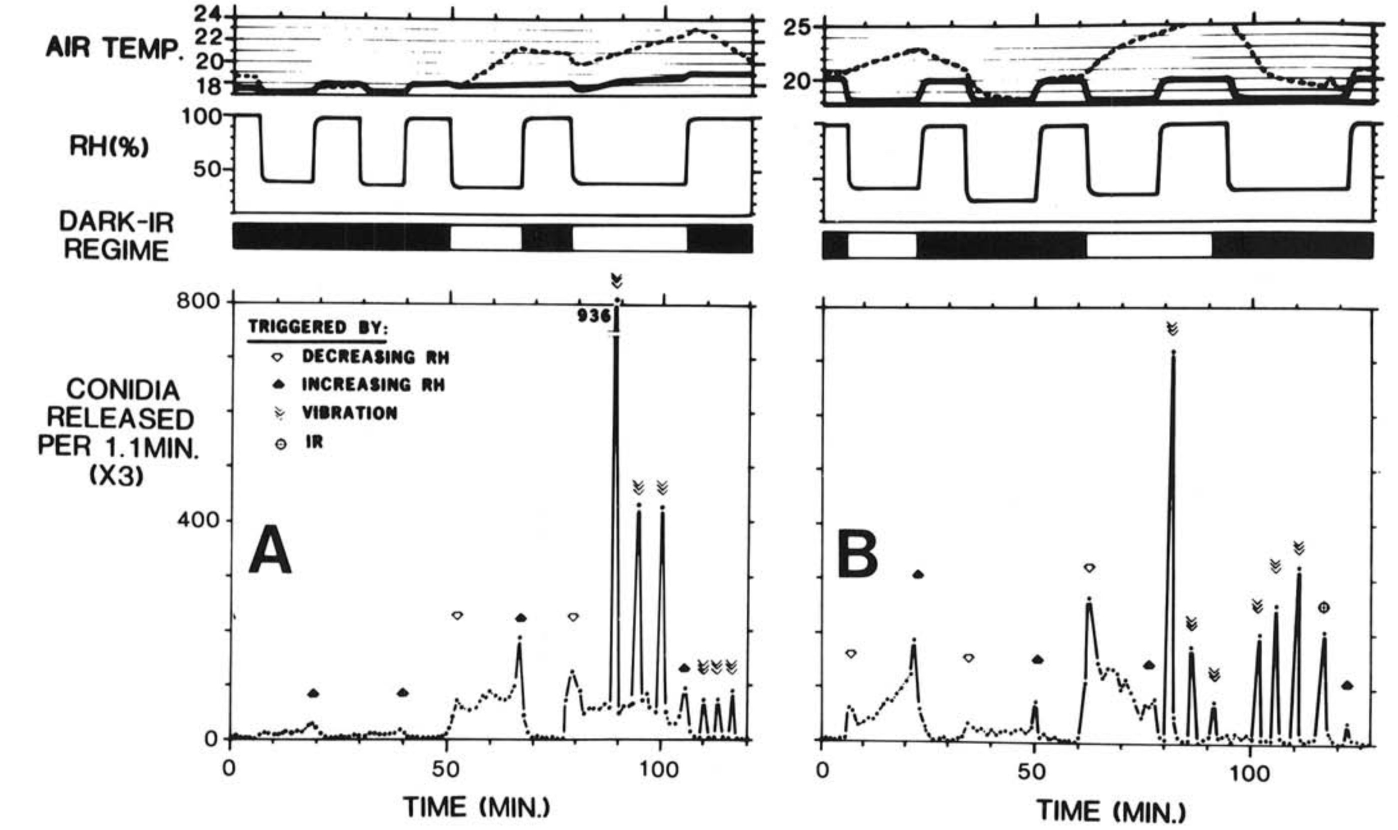

Fig. 2. Spore release by *Drechslera maydis* related to relative humidity (RH), exposure to red-infrared radiation (IR) and vibrations (A and B represent two experiments; air velocity at specimen 0.5 m/sec; temperatures of air entering the specimen chamber are represented by a solid line, those of the air leaving chamber are represented by a dotted line).

