Effects of cyst-nematodes on the water relations of two potato varieties*[1/]

A E KLAR**, J FRANCO***

RESUMO

Duas variedades de batata, 'Maris Piper' e 'Pentland Dell', (10 semanas de idade) foram estudadas em pequenos vasos, com o solo infestado com três níveis de nematóide, Globodera rostochiensis *(0, 160 e 800 ovos/g solo) sob condições de solo úmido e seco.*

A variedade resistente 'Maris Piper', em todos os casos, teve maior área foliar, mais altas resistências difusivas das folhas e menores taxas de transpiração ao longo do intervalo dos potenciais de água das folhas estudado e, portanto, maior resistência à seca que a variedade susceptível 'Pentland Dell'.

Ambas as variedades comportaram-se semelhantemente sob condições de solo úmido, porém, em condições de baixos potenciais de água do solo, os potenciais de água das folhas foram significativamente mais baixos para a variedade 'Pentland Dell' sob os três níveis de nematóides.

Introduction

THE damaging effects of plant nematodes is more than just an act of parasitism; rather, it is a deleterious change in the biochemical and physiological processes required for normal cellular function, differentiation and reproduction. Trudgill (11) found that potato cyst-nematodes affect root growth, since it was virtually stopped when nematode attack was severe. The functioning of plants with infested roots has been studied by many workers who have examined water absorption and nutrient uptake, but their conclusions are often contradictory. O'Bannon and Reynolds (8) concluded that the water consumption of *Meloidogyne incognita* infested cotton plants was as great as or greater than that of non-infested plants when water was not limiting, but under water deficits, infested roots are not able to transport sufficient water to maintain normal growth of cotton plants. Meinl and Stelter (7) found that the water requirement of potato plants infested with potato cyst-nematodes was greater than that of non-infested plants to produce the same amount of dry matter. Webber *et al.* (12) reported that under water stress, transpiration rates from *M. incognita* infested tomato plants were greater than from non-infested plants and were disproportionally higher in relation to the amount of leaf tissue. Odihirin (9) found that the same nematode greatly increased the rate of transpiration of infested tobacco plants, but that eventually the plants wilted even when abundant water was available. Evans *et al* (2), under field conditions and with potato plants subjected to intermitent water supply in the form of natural rainfall, determined that plants highly infested with potato cyst-nematodes had greater stomatal resistances and lower water potentials than lightly infested plants.

In this paper we examined the water relations of two varieties, known to differ in response to infection by the nematode *Globodera rostochiensis,* under controlled conditions, where water flux through the plant and stomatal resistance approach a steady state.

Materials and methods

Two varietes of potatoes were used, 'Maris Piper' (MP), resistant to *G. rostochiensis* (Pathotype Ro_1) and 'Pentland Dell' (PD), a susceptible variety. Tuber pieces were planted in 9 cm pots filled with 350 g of sterilized sandy-loam soil, containing a standard commercial fertilizer. Before planting, cysts were added to some of the pots to give nematode densities of 0, 160 and 800 eggs of *G. rostochiensis* per gram of soil.

The plants were grown for ten weeks after planting in a glasshouse. Then, they were removed to a

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** Professor of Irrigation and Drainage - F.C.A. - UNESP - Botucatu SP - Brazil.

*** Nematologist - International Potato Center - Lima - Perú

growth-room subjected to the following conditions: 20°C (day) and 15°C (night), 16 hours photoperiod, 1000 μ E m $^{-2}$ s $^{-1}$ (400-700 mm - LI - 170 Lambda Instruments sensor) light intensity measured at the top of the plants, and a water vapour content of 9.30 g m^{-3} (day) and 6.94 g m^{-3} (night). The temperature and water vapour content of the air were monitored continuously with an aspirated wet and dry bulb psychrometer. Two soil moisture conditions were considered: wet, soil water potential near zero, and dry, by withhholding water supply for two days. All treatments were replicated three times.

After reaching steady state conditions, the evaporative flux density E (g m^{-2} s^{-1}) was estimated over a period of 4 hours by measuring the change in weight of the pots and plants, and leaf area (measured with photoelectric area meter). It was assumed that evaporation from soil surface was negligible because, it was covered by polyethylene granules.

