Journal of Nematology 25(3):454–460. 1993.

Influence of Temperature on the Virulence of Two Races of *Meloidogyne chitwoodi* on Wheat and Barley[1]

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Abstract: Races of the Columbia root-knot nematode, *Meloidogyne chitwoodi,* from Idaho (R1) and Utah (R2) suppressed ($P < 0.05$) tillering of Dusty winter wheat, Fielder spring wheat, Luther winter barley, and Steptoe spring barley at 15–30 C. Nematode inoculum density was negatively correlated with tillering ($r = -0.79$). Inoculum densities of both nematode races were negatively correlated with heads per plant ($r = -0.83$), head length ($r = -0.87$), and head dry weight ($r = 0.73$) of Fielder spring wheat and Steptoe spring barley at all temperatures; the greatest growth restrictions occurred at Pi 20 eggs/cm^3 soil. Both nematode races were most damaging at 25–30 C. Fielder spring wheat and Steptoe spring barley inoculated with R2 produced fewer heads than R1 when inoculated at 15 C, whereas the same cultivars inoculated with R1 produced fewer heads than R2 at 30 C. No differences were observed between root growth of winter and spring wheat or between winter and spring barley. Nematode reproduction was positively correlated to temperature ($r = 0.87$) and negatively correlated with inoculum density ($r = -0.86$). Reproductive rates were greatest with Pi = 2 eggs/cm^3 soil at 25 C and lowest with Pi = 20 eggs/cm^3 soil at 15 C for both nematode races.

Key words: barley, Columbia root-knot nematode, damage potential, nematode, plant growth, reproductive index, root-gall rating, susceptibility, temperature, tillering, wheat.

Intraspecific variations in damage potential of populations or races of *Meloidogyne* spp., including the Columbia root-knot nematode, *Meloidogyne chitwoodi* Golden, O'Bannon, Santo, & Finley, have been differentiated (5,8,9,14). These races or populations, including those of *M. chitwoodi,* differ in their effects on cereals and in their response to soil temperature (4,11, 12,15). Populations or races of some species may be found surviving at abnormally cool or warm temperatures. For example, a Netherlands population of *M. incognita* (Kofoid & White) Chitwood infects and reproduces at a temperature that is about 5 C lower than a Venezuelan population (2). A desert population of *M. hapla* Chitwood is pathogenic to lettuce in southern California at high soil temperatures (10), indicating that these pathogens can adapt to different geographical temperature regimes.

Wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.), which are hosts for *M. chitwoodi,* are grown in rotation with potato (*Solanum tuberosum* L.) in different regions of the western United States. Because Columbia root-knot nematode races differ in their host preference and damage potential (5,14) and because *M. chitwoodi* is pathogenic on cereals (4,13), this study was initiated to determine whether temperature affected the host–parasite relationships of two geographically separate *M. chitwoodi* races on spring and winter wheat and barley.

Materials and Methods

Nematode inocula: Meloidogyne chitwoodi races, taken from potato fields at Ft. Hall, Idaho (R1), with a growth period of 1,500–2,000 degree days (3), and Beryl, Utah (R2), with a growth period of less than 1,000 degree days (G. D. Griffin, unpubl. data) were cultured on barley cv. Steptoe in the greenhouse at 24 ± 3 C. Inocula (eggs) were collected by a NaOCl method (6).

Seedlings (3–6 mm radicle) of winter wheat cv. Dusty, spring wheat cv. Fielder, winter barley cv. Luther, and spring barley cv. Steptoe were planted into individual 6-cm-d plastic pots containing 540 cm^3 steam-sterilized Kidman fine sandy loam soil (coarse–loamy mixed mesic Calcic Haploxeroll; 85% sand, 8% silt, 7% clay; pH 7.1, 0.5% OM). Twelve days after emergence, wheat and barley seedlings

Received for publication 19 August 1992.