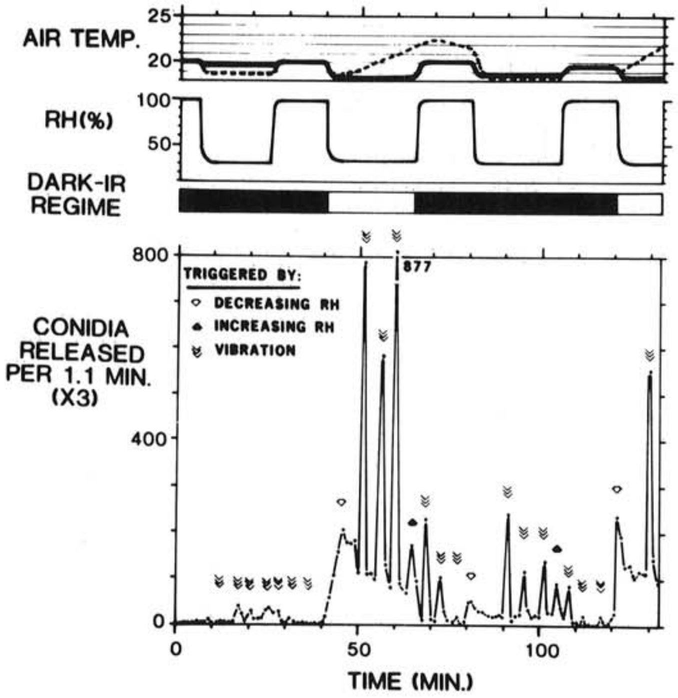

Fig. 3. Spore release by *Drechslera maydis* caused by vibrations under different relative humidity (RH) and red-infrared radiation (IR) regimes (air velocity and temperatures were the same as for Fig. 2).

relative humidities. Examples for *D. maydis* are in Fig. 2B for the three vibrations between 100 and 115 min, and Fig. 3 for the three vibrations between 90 and 102 min.

Vibrational spore discharge from irradiated specimens. Vibration of specimens of *D. maydis* and *D. turcica* while exposed to IR, particularly at decreased humidities, generally resulted in massive discharge of spores. The numbers of spores liberated vibrationally from irradiated specimens consistently far exceeded the numbers released spontaneously in response to humidity changes alone. Examples of vibrational release from irradiated specimens of *D. maydis* at decreased RH are in Fig. 2A (three vibrations between 80 and 105 min) and Fig. 3 (three vibrations between 50 and 65 min). Examples of a similar response are in Fig. 4B (three vibrations between 100 and 115 min). In addition to increasing the numbers of spores released at reduced humidities, there was evidence that IR also caused a rise in numbers of conidia liberated by vibrations at saturation (Fig. 2B, vibration at 82 min).

DISCUSSION

Earlier studies on spore liberation by *D. turcica* (12,13,16,17) demonstrated the importance of changes of atmospheric humidity and exposure to red-infrared radiation. These same factors are equally important in the liberation of conidia by *D. maydis*; in addition, both fungi respond similarly to vibration. Slight vibrations, even the click of a camera shutter used to photograph spore discharge (Fig. 1), are sufficient to trigger major discharges of conidia. The magnitude of vibrational release depends on the relative humidity and the presence or absence of red-infrared radiation. Greatest liberation of conidia occurs when sporulating leaf lesions are subjected to low relative humidities and exposed to red-infrared radiation. In maize fields, plants continuously are being vibrated by wind and rain. The large releases of conidia that can accompany brief rain showers (8,17,21) may well be examples of vibrational release rather than discharge by rain splash (9).

Drechslera maydis and *D. turcica* both exhibit a bimodal pattern of spore liberation under laboratory conditions. A major peak of spore discharge consistently is associated with decreasing humidities, another usually minor peak, with increasing humidities.