The temperature difference between leaf canopy and ambient air was measured with four pairs of 40 s.w.g. constantan-chromel P differential thermocouples in parallel; one junction of each pair was in air and the other inserted into a leaf lamina at different parts of the canopy. Canopy diffusive resistance was calculated from:

$$E = \frac{\triangle X}{r_a + r_c}, \text{ where}$$

$\triangle X$ (g cm^{-3}) is the difference in water vapour content between the ambient air (^{X}a) and air at the evaporating surfaces within the leaves (^{X}c), which was assumed to be the saturation vapour pressure at the temperature of the canopy; ^{r}a and ^{r}c (s cm^{-1}) are the resistances to the diffusion of water vapour offered by the canopy boundary layer, and the stomata plus intercellular spaces of leaves within the canopy, respectively. The air close to the plants was stirred vigorously, terefore, ^{r}a was neglected (6). Leaf water potential (ψ) was measured on four leaves per plant with pressure bomb (10). The same leaves were used to evaluate relative water content (RWC) (1), and osmotic potential (π), which was determined after freezing and thawing leaf discs in a psychrometer (sample chamber Wescor, model C-52).

Results and discussion

The relationships between leaf water potential and relative water content and leaf osmotic potential and RWC had similar tendency for both varieties, except that ψ and π decreased slightly more on MP per unit decrease in RWC (Fig. 1). In any case, a larger decrease of ψ per unit decrease of RWC confers better drought resistance (5). Also turgor pressure (P) was about 13 per cent larger in MP than in PD throughout the range of RWC studied. This allowed MP to grow better than PD. According to Hsiao (3) turgor pressure is the main responsible for cell elongation, and PD have had only 45 per cent of MP leaf area.

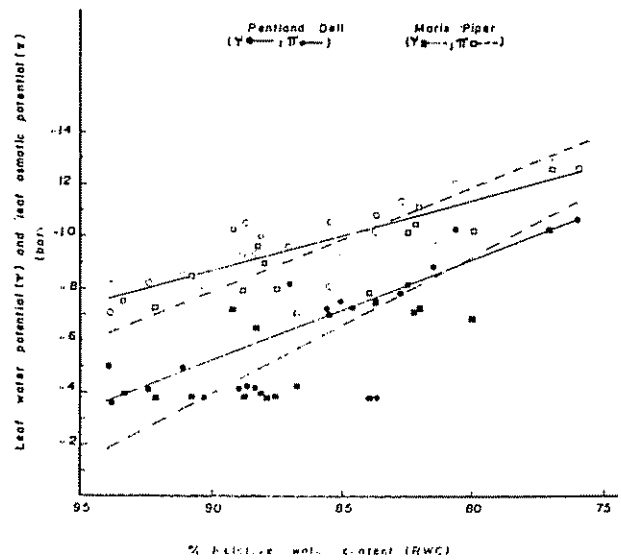

Fig. 1.—*Relations between relative water content (RWC) and leaf water potential (ψ) and leaf osmotic potential (π) of resistant (ψ = 51.57 — 0.53 RWC; r = 0.76°°; π = 44.76 — 0.41 RWC; r = 0.60°°) and susceptible (ψ = 40.34 - 0.39 RWC; r = 0.73°°; π = 33.00 - 0.27 RWC; r = 0.85°°) potato varieties.*

The canopy diffusive conductance (Kc) of both varieties decreased when leaf water potential decreased (Fig. 2), but Kc was always greater in PD than MP under same ψ, throughout the range of values studied, again suggesting better drought resistance for MP.

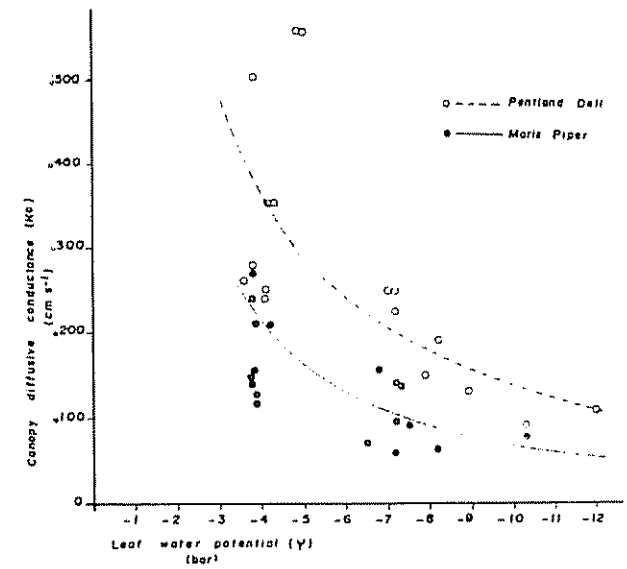

Fig. 2.—*Relations between leaf water potential (ψ) and canopy diffusive conductance (Kc) of Maris Piper-resistant (Kc = 1.24 - 1.28 ψ; r = 0.56°) and Pentland Dell-susceptible (Kc = 1.50 - 1.02 ψ; r = 0.77°°) potato varieties.*