[1] Cooperative investigation, USDA ARS and the Utah Agricultural Experiment Station. Journal Paper No. 4312.

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were inoculated with either 0, 2, 10, or 20 eggs/cm^3 soil of one of the two nematode races. Eggs suspended in 10 ml deionized water were poured into four holes 10 cm deep in the soil around the hypocotyl base. Containers were maintained in growth chambers at 15, 20, 25, or 30 C (±1 C), and a 19-hour daylength was provided by high-output fluorescent lamps.

The experiment was a 4 × 4 × 2 factorial (4 cultivars × 4 inoculations × 2 nematode races) in a randomized complete block design with 20 replications, one plant per replicate. Plants were watered daily and fertilized monthly. All plants were harvested 108 days after inoculation. Tillers per plant, plant height, and shoot and root dry weights were recorded. Root-galling index (1 = no galling, 2 = 1–10, 3 = 11–20, 4 = 21–50, 5 = 51–80, 6 = 81–100% root tissue galled), and nematode reproductive indices (Pf/Pi = final nematode population per plant ÷ initial nematode population per plant) were determined (4). Because plants were not vernalized, there was no head set on winter wheat and barley (1,7), and data involving heads are shown only for spring wheat and spring barley. Data were recorded and statistically analyzed, with means being separated by Duncan's multiple-range test.

Results and Discussion

Temperature affected the host–parasite relationship of *M. chitwoodi* on wheat and barley, which agrees with previous studies involving *M. incognita* and *M. javanica* on wheat (11,12,15). Tillering was greater ($P < 0.05$) in Dusty winter wheat than in Fielder spring wheat, Luther winter barley, and Steptoe spring barley (Fig. 1). *Meloidogyne chitwoodi* suppressed tillering, whereas plant height was not affected ($P > 0.05$). Maximum tillering in Dusty winter wheat occurred at 25 and 30 C, and the greatest suppression in tillering ($P < 0.05$) occurred at 25 and 30 C. Inoculum density was negative correlated ($r = -0.79$) with tillering. At 30 C and Pi of 20 egg/cm^3 soil, tillering of Dusty winter wheat inoculated with R2 rather than with R1 was minimal ($P < 0.05$), whereas tillering of the other three cultivars was not differentiated by nematode race.

Plant shoot growth (dry weight) of the four cultivars was not suppressed ($P > 0.05$) by R1 and R2 at any inoculum density at any temperature (Fig. 2). However, physiological differences ($P < 0.05$) were evident in shoot dry weights of wheat and barley cultivars; the greatest shoot dry weight occurred with Dusty winter wheat at 20 C. No differences ($P > 0.05$) were detected between root growth of winter and spring wheat and winter and spring barley; barley had greater root growth ($P < 0.05$) than wheat (Fig. 2). Root growth of uninoculated wheat was greatest at 20 C, whereas that of barley was greatest at 30 C. R1 and R2 did not differ in their effects on root growth, and the greatest root depression by *M. chitwoodi* ($P < 0.05$) occurred at 25 and 30 C.

R1 and R2 restricted ($P < 0.05$) the number of heads of Fielder spring wheat and Steptoe spring barley, and inoculum densities were inversely correlated ($r = -0.83$) with heads per plant (Fig. 3). The greatest restriction in head development per plant ($P < 0.05$) occurred at 30 C with 20 eggs cm^3 soil. Head set of plants inoculated with 20 eggs/cm^3 soil of R2 were generally less ($P < 0.05$) than those inoculated with R1 at 20 and 25 C. The reverse was true at 30 C where there was less head set on plants inoculated with R1. Inoculum densities of both nematode races were negatively correlated with heads per plant ($r = -0.73$). Great variability was noted in head length of both wheat and barley, and head length was not affected ($P > 0.05$) by temperature, nematode race, or inoculum density. R1 and R2 restricted ($P < 0.05$) head development of both wheat and barley at all temperatures. However, no differences were observed ($P < 0.05$) in head dry weights between nematode races, plant cultivars, and temperature. Head dry weight was negatively correlated ($r =$

