TRAP CROPS AS A COMPONENT FOR THE INTEGRATED MANAGEMENT OF *GLOBODERA* SPP. (POTATO CYST NEMATODES) IN BOLIVIA

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ABSTRACT

Franco, J., G. Main, and R. Oros. 1999. Trap Crops as a component for the integrated management of *Globodera* spp. (potato cyst nematodes) in Bolivia. Nematropica 29:51-60.

Globodera spp. is one of the most important nematodes of potato in Bolivia. The development of a management strategy with non-host crops has been considered, but this option is limited by several factors. The objective of this study was to identify lines of common crops in Bolivia with activity on egg hatch of *Globodera* spp. that could reduce the effective length of the crop rotation cycle in potato fields. We evaluated effects on egg hatch of *Globodera* spp. of 127 lines of *Lupinus mutabilis,* 303 lines of oca (*Oxalis tuberosa*), 27 lines of isaño (*Tropaeolum tuberosum*), 85 ollucus (*Ullucus tuberosus*), 5 quinuas (*Chenopodium quinua*), and 13 barleys (*Hordeum vulgare*), in relation to three controls (potato var. Waych'a, barley IBTA-80 and fallow) under greenhouse conditions. A number of lines exhibited egg hatching activity similar to potato (trap lines), or a permanent hatching inhibitory effect (antagonistic lines). The incorporation of these selected lines of Andean crops in rotation schemes by farmers may play an important role in the integrated management of potato cyst nematodes since these crops are quite common in traditional Andean cropping systems in Bolivia.

Key words: Bolivia, *Chenopodium quinoa, Globodera* spp., *Hordeum vulgare, Lupinus mutabilis, Oxalis tuberosa,* potato cyst nematode, trap crops, *Tropaeolum tuberosum, Ullucus tuberosus.*

RESUMEN

Franco, J., G. Main y R. Oros. 1999. Cultivos Trampa como un componente para el manejo integrado de *Globodera* spp. en Bolivia. Nematrópica 29:51-60.

Globodera spp. es uno de los nematodos más importantes del cultivo de la papa en Bolivia. El desarrollo de una estrategia de manejo, considera la rotación con plantas no hospedantes, pero esta opción esta limitada por diversos factores. El objetivo de este estudio fue el de identificar líneas de cultivos tradicionales en Bolivia con actividad sobre la eclosión de huevos de *Globodera* spp. que podrían reducir los ciclos de rotación entre los cultivos de papa. Luego de evaluar 127 líneas de *Lupinus mutabilis,* 303 líneas de oca (*Oxalis tuberosa*), 27 de isaño (*Tropaeolum tuberosum*), 85 de ollucu (*Ullucus tuberosus*), 5 quinuas (*Chenopodium quinua*), 13 cebadas (*Hordeum vulgare*), en relación a tres testigos (papa cv. Waych'a, cebada IBTA-80 y descanso), bajo condiciones de invernadero, algunas de ellas mostraron un efecto estimulador de la eclosión de juveniles en forma similar al de la papa ("plantas trampa") y otras un efecto inhibitorio (plantas antagónicas en lupinos). El empleo de estas lineas seleccionadas de cultivos andinos en un sistema de rotación en campos de agricultores podría jugar un rol importante en el manejo integrado de *Globodera* spp., ya que estos cultivos son comunes en los sistemas tradicionales de cultivo de la región andina de Bolivia.

Palabras claves: Bolivia, *Chenopodium quinoa,* cultivos trampa, *Globodera* spp., *Hordeum vulgare,* nematodo quiste de la papa, *Lupinus mutabilis, Oxalis tuberosa, Tropaeolum tuberosum, Ullucus tuberosus.*

INTRODUCTION

Globodera rostochiensis (Wollenweber, 1923) Behrens, 1975 and *G. pallida* (Stone, 1973) Behrens, 1975 are two of the most important plant-parasitic nematodes in Bolivia and other countries in the Andean region. These potato cyst nematodes (PCN) are widely distributed in most cultivated areas in Bolivia, causing severe direct yield losses (Franco, 1994) and indirect losses due to the rejection of seed potatoes from nematode-infested fields (Dirección Nacional de Semillas, 1996).

Eradication of PCN is almost impossible and no effective management strategies are being utilized or developed to reduce nematode population densities. Thus, soil productivity (sustainability) will increasingly deteriorate. An effective management strategy for PCN in Bolivia is complex due to mixed field populations consisting of both species and different pathotypes (Franco *et al.*, 1998). It is likely that an effective management strategy will require the rational use of several components in order to preserve the environment and to maintain plant productivity.