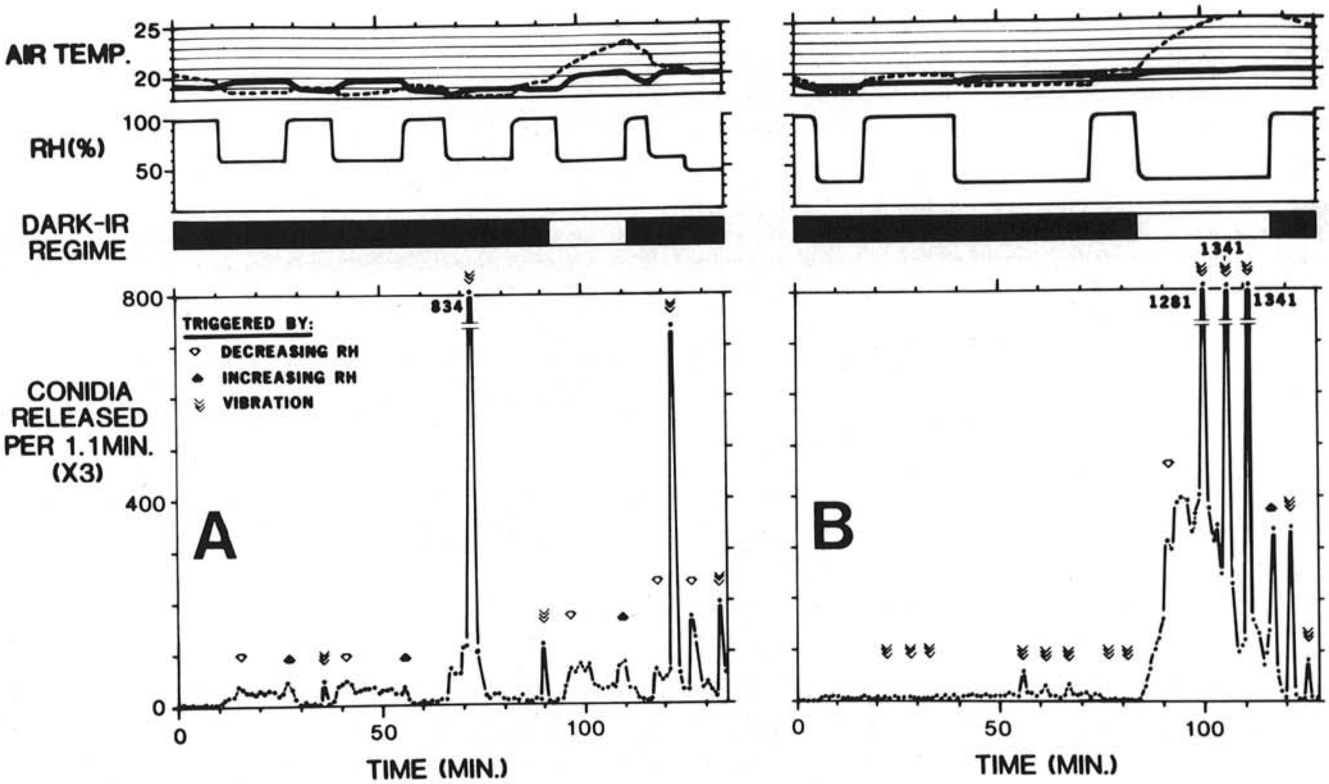

Fig. 4. Spore release by *Drechslera turcica* related to relative humidity (RH), exposure to red-infrared radiation (IR) and vibrations. **A,** Minimum relative humidity during first four cycles was 57%; **B,** Minimum RH for three cycles was 32% (air velocity and temperatures were the same as for Fig. 2).