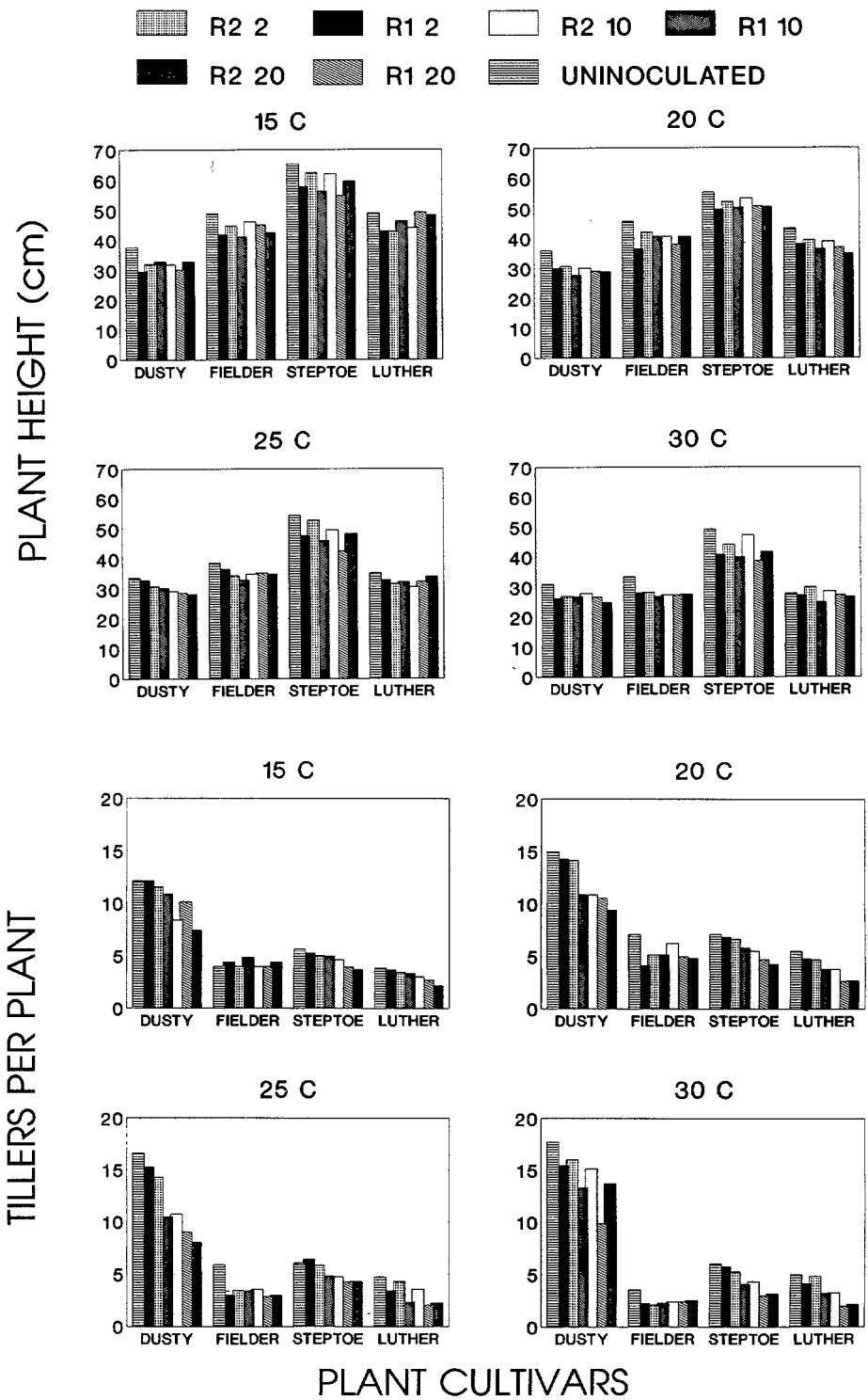

FIG. 1. Effects of an Idaho race (R1) and a Utah race (R2) of *Meloidogyne chitwoodi* at inoculum densities of 2, 10, and 20 eggs/cm^3 soil on tillering and plant height of Dusty winter wheat, Fielder spring wheat, Luther winter barley, and Steptoe spring barley at four different temperatures. LSD ($P < 0.05$). Tillering: 15 C = 2.1; 20 C = 1.8; 25 C = 1.5; 30 C = 1.7. Plant height: 15 C = 7.3; 20 C = 6.3; 25 C = 7.6; 30 C = 6.5.