Among the tactics to manage PCN, crop rotation plays a very important role in traditional Andean agricultural systems (Herve, 1994). However, the development of rotation systems with antagonistic and non-host crops for nematode control depends not only on yield responses, but on economic, ecological, and other constraints in individual situations. Although it is widely known that crop rotations can aid in nematode management, many producers do not view currently available rotation plans as economically feasible (Rodriguez *et al.*, 1992). Therefore, more crops and cultivars should be evaluated against important nematode pests, in order to increase the number of useful rotation crops. Such crops can either be non-hosts or antagonistic to nematodes. For example, studies in Bolivia have shown that there are lines and varieties within non host crops to *Nacobbus aberrans* which can be utilized as trap crops; nematodes hatch and/or root invasion occurs, but nematode multiplication does not (Céspedez, 1994; Franco *et al.*, 1997).

Although potato (*Solanum tuberosum* L.) is the only major world-wide tuber with origins in the Andean region, other indigenus tuber crops (*Oxalis tuberosa, Ullucus tuberosus,* and *Tropaeolum tuberosum*), legumes (*Lupinus mutabilis*) and grains (*Chenopodium quinoa*) have been cultivated in the region to varying degrees. Some of these crops are favored more than others, hence the intensity of domestication and the range of biodiversity generated in terms of local varieties differ widely from crop to crop. The amount of heterogeneity represented by morphological types of these crops is significant and reflected in existing germplasm collections of different Andean countries (Tapia, 1990). Although the most important tuber crop in the Andean region is the potato, *O. tuberosa, U. tuberosus,* and *T. tuberosum* are quite common in traditional farming systems and are often intercropped with potato under different agroecological conditions.

The most common pattern of rotation for potato under central Andean Peruvian conditions is two consecutive years of potato, an Andean tuber-bearing crop, cereals, and a fallow period. Previously, when human population pressure was slight, fallow periods were often as long as 20 years, but these periods have been reduced in recent decades to an average of 2-3 years and sometimes are left out altogether (Horton, 1980).

The Andean tuber crops such as *Ullucus tuberosus, Oxalis tuberosa,* and *Tropaeolum tuberosum* are grown in similar ecological niches from 3 000 to 3 900 meters above sea level. Among these crops, *U. tuberosus* is the most widely accepted and resembles the potato plant morphologically. *T. tuberosum*, although less cultivated than the others, is tolerant to frost and several pests. *O. tuberosa* is a very long-growing crop (200 days), but yields are quite high (57.5 T/ha). These crops are quite frequently planted after a potato crop to obtain advantage from residual fertilizer applied to the potato crop. Except for *U. tuberosus*, these crops are generally produced for grower consumption as a carbohydrate source, but their demand could be increased if other attributes and advantages are investigated.

Among the grains, *Chenopodium quinoa* Wild is a staple food and a major source of protein of high quality and better amino acid balance than the proteins in most of the common cereals (barley, wheat). The cultivated plants show great variability and there is an enormous range of diversity (over 2 000 ecotypes).

Finally, among traditional Andean legume crops, *Lupinus mutabilis* Sweet, locally known as "tarwi" is one of several unique food crops that have been cultivated in the Andean region for thousands of years. It is distributed along the central Andes from southern Colombia to Bolivia, where cultivation occurs at altitudes from 2 000 to 3 400 m above sea level. This crop rivals soybean in protein composition (40%) and nutritive value. Lupine is an excellent green manure crop, fixing as much as 400 kg of nitrogen per hectare for use by succeeding crops. It appears most likely that *L. mutabilis* was domesticated along the central Andes from Ecuador to Bolivia, because most of the wild species which resemble tarwi are found in this area (Tapia and Vargas, 1982). Classification of the Andean lupine is made difficult by the large variation within and between populations, as denoted by the name "mutabilis." On the basis of morphological and phenological differences, three subspecies or varieties of *L. mutabilis* have been described (Gross, 1982; Tapia, 1990) with high variability within and between them and a very large number of land races or accessions.

Survival of *Globodera* spp. in the absence of host plants occurs in the egg stage, and density of eggs in soil declines slowly over a period of years. Non-host crops that significantly affect egg survival by antagonism or by inducing egg hatch, are desirable to reduce the necessary length of the rotation cycle. The purpose of this study was to establish the effects of different lines of the non-host crops *U. tuberosus, O. tuberosa, T. tuberosum, C. quinoa, L. mutabilis* and *Hordeum vulgare* on the behavior of eggs of *Globodera* spp.