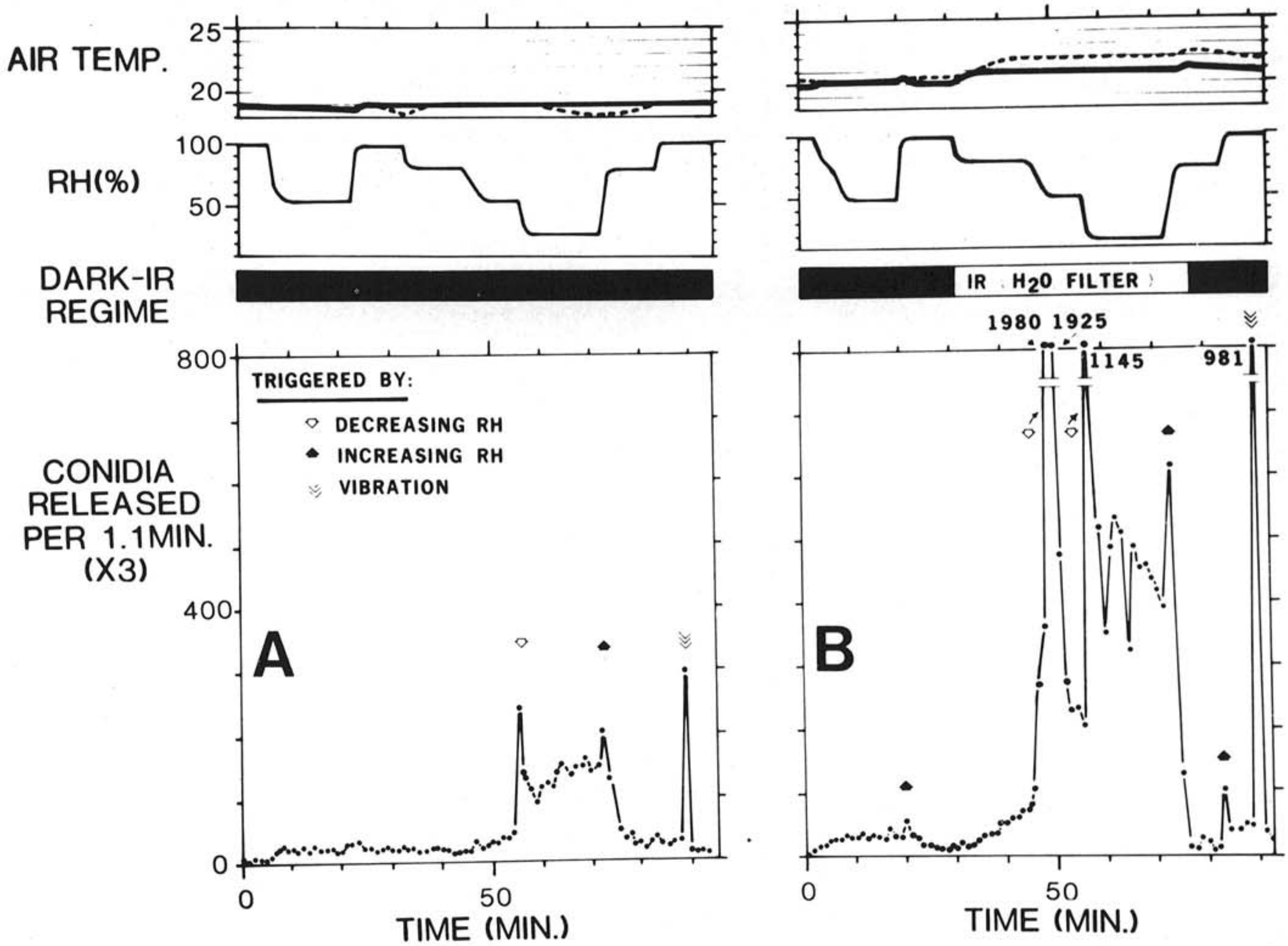

Fig. 5. Spore release by *Drechslera turcica* caused by vibration following the stepwise lowering and raising of the relative humidity (RH). **A,** Experiment conducted in darkness; **B,** specimen exposed to red-infrared (IR) radiation (air velocity and temperatures were the same as for Fig. 2).

The results of spore trapping studies on other fungi under natural conditions have revealed bimodal distributions of airspora during the day (8,19,20). Jarvis' (11) carefully conducted field study on *Botrytis cinerea* (11) showed a distinct bimodal pattern of spore liberation with one peak related to decreasing humdidity and a second peak to increasing humidity.

Light, especially blue light, will trigger spore discharge in some fungi, particularly the Ascomycetes (10). Brook (6,7) was the first to report a red-infrared response in the ascomycete *Venturia inaequalis*. It is not generally recongnized that light also influences spore discharge in a number of dry-spored Fungi Imperfecti. This and earlier studies on *Drechslera turcica* (12,16), have clearly shown that red-infrared radiation profoundly influences spore release whether it be triggered by changing humidities or by vibration (Figs. 2–5).

The mechanism of spore liberation by *Drechslera* is a controversial subject (3,14). Waggoner (22) considered only wind in his experiments on liberation of conidia by *D. maydis*. He reported that only 20% of available conidia were removed by air velocities of 3 m/sec. Aylor and Lukens (4) in contrast, reported 60–70% removal of conidia for this same fungus at wind velocities of about 1 m/sec under natural conditions, though much higher velocities (3–6 m/sec) were required to remove 80% of the conidia in the laboratory. Aylor and Lukens stated: "since jarring due to leaf flapping does not impart sufficient impulse to dislodge spores because of their small mass, leaf flapping would not liberate spores." My vibrational studies on *D. maydis* and *D. turcica* suggest that this conclusion is wrong. Bainbridge and Legg (5) found that conidia of powdery mildew were liberated from flapping barley leaves at an air speed of 0.6 m/sec. They attributed the dislodgement of conidia to the acceleration caused by the flapping rather than to direct wind removal. My findings indicate that at a low air speed of 0.5 m/sec many spores of *D. maydis* and *D. turcica* are liberated and I attribute this to the violent discharge of spores rather than the direct removal by "wind." Neither Aylor (1,2), nor Bainbridge and Legg (5), have seriously considered the influence of atmospheric humidity and red-infrared radiation on spore release. My results for *D. maydis* and *D. turcica* suggest that these factors cannot be ignored. Zoberi (23) also reported the importance of humidity on the liberation of spores.