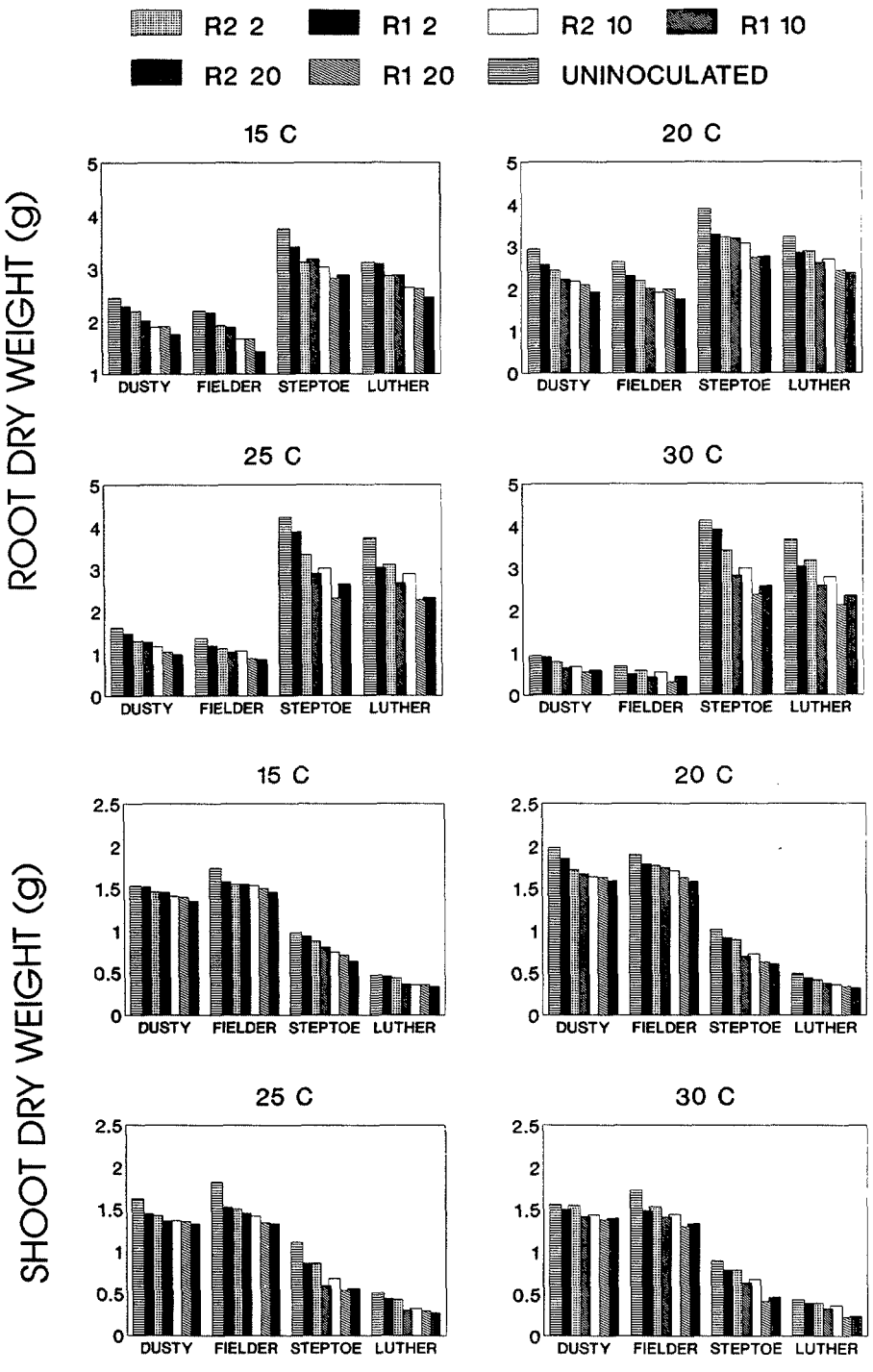

FIG. 2. Influence of an Idaho race (R1) and a Utah race (R2) of *Meloidogyne chitwoodi* at inoculum densities of 2, 10, and 20 eggs/cm^3 soil on shoot and root growth of Dusty winter wheat, Fielder spring wheat, Luther winter barley, and Steptoe spring barley at four different temperatures. LSD ($P < 0.05$). Shoot dry weight: 15 C = 0.34; 20 C = 0.39; 25 C = 0.30; 30 C = 0.26. Root dry weight: 15 C = 0.75; 20 C = 0.59; 25 C = 0.64; 30 C = 0.70.