MATERIALS AND METHODS

One hundred and seven lines of *Lupinus mutabilis* from a germplasm bank (Pairumani, Bolivia) were evaluated under greenhouse conditions for their effect on the hatching of *Globodera* spp. Clay pots containing 1000 cm^3 of steam sterilized soil were planted with different *L. mutabilis* lines (3 replications/line). At planting, small muslin bags containing 80 cysts with an initial total viability of 100 eggs/cyst of *Globodera* spp. (Pi = 8 eggs/g soil) were introduced into the soil of each pot. Cysts were obtained from field soil infested with a mixed population of *G. rostochiensis* and *G. pallida.* Plants were maintained in a greenhouse in a completely randomized design. Ambient temperature during the experiment ranged from 5-28°C. Six months after planting, root systems of each plant were examined for evidence of nematode development. Cysts were recovered from the muslin bags and two evaluations were conducted. Cyst infectious viability (IV) was estimated by placing cysts in potato root exudate (PRE) for hatching activity. Residual viability (RV) was determine by crushing the same cysts to count non-hatched eggs. By adding up these values, a final cyst total viability (FCTV) was estimated. The difference between both values of total cyst viability (Initial and Final) was used to establish the effect of each lupine line on PCN hatching.

In a second experiment, lines of *Ullucus tuberosus*, *Oxalis tuberosa*, *Tropaeolum tuberosum*, *Chenopodium quinua* and barley (*Hordeum vulgare*) were also evaluated under greenhouse conditions (Table 1). Clay pots were inoculated as in the previous study with small muslin bags containing cysts from a mixed field population of *G. pallida* and *G. rostochiensis* to obtain an initial population density (Pi) of 20 eggs/g soil (200 cysts with a initial total viability of 100 eggs/cyst). Three replications were established for each line and three control treatments: potato cv. Waych'a, was included as a standard against which to measure hatching activity, barley var. IBTA-80 is a common non-host rotation crop used by growers, and fallow which is also a common practice in potato rotation schedules.

The effects of different crop lines on the mixture of *Globodera* spp. was evaluated six months after planting by examining root systems for evidence of nematode development and by maceration of cysts recovered from muslin bags to determine the number of unhatched eggs left within the cysts (RV). The difference between Pi and RV gave the estimated number of hatched juveniles as response to plant root stimuli. In all cases, efficiency of the J2 hatching as a response to plant stimuli was compared to estimated hatching obtained with potato plants (considered as 100%) and the other control plants. Those genotypes with a hatching stimulus similar (>80%) to that of potato were identified as highly efficient, those less than potato (50-79%) were moderately efficient, and those with hatching effects less than 49% were considered as poorly efficient.

RESULTS

Following the growth period for the different plants, no adult female formation of *Globodera* spp. was observed, confirming their non-host status, except in potato controls where nematode multiplication was successful (data not shown).

The *Globodera* cysts exhibited three general responses when hatching tests were performed in potato root exudate (PRE) following 6 months exposure to the 107 *L. mutabilis* entries (Fig. 1). In the first type of response, IV of cysts was high because many juveniles from the cysts readily emerged

Table 1. Non host crop species for *Globodera* spp. that were evaluated for their effect on nematode egg hatch.

Common name	Scientific name	Crop	No. lines/genotypes
Lupine	*Lupinus mutabilis* Sweet	Grain	107
Oca	*Oxalis tuberosa* Molina	Tuber	303
Papalisa	*Ullucus tuberosus* Caldas	Tuber	85
Quinoa	*Chenopodium quinoa* Wild	Grain	5
Isaño	*Tropaeolum tuberosum* Ruíz and Pavon	Tuber	27
Barley	*Hordeum vulgare* L.	Grain	13

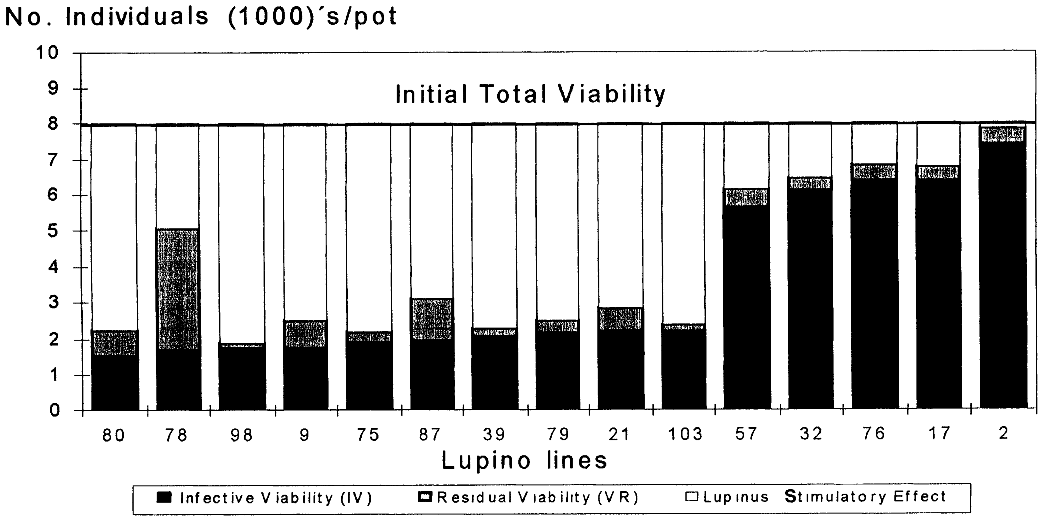

Fig. 1. Effect of 15 selected *Lupinus mutabilis* lines on hatching, infection viability (IV) and total viability (TV) of *Globodera* spp.