LITERATURE CITED

1. AYLOR, D. E. 1975. The force required to detach conidia of *Helminthosporium maydis*. Plant Physiol. 55:99-101.
2. AYLOR, D. E. 1977. Force required to liberate conidia. Trans. Br. Mycol. Soc. 69:160-161.
3. AYLOR, D. E., and P. R. DAY. 1976. Conidial release in *Helminthosporium*. Phytopathology 66:537.
4. AYLOR, D. E., and R. J. LUKENS. 1974. Liberation of *Helminthosporium maydis* spores by wind in the field. Phytopathology 64:1136-1138.
5. BAINBRIDGE, A., and B. J. LEGG. 1976. Release of barley-mildew conidia from shaken leaves. Trans. Br. Mycol. Soc. 66:495-498.
6. BROOK, P. J. 1968. Stimulation of ascospore release in *Venturia inaequalis* by far red light. Nature 222:390-392.
7. BROOK, P. J. 1969. Effects of light, temperature and moisture on release of ascospores by *Venturia inaequalis* (Cke.) Wint. N. Z. J. Agric. Res. 12:214-227.
8. GREGORY, P. H. 1973. Microbiology of the Atmosphere. Wiley, New York 377 pp.
9. HIRST, J. M, and O. J. STEDMAN. 1963. Dry liberation of fungus spores by raindrops. J. Gen. Microbiol. 33:335-344.
10. INGOLD, C. T. 1971. Fungus Spores—their Liberation and Dispersal. Clarendon Press, Oxford, England. 302 pp.
11. JARVIS, W. R. 1962. The dispersal of spores of *Botyrtis cinerea* Fr. in a raspberry plantation. Trans. Br. Mycol. Soc. 45:549-559.
12. LEACH, C. M. 1975. Influence of relative humidity and red-infrared radiation on violent spore release by *Drechslera turcica* and other fungi. Phytopathology 65:1303-1312.
13. LEACH, C. M. 1976. An electrostatic theory to explain violent spore liberation by *Drechslera turcica* and other fungi. Mycologia 68:63-86.
14. LEACH, C. M. 1976. Further comments on spore release by *Drechslera (Helminthosporium)* spp. and other fungi. Phytopathology 66:1265-1266.
15. LEACH, C. M. 1980. An apparatus for precise control of humidity, temperature, air flow and light in spore discharge studies. Phytopathology 70:189-191.
16. LEACH, C. M. 1980. Influence of humidity and red-infrared radiation on spore discharge by *Drechslera turcica*—Additional evidence. Phytopathology 70:192-196.
17. LEACH, C. M., R. A. FULLERTON, and K. YOUNG. 1977. Northern leaf blight of maize in New Zealand: release and dispersal of conidia of *Drechslera turcica*. Phytopathology 67:380-387.
18. MEREDITH, D. S. 1973. Significance of spore release and dispersal mechanisms in plant disease epidemiology. Annu. Rev. Phytopathology 11:313-341.
19. PADY, S. M., C. L. KRAMER, and R. CLARY. 1969. Periodicity in aeciospore release in *Gymnosporangium juniperi-virginianae*. Phytopathology 58:329-331.
20. PADY, S. M., C. L. KRAMER, and R. CLARY. 1969. Sporulation in some species of *Erysiphe*. Phytopathology 59:844-848.
21. SUTTON, J. C., C. J. SWANTON, and T. J. GILLESPIE. 1978. Relation of weather variables and host factors to incidence of airborne spores of *Botrytis squamosa*. Can. J. Bot. 56:2460-2469.
22. WAGGONER, P. E. 1973. The removal of *Helminthosporium* spores by wind. Phytopathology 63:1252-1255.
23. ZOBERI, M. H. 1961. Take-off of mold spores in relation to wind speed and humidity. Ann. Bot. 25:53-64.