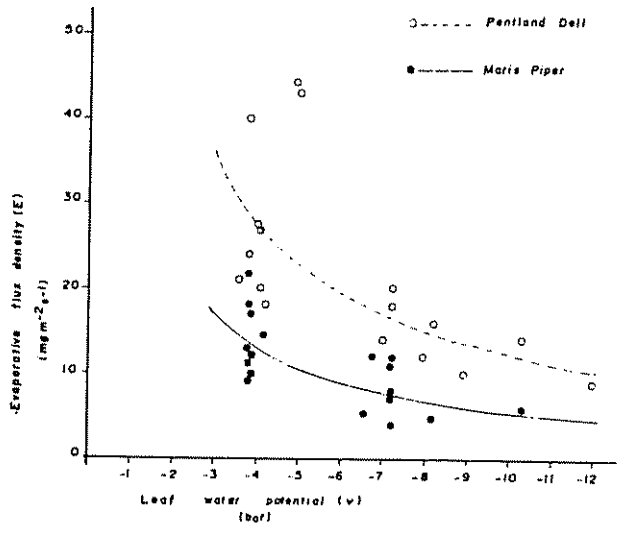

Fig. 3 —*Relations between leaf water potential (ψ) and evaporative flux density (E) of Pentland Dell - susceptible ($E = 96.36 - 0.90\ \psi$; $r = 0.74^{**}$) and Maris Piper-resistant ($E = 49.79 - 0.96\ \psi$; $r = 0.70^{**}$) potato varieties*

In Fig. 3, it is indicated that MP had lower transpiration rate than PD throughout the range of ψ tested, mainly under high leaf water potentials.

The combination of slightly greater values of turgor pressure and large leaf diffusive resistance for MP compared to PD indicates that MP has a greater ability to minimise water loss and maintain growth.

When infested by nematodes, both varieties had similar leaf water potentials in wet soil, but in dry conditions, leaf water potentials of PD were significantly lower, under the three nematode treatments (Fig. 4a). This behavior becomes more important if we consider that soil moisture content averages under dry conditions were 6.04; 9.80 and 11.80 per cent for MP, respectivelly for the treatments 0, 160 and 800 eggs/g to soil, and 6.70, 13.87 and 14.33 per cent, for PD following the same order. Therefore, there was larger exploitation of water by MP and for non-infested plants, which had greater capability to exploit soil mass to extract water and nutrients. On the other hand, MP presented larger leaf area, but the susceptible variety 'Pentland Dell' showed larger evaporative flux density than 'Maris Piper', mainly under wet conditions. These results are different than those of Evans *et al.* (2), but we have to consider the different growing conditions; measurements were taken just at one age and small pots with restricted soil volume, whereas Evans *et al* made field observations. In small pots, plants without nematodes (with larger root systems and tops) use water more quickly than those with nematodes (Fig. 4 b). As the plants were left for two days without watering, the plants in pots without nematodes used more water and developed greater water stress, than those with nematodes, a situation which

