Effects of *Globodera rostochiensis* and water stress on shoot and root growth and nutrient uptake of potatoes

Farrokh FATEMY and Ken EVANS

Nematology Department, Rothamsted Experimental Station, Harpenden, Herts, AL5 2JQ, England.

SUMMARY

Potato plants were grown in pots and were either well-watered or water-stressed; half of the plants receiving each of these two treatments were infected with *Globodera rostochiensis*. The effects of nematode infection were similar to those of water stress in that nematode infected and water stressed plants both had smaller shoot/root ratios when compared with uninfected and well watered plants. Nematode infection and water stress resulted in decreased tuber production, especially in combination; total P, K and Mg uptakes were also decreased. Nematode infection and water stress differed in that Ca uptake was increased in nematode infected plants but was less in water stressed plants than well watered plants.

RÉSUMÉ

Effets de Globodera rostochiensis *et du déficit hydrique sur la croissance aérienne et souterraine et sur l'alimentation minérale de la pomme de terre*

Des plants de pomme de terre cultivés en pots ont été soit abondamment, soit insuffisamment arrosés. La moitié des plants de chaque lot ont été inoculés avec *Globodera rostochiensis.* Les effets de l'inoculation par les nématodes se sont révélés similaires à ceux du manque d'eau : les plants inoculés et les plants manquant d'eau ont un rapport tige/racine plus petit que les plants non infectés et bien arrosés. L'inoculation par les nématodes et le manque d'eau aboutissent à une moindre production de tubercules, spécialement quand ces deux facteurs sont combinés; le prélèvement total de P, K et Mg est également diminué. L'inoculation par les nématodes et le manque d'eau ont un effet différent sur le prélèvement de Ca qui augmente avec l'inoculation, mais diminue quand l'arrosage est déficient.

Fatemy *et al.* (1985) compared the effects of potato cyst nematodes with those of water stress on abscisic acid (ABA) level and stomatal function of two potato cultivars. Both treatments increased stomatal resistances and decreased transpiration of both cultivars. Cara, which is both resistant to and tolerant of *Globodera rostochiensis* (Wollenweber, 1923) Behrens, 1975, contained up to nine times the concentration of ABA in its leaves as the non-resistant and intolerant Pentland Dell. Proportional changes in ABA concentration, however, were greater in the latter cultivar after both nematode infection and water stress, even though water stress treatment was applied for only five days to 43 day old plants. This appears to support the suggestion that the damage to plant growth caused by nematodes is a result of water stress (Evans, Parkinson & Trudgill, 1975; O'Brien & Fisher, 1981) and nutrient deficiency (Gair, 1965) caused by root damage.

One effect of increased ABA levels in plants is to increase root growth relative to shoot growth (Watts *et al.,* 1981), a common plant response to water stress (Hsiao, 1973). The experiment reported in this paper compared the effects of nematode infection and water stress on shoot and root growth and nutrient uptake at different plant ages.

Materials and methods

Plastic pots (12.5 cm diam.) were filled with 1 kg of sterilised sandy loam. To half of them were added sufficient cysts of *G. rostochiensis* Ro 1 to give 100 eggs/g soil; tuber pieces of the non-resistant potato cultivar Désirée were planted in each. Seven grammes of slow-release fertiliser (18 % N, 11 % P_2O_5, 10 % K_2O) were added and 100 g of polyethylene granules were spread over the soil surface to minimise evaporation. Plants were given either plenty of water (211 g per pot, which approximated to field capacity) or a restricted amount (135 g per pot). Pots were watered to a constant weight which was increased at regular intervals by an amount corresponding to the weight of the plant.

Watering was done every two days initially and every day later on. Three plants of each treatment combination were harvested at weekly intervals for nine weeks, starting fifteen days after planting, with the exception that six plants of each combination were harvested on the last occasion, 75 days after planting. Fresh weights of tops and roots were recorded and plant material was then oven dried at 80° for 48 hr, and nutrient contents measured by standard procedures.

Results

Shoot dry weight

Under both water regimes, infected plants produced similar amounts of shoot to uninfected plants (Fig. 1) but water stress decreased shoot weights significantly throughout the experiment after the first harvest.

