Rust Infection protects Beans against Heat Injury

THE greater tolerance of rusted (uredinial stage of *Uromyces phaesoli* on *Phaseolus vulgaris* var. 'Pinto') than healthy bean tissue to heat has been reported[1]. This study shows that with a properly chosen age of infection, heat dosage and period in darkness, rusted plants may outyield healthy plants, and may survive when healthy plants are killed by the same heat dosage (Fig. 1).

Primary leaves of beans in 3 inch pots of a mixture of sand, peat and fertilizer were inoculated at about 9 days after seeding to give 50–200 rust pustules/cm^2. The plants were heated by dipping the tops for 14 s at 55° C in water between 0700 h and 1500 h at 4 or 5 days after inoculation, placed in darkness until the evening of the second day and weighed at 14–24 days after inoculation. The three experimental factors of inoculation, heat and dark were applied in all eight possible combinations. In all six independent trials during August and September with a total of twelve pairs of plants (one healthy and one inoculated) in each trial, the final green weight of the primary leaves + new growth of the heated, darkened, rusted plants averaged more than four times that of the non-rusted and was similar to that of rusted but untreated plants. Results are given in Table 1 and typical plants are illustrated in Fig. 1.

Table 1. GREEN WEIGHTS OF BEANS IN RELATION TO RUST INFECTION, HEAT AND DARK TREATMENTS

Treatment	Average green weight per plant (g) Healthy	Rusted
Non-heated controls	22·2	7·36
Non-heated controls, held 48 h in darkness	19·4	3·66
Heated 14 s at 55° C	1·37	1·58
Heated 14 s at 55° C, held 48 h in darkness	1·73	7·99

Each aspect of the treatment sequence has been shown to be important. Most of the preliminary results were secured with studies of half-rusted leaves (ref. 1; Fig. 7), but these results are not presented. With heavy rust infection there may be a transient increase in photosynthesis[2,3] and in green and dry weights[4,5] at 3–6 days after inoculation. After about 8 days from inoculation, infection caused a progressive decrease in green or dry weights. By 16–24 days after inoculation, heavily rusted, non-heated, non-darkened plants averaged 33 per cent of the green weight of the controls. This reduction in green weight was primarily in new growth, as the inoculated primary leaves were commonly increased in weight as a result of rust infection.

Plants inoculated at 8, 9 and 10 days after seeding, with primary leaves from 25–60 mm in width, gave greater increases in green weight as a result of rust than older plants with larger leaves. Plants heated at less than 3 days after inoculation or more than 6 days after inoculation have not shown this protective action of rust against heat injury. At 10 days after inoculation rusted leaves were more injured by the same dosage of heat than were healthy leaves.

Heating of plants may be used to kill out rust infections[1]. The dosage of heat necessary to bring about the greater green weight of rusted than healthy plants was much greater than that necessary to kill the rust. The rust was killed out without host injury by 40 s at 45° C, 4 s at 50° C, or 0·5 s at 55° C, but to produce the increased growth associated with rust infection required 70–120 s at 50° C or 11–18 s at 55° C, which latter dosages caused injury to the host.

Time in darkness was important. When unheated rusted and non-rusted leaves were placed in darkness for 3–4 days, the rusted leaves or half-leaves were commonly more injured than the non-rusted. When similar leaves were heated for 14 s at 55° C and placed in darkness, the greater injury to healthy than to rusted tissue increased

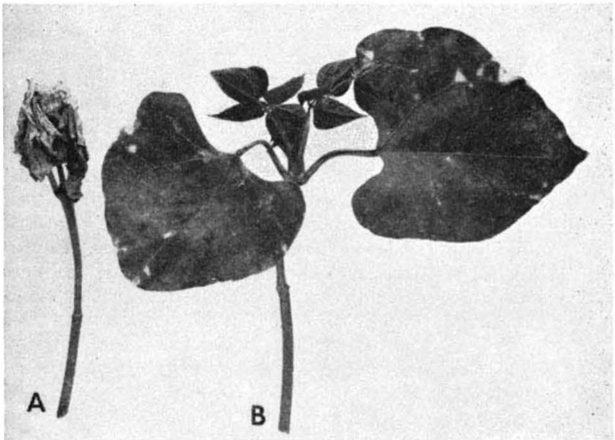

Fig. 1. Representative plants, showing comparative response of healthy (*A*) and rusted (*B*, inoculated August 31) beans to heat. Both plants were seeded August 22, heated for 14 s at 55° C at 0700 h, September 5, and placed in the dark, returned to the greenhouse environment 0700 h, September 7, and photographed September 13. The leaves of the healthy (non-rusted) plants were killed, but these dead leaves, but not stems, are included in values for green weight, as in Table 1.

with time in darkness up to 2 days. More than 3 days in darkness caused severe injury to healthy and rusted tissue.

This may be the first case where, with a properly chosen environmental niche[6], plants heavily infected with a conventional pathogen have substantially outyielded healthy plants.

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Horn-like Structures as Rank Symbols, Guards and Weapons

STONEHOUSE[1] has put forward a hypothesis on the thermoregulatory function of antlers which seems plausible but which rests on doubtful assumptions and fails to predict correctly.

There is little to quarrel with in the idea that growing antlers can serve in thermoregulation—any well vascularized appendage can fulfil such a purpose—but to claim that antlers evolved as thermoregulatory organs is a different matter. It is not surprising that growing antlers and horns are well vascularized, for how else would a moose (*Alces*) grow up to 50 pounds of antler mass in a little more than 4 months ? To demonstrate that antlers or horns[2] can lose heat and that ruminants can control blood flow through these organs argues no more for their evolution as variable heat radiators than such a demonstration argues that fore and hind limbs evolved as variable heat radiators, other functions being secondary.

The premise that deer grow antlers to rid the body of excessive heat during fattening in spring and summer does not hold for the roe deer (*Capreolus*). Roe deer grow antlers during winter (January to the end of March);