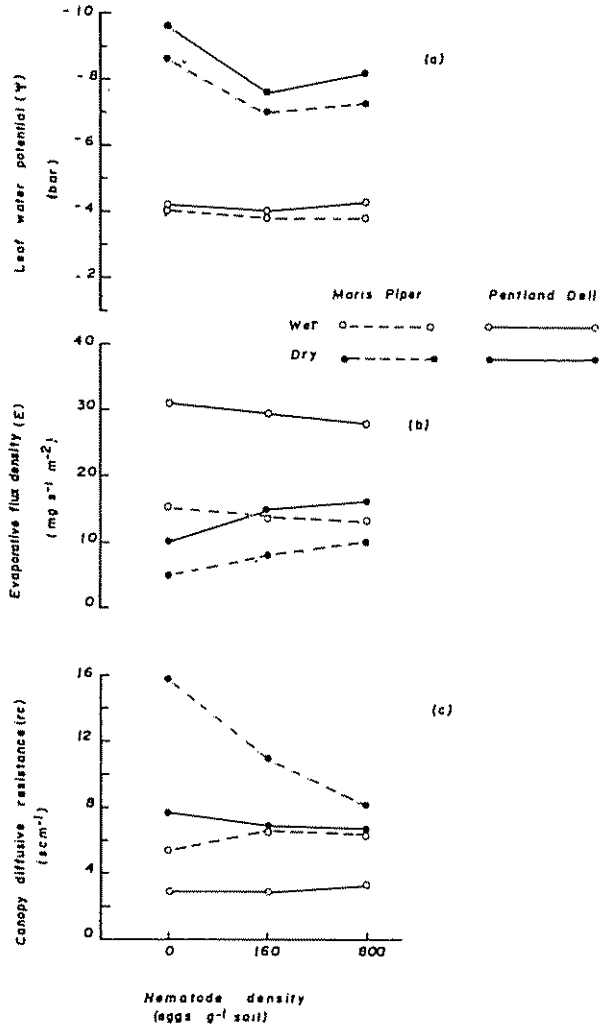

Fig. 4 —*Effects of different nematode densities on (a) leaf water potential (b) evaporative flux density, and (c) stomatal resistance of resistant and susceptible potato varieties under wet and dry soil moisture conditions*

would not occur under field conditions, where water in deeper soil layers could be easily available and used by plants with well developed root systems.

There were significant correlations between canopy diffusive resistance (r_c) and leaf diffusive resistance (r_e), measured through porometer (4) with the following regression equations:

$$r_c = 2.47 + 0{,}29\ r_e \text{ (MP)}$$

$$r_c = 1.45 + 0{,}17\ r_e \text{ (PD)}$$

r_c of both varieties in the wet conditions followed a similar pattern, but in the dry conditions the plants without nematodes chiefly MP had greater resistances (Fig. 4 c) than those with nematodes. This also differs from the results of Evans *et al.* (2) but agrees with those of Odihirin (9): a nematode infested plant may transpire as much as a healthy plant depending on

the stage of infection, plant age and soil water content. Initial infection by nematodes may promote a mechanism of defence, so obliging infested plants to use more water to maintain their metabolic equilibrium. Stelter and Meinl (13) reported that consumption of water for production of one gram of dry matter was much greater in plants grown in nematode infested soil. This means that the efficiency of water use is lower in susceptible nematode infested plants than in healthy or resistant plants.

Summary

Studies have been made under controlled conditions of two potato varieties 'Maris Piper' and 'Pentland Dell' (ten weeks old) in small pots with soil infested with three levels of potato cyst-nematode, *Globodera rostochiensis* (0, 160 and 800 eggs/g soil) under wet and dry soil moisture conditions.

Maris Piper, a resistant variety, showed greater leaf area, larger canopy diffusive resistance and transpiration rate at the same leaf water potential along the range of leaf water potentials studied, and therefore, higher drought resistance than Pentland Dell, a susceptible variety.

Both varieties behaved similary in wet soil when infested by nematodes, but leaf water potentials of Pentland Dell were significantly lower for the investigated three nematode levels under low soil water potentials.

Resumen

Dos variedades de papa, 'Maris Piper' y 'Pentland Dell', de 10 semanas de edad, fueron estudiadas en pequeños vasos, con un suelo infestado con tres niveles del nematodo dorado de la papa, *Globodera rostochiensis,* (0, 160 y 800 huevos/g suelo) en condiciones de suelo húmedo y seco.

La variedad resistente 'Maris Piper', en todos los casos, presentó una superficie foliar más grande, más altas resistencias difusivas de las hojas y menores tasas de transpiración a lo largo del intervalo de los potenciales de agua estudiado en las hojas y, por tanto, resistencia más alta a la sequía que la variedad susceptible 'Pentland Dell'.

Ambas variedades se comportaron similarmente en condiciones de suelo húmedo, pero en condiciones de bajos potenciales de agua del suelo, los potenciales de agua de las hojas fueron significativamente más bajos para la variedad 'Pentland Dell' en los tres niveles de nematodos.

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