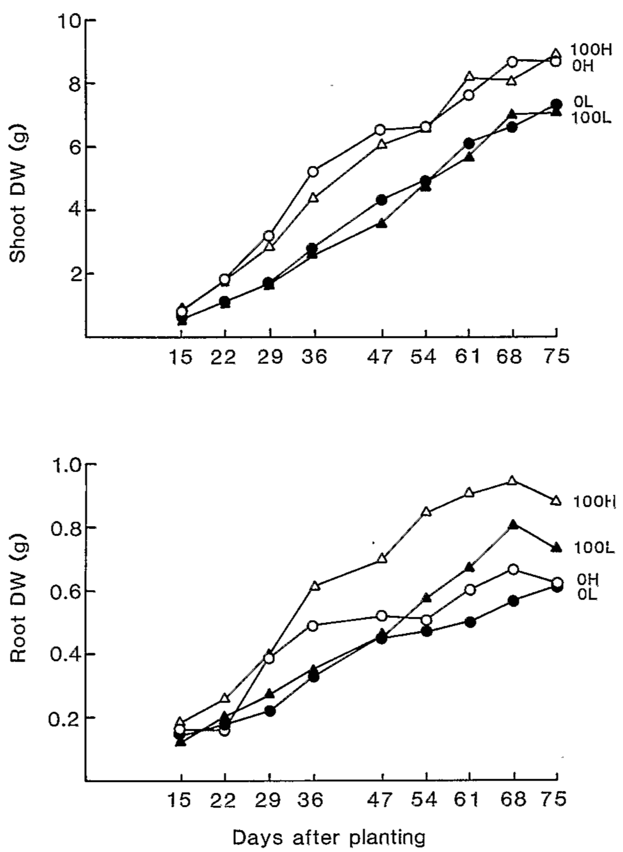

Fig. 1. Shoot and root dry weights (g) of Désirée potato plants growing at 0 or 100 eggs/g soil of *G. rostochiensis*, under either high (H) or low (L) water regimes.

Root dry weight

Uninfected plants produced similar amounts of roots during the growing period under the two water regimes (Fig. 1) except at days 29 and 36, when water stressed plants had significantly ($P < 0.05$) smaller roots. Infected plants produced the largest root systems of all when water was freely available but, under conditions of limited water, they had root weights similar to uninfected plants up to day 47 and increasingly larger roots from then on.

Shoot/root ratio

Initially (days 15 and 22) water stressed plants had significantly smaller shoot/root ratios than well watered plants, whether infected or not (Fig. 2) but from day 29

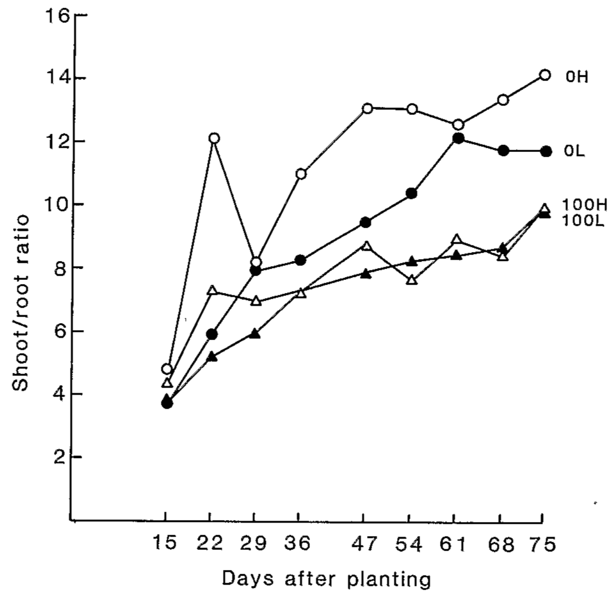

Fig. 2. Shoot/root ratios of Désirée potato plants growing at 0 or 100 eggs/g soil of *G. rostochiensis*, under high (H) or low (L) water regimes.

infected plants from the two watering regimes had the smallest ratios and watering regime did not affect their ratios significantly on any harvest date. Of the uninfected plants, those grown under the high water regime produced consistently larger ratios.

Tuber production

Water stress or nematode infection alone did not delay tuber initiation but decreased tuber growth rate and final tuber weight (more so for uninfected water stressed than for infected non-water-stressed plants, Fig. 3). Water stress in combination with nematode infection

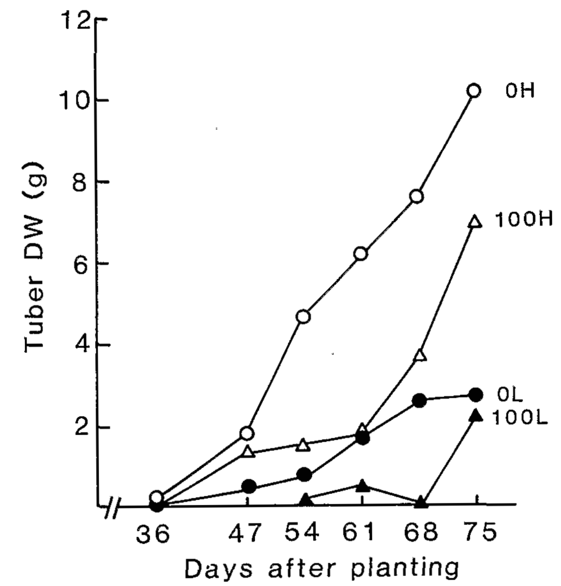

Fig. 3. Tuber dry weights (g) of Désirée potato plants growing at 0 or 100 eggs/g soil *G. rostochiensis*, under high (H) or low (L) water regimes.

