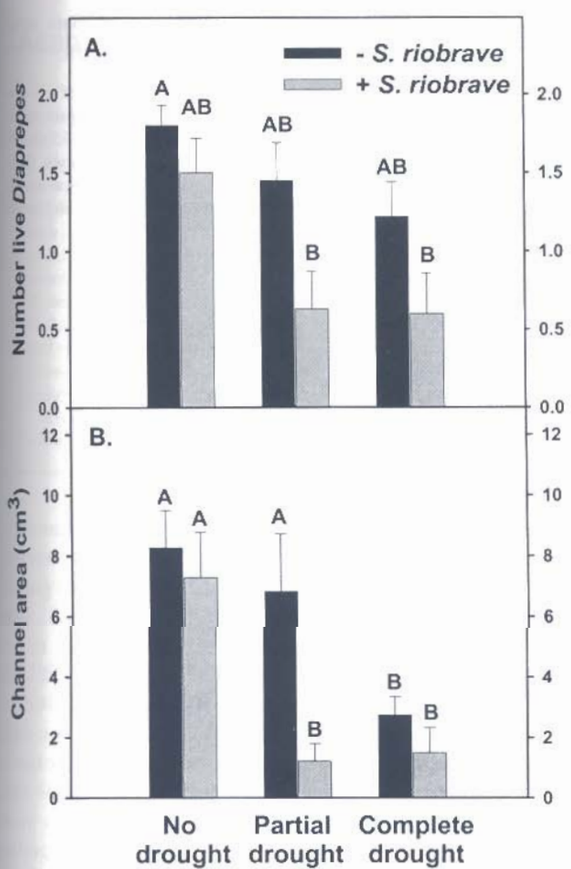

FIG. 3. Numbers of live larvae of *Diaprepes abbreviatus* (A) and cumulative area of channels in root cortex caused by insect feeding (B) in the top pots of double pot systems that were treated or not treated with *Steinernema riobrave*. Bars with the same letters do not differ ($P = 0.05$) according to Tukey's Honestly Significant Difference Test. Thin bars represent standard errors of means.

under partial drought, compared to 45% under complete drought and 12% under no drought (Fig. 3B). Both moisture regime ($P = 0.001$) and nematodes ($P = 0.01$) affected channel area with no significant indication of interaction ($P = 0.11$).

Insect larvae appeared to be relatively inactive under complete drought. In the absence of nematodes, numbers of live insect larvae under complete drought were 39% fewer than under no drought, but the feeding damage was reduced by 68%. In contrast, in the absence of nematodes, numbers of live insect larvae and amount of feeding damage were reduced (ns) by only 20% and 18%, respectively, under partial drought compared to no drought. Duncan and El Morshedy (1996) found that water content in citrus fibrous roots was 25%, 65%, and 79% after 23 days of complete, partial, and no drought, respectively. Because soil water potential was similar between the partial-drought and complete-drought treatments, water content of the root systems may have caused the differences observed in the insect feeding behavior in these two treatments.

Adequate soil moisture is a critical consideration for successful establishment of exogenously applied entomopathogenic nematodes that are harmed by rapid desiccation and prolonged exposure to ultraviolet radiation (Downing 1994; Gaugler and Boush, 1978). *Steinernema riobrave* IJ that remain near the soil surface following application persist less well than IJ that move more deeply into the soil, either actively or passively in irrigation water (Duncan and McCoy, 1996). However, following application of IJs, normal drying of the surface soil between irrigation cycles may not be detrimental to the survival of these nematodes. Indeed, these experiments suggest that if crop plants have roots in humid deep soil horizons, the roots in the dry shallow soils may provide a mechanism to prolong persistence and efficacy of entomopathogenic nematodes in the soil.

The data from this and a previous study (Duncan and El Morshedy, 1996) indicate that the behaviors of subterranean herbivores and nematode parasites of plants and insects are fundamentally different in dry soil containing plant roots, depending on whether the complete root system is contained only within dry soil or is apportioned between dry and humid soil. The latter conditions occur commonly in nature where surface soils tend to dry more rapidly due to transpiration and evaporation than do deeper layers of the soil profile. Our findings confirm that the role of plant root systems and hydraulic lift are important factors to consider when studying the fate of rhizosphere organisms in dry soils.

LITERATURE CITED

Caldwell, M. M., T. E. Dawson, and J. H. Richards. 1998. Hydraulic lift: Consequences of water efflux from the roots of plants. Oecologia 113:151–161.

Downing, A. S. 1994. Effect of irrigation and spray volume on efficacy of entomopathogenic nematodes (Rhabditida: Heterorhabditidae) against white grubs (Coleoptera: Scarabaeidae). Journal of Economic Entomology 87:643–646.

Duncan L. W., D. C. Dunn, and C. W. McCoy. 1996a. Spatial patterns of entomopathogenic nematodes in microcosms: Implications for laboratory experiments. Journal of Nematology 28:252–258.

Duncan L. W., and M. M. El Morshedy. 1996. Population changes of *Tylenchulus semipenetrans* under localized vs. uniform drought in the citrus root zone. Journal of Nematology 28:360–368.

Duncan L. W., and C. W. McCoy. 1996. Vertical distribution in soil, persistence, and efficacy against citrus root weevil (Coleoptera: Curculionidae) of two species of entomogenous nematodes (Rhabditida: Steinernematidae; Heterorhabditidae). Environmental Entomology 25:174–178.

Duncan L. W., C. W. McCoy, and A. C. Terranova. 1996b. Estimating sample size and persistence of entomogenous nematodes in sandy soils and their efficacy against the larvae of *Diaprepes abbreviatus* in Florida. Journal of Nematology 28:56–67.

Gaugler R., and G. M. Boush. 1978. Effects of ultraviolet radiation and sunlight on the entomogenous nematode *Neoaplectana carpocapsae*. Journal of Invertebrate Pathology 32:291–296.

Gouge D. H., K. A. Smith, L. L. Lee, and T. J. Henneberry. 2000. Effect of soil depth and moisture on the vertical distribution of *Steinernema riobrave* (Nematoda: Steinernematidae). Journal of Nematology 32:223–228.

Jenkins, W. R. 1964. A rapid centrifugal-floatation technique for separating nematodes from soil. Plant Disease Reporter 48:692.

Koppenhofer A. M., M. E. Baur, S. P. Stock, H. Y. Choo, B. Chinnasri, and H. K. Kaya. 1997. Survival of entomopathogenic nematodes within host cadavers in dry soil. Applied soil ecology: A section of Agriculture, Ecosystems and Environment 6:231–240.

Kung S. P., R. Gaugler, and H. K. Kaya. 1991. Effects of soil temperature, moisture, and relative humidity on entomopathogenic nematode persistence. Journal of Invertebrate Pathology 57:242–249.

McCoy, C. W., D. I. Shapiro, L. W. Duncan, and K. Nguyen. 2000. Entomopathogenic nematodes and other natural enemies as mortality factors for larvae of *Diaprepes abbreviatus*. Biological Control 19:182–190.

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