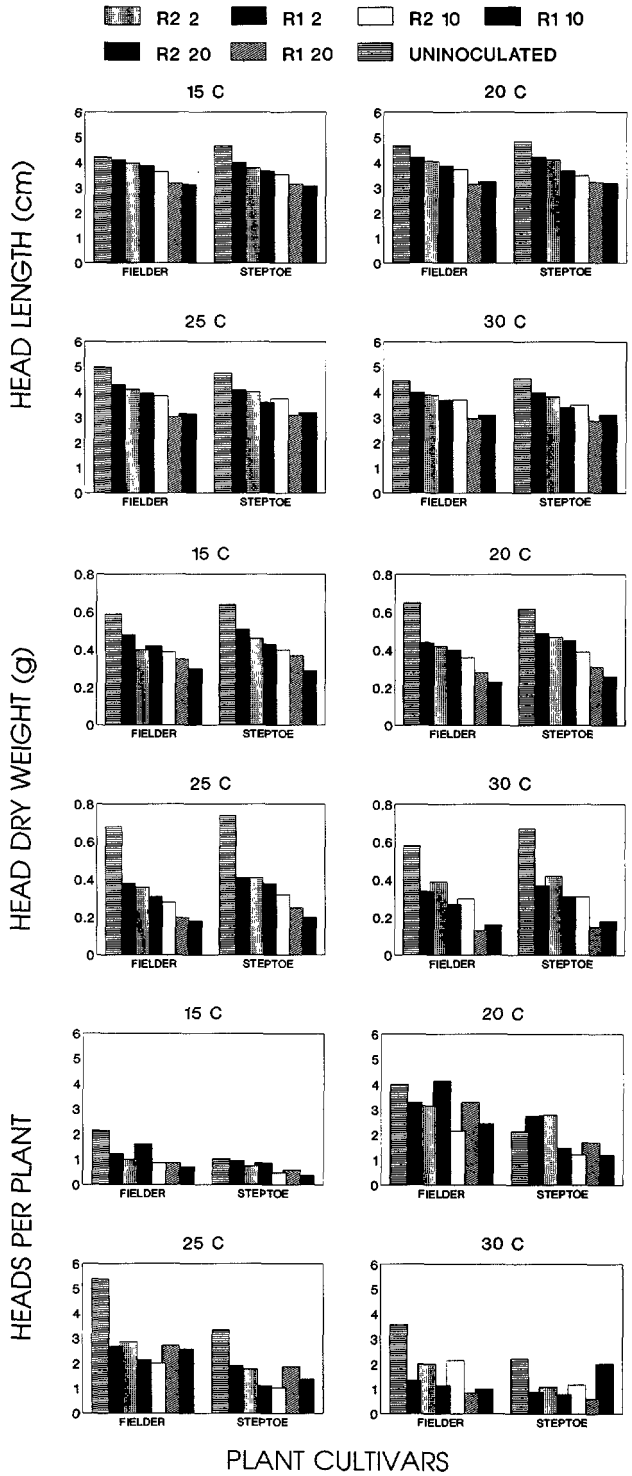

FIG. 3. Effects of an Idaho race (R1) and a Utah race (R2) of *Meloidogyne chitwoodi* at inoculum densities of 2, 10, and 20 eggs/cm^3 soil on head growth of Fielder spring wheat and Steptoe spring barley at four different temperatures. LSD ($P < 0.05$). Heads per plant: 15 C = 0.36; 20 C = 0.46; 25 C = 0.67; 30 C = 0.58. Head dry weight: 15 C = 0.29; 20 C = 0.18; 25 C = 0.21; 30 C = 0.26. Head length: 15 C = 1.42; 20 C = 1.24; 25 C = 1.38; 30 C = 1.12.