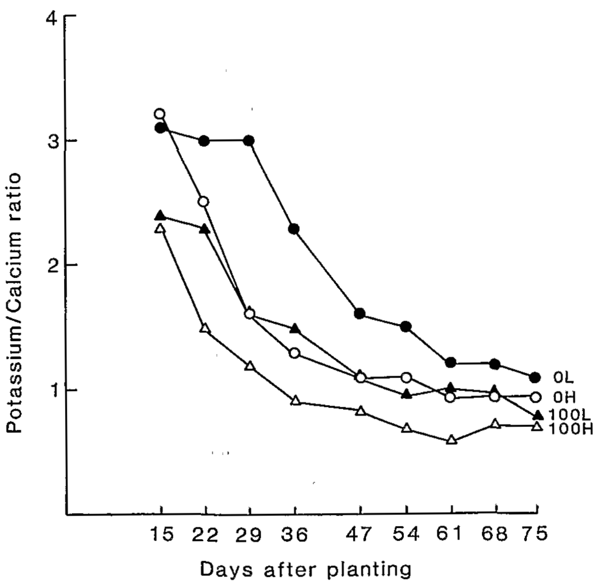

Fig. 4. Potassium/Calcium ratio in the dry matter of Désirée potato plants growing at 0 or 100 eggs/g soil of *G. rostochiensis*, under high (H) or low (L) water regimes.

delayed tuber initiation for nearly 18 days and these plants produced least tubers of all.

Potassium/Calcium ratio

Fatemy and Evans (1986) reported that the K/Ca ratio, by combining estimates of the status of these two minerals in the plants, indicates the degree of nematode damage. These two elements are to some extent antagonistic : a decrease in one may cause an increase in the uptake of the other. The K/Ca ratios in plant dry matter declined with time for all plants and were smaller in plants under the high water regime ($P < 0.05$) (Fig. 4). Nematode infected plants also had smaller ratios than uninfected plants and, as the experiment progressed, the ratio declined, more for well watered than for water stressed infected plants.

Phosphorus, Magnesium, Sodium

Total uptake of P, Mg and Na was decreased in water stressed and nematode infected plants, although the Na content of well watered infected plants was greater than that of well watered nematode free plants (see Tab. 1 for mineral contents of 75 day old plants).

Table 1

Total P, Mg and Na content (mg) 75 days after planting of Désirée potato plants grown in soil with 0 or 100 eggs/g of *Globodera rostochiensis* under high or low (H or L) water regimes.

	Eggs/g soil	*H*	*L*	*LSD (5 %)*
P	0	60.0	46.7	2.9
	100	54.5	37.6	
Mg	0	73.2	47.5	4.3
	100	59.6	42.6	
Na	0	13.4	9.2	1.4
	100	14.4	9.2	

Discussion

These results show some similarities between the effects of nematode infection and water stress on potato plants. The response to both water stress and nematode infection varied with time, but this might be explained by differences in the severity of stress imposed by the two treatments. Nevertheless, uptake of essential nutrients was decreased by both.

Decreasing the water supply reduced the dry weight of shoots more than that of the roots but nematode infected plants actually produced larger roots (Fig. 1). However, the efficiency of these roots, as measured by the shoot/root ratio, was decreased (Fig. 2). A common effect of water stress is to increase the ratio of roots to shoots. This increase may result from a greater stress-stimulated reduction in the growth of shoots relatives to roots, or from a stress-stimulated increase in the growth of roots (Sharp & Davies, 1979). Both situations occurred in this experiment. Water stressed plants and nematode infected plants had smaller shoot/root ratios than uninfected well watered plants, and infected plants under the low water regime had the smallest shoot/root ratios of all. In the experiments of Trudgill and Cotes (1983) and Evans (1982) infection by nematodes decreased plant size and shoot/root ratio of all cultivars. However, the ultimate effect was less in tolerant cultivars because they had larger root systems when grown in heavily infested soil, probably to compensate for that part of the root system which had been damaged. A greater proportion of photosynthate would be diverted to root development in infected plants because, presumably, the root systems of infected plants are less efficient than those of uninfected plants and so can only meet the demands of the shoots when they are relatively larger. This change in root system size also affected tuber production, as all plants produced less tubers than control plants, with nematode infected plants producing least of all when water stressed.

Holliday (1970) has shown that at least part of the sensitivity of the potato crop to small reductions in soil water status could be due to the indirect effect of soil water stress on nutrient availability. Total nutrient uptake may have been decreased in water stressed plants in this experiment because nutrients were less available from the dry soil. Nematode infection also decreased total P, K and Mg content with the effect being more severe when the plants were also water stressed. Infected plants had smaller K/Ca ratios than uninfected plants because infected plants took up less K and more Ca than uninfected plants; increased Ca uptake by plants infected with cyst nematodes has been reported by Price and Sanderson (1984) and Fatemy and Evans (1986) and may be due to endodermis damage by the nematodes. On the other hand, water-stressed plants had greater K/Ca ratios than well-watered plants, presumably because well-watered plants were able to take up and transpire water very freely and therefore took up and accumulated much Ca.

Plants were severely stunted when soil water content was low but the effect of nematode infection on plant growth was much less. The severity of the water stress was probably much greater than that imposed by invading juvenile nematodes. However, the effects of nematode invasion are due not only to the mechanical damage of juvenile penetration but also to induction of syncytia (which act as powerful sinks for solutes and minerals) and reduced root efficiency. Together, these may cause plant responses some of which are similar to responses to water stress and some of which are not, such as the increase in Ca or Na content.

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