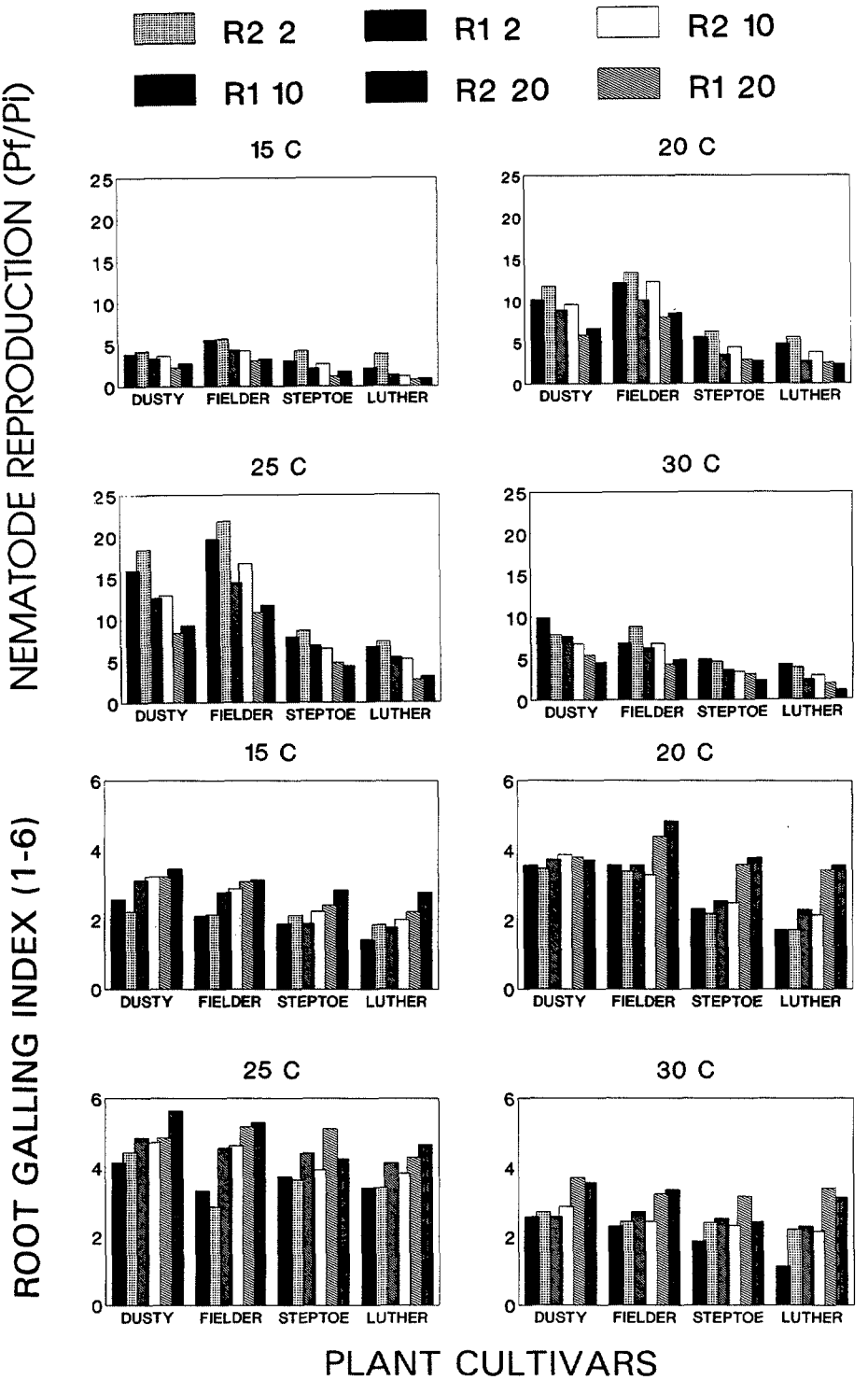

FIG. 4. Relationships of an Idaho race (R1) and a Utah race (R2) of *Meloidogyne chitwoodi* at inoculum densities of 2, 10, and 20 eggs/cm^3 soil to root galling and nematode reproduction of Dusty winter wheat, Fielder spring wheat, Luther winter barley, and Steptoe spring barley at four different temperatures. LSD ($P < 0.05$). Root-galling index (1 = no galling, 2 = 1–10, 3 = 11–20, 4 = 21–50, 5 = 51–80, 6 = 81–100% root tissue galled): 15 C = 0.75; 20 C = 0.59; 25 C = 0.64; 30 C = 0.70. Nematode reproduction rates (Pf/Pi): 15 C = 1.8; 20 C = 2.0; 25 C = 2.4; 30 C = 2.2.

-0.79) with nematode Pi, the greatest restriction occurring at 30 C with 20 eggs/cm^3 soil.

Root galling differed among wheat and barley cultivars (Fig. 4). Maximum root-galling indices on all cultivars occurred at 25 C, and there was a positive correlation ($r = 0.73$) between the root galling index and inoculum Pi. Nematode reproductive indices were greater ($P < 0.05$) on wheat than on barley. Maximum nematode reproduction occurred on Fielder spring wheat, whereas minimum reproduction occurred on Luther winter barley (Fig. 4). Nematode reproduction was positively correlated with temperatures from 15 to 25 C ($r = 0.87$), whereas reproduction was negatively correlated with inoculum density ($r = -0.86$). R1 and R2 did not differ in nematode reproduction on winter and spring barley, but *M. chitwoodi* reproduction was greater ($P < 0.05$) on Fielder spring wheat than on Dusty winter wheat.

This study shows that temperature affects both the virulence and reproduction of *M. chitwoodi* on wheat and barley and that the host–parasite relationship may differ between geographical areas, affecting the importance of the nematode in a grain–potato rotation. These responses were underscored by the effects of temperature on the impact of R1 and R2 on heads per plant of Fielder spring wheat. As observed in a previous study (4), *M. chitwoodi* differed in reproduction on wheat and barley, and different phenological stages of plant development were affected by the nematode. This finding agrees with the general observation that factors affecting the virulence and reproduction of plant-parasitic nematodes may be governed by different genetic variables (4). Because wheat is a better host of *M. chitwoodi* than is barley, barley would be a better cultivar for use in a rotational program with potato. Differences in wheat and barley growth are attributed to physiological differences between cultivars (1).

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