in PRE, indicating no previous effect on hatching by most of the *Lupinus* entries tested (i.e. lines 57, 32, 76, 17, and 2). In the second response, lupine entries exhibited a hatching stimulus because IV and RV were very low after exposure to PRE (i.e., 80, 98, 9, 75, 39, 79, 21, and 103). Finally, some lines (i.e., 78 and 87) produced a very low IV for cysts placed in PRE, but had a relatively high RV compared to the previous group. Lines exhibiting responses 2-3 are shown in Fig. 1. All of the other 97 lines exhibited the first response, shown by selected lines in Fig. 1.

Lines of *O. tuberosa, U. tuberosus, H. vulgare, C. quinoa,* and *T. tuberosum* also effected egg hatch of *Globodera* spp. Among the 303 lines of *O. tuberosa,* estimated hatching of *Globodera* spp. ranged from approximately 50-95% (Fig. 2). The least effective lines (groups 4-8) resulted in equivalent or less hatch than did bare fallow (74%); however more than 90% of the lines (groups 1-3) induced hatch rates as high or higher than did potato (85%).

Lines of *U. tuberosus* produced widely disparate effects on egg hatch of *Globodera* spp. (Fig. 3). Fifty eight percent of the lines (group 1) caused average egg hatch of 89%, while 33% and 9% of the lines (groups 2-4 and 5-8, respectively) showed a moderate hatching stimulus or inhibited egg hatch (11-33%) to a greater extent than did barley (56%).

Of the 5 lines of *Chenopodium quinoa* evaluated, all stimulated hatching in a manner very similar to the controls (Fig 4). Within the *T. tuberosum* material, the lines Bol4382, Bol4071, Bol4179 and Bol4040 exhibited a high hatching stimulus. Fifteen other lines were moderately efficient, and 8 lines exhibited poor hatching stimulation in relation to controls (Fig. 5).

None of the 13 lines of *H. vulgare* stimulated egg hatch to the same degree as potato (Fig. 6). However, lines such as 9-15-92 and the variety Zapata caused nearly 40% greater hatch of *Globodera* spp. eggs than did the least effective lines of barley or the one line of *Triticum sativum.*

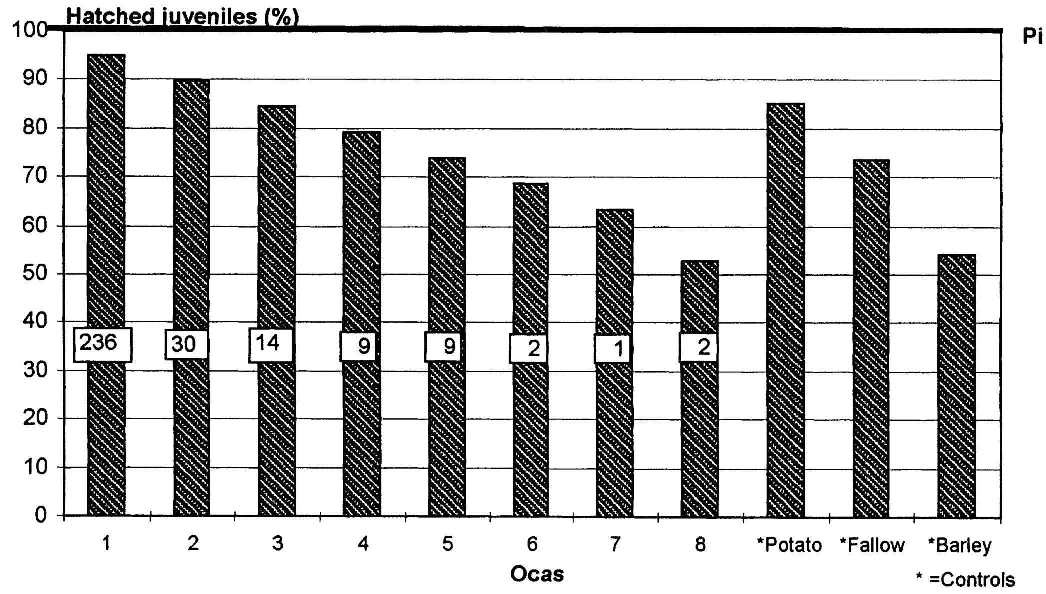

Fig. 2. Percentage of hatched J2 of *G. pallida* in 305 lines of *Oxalis tuberosa* (Oca) in relation to three control treatments. Numbers of lines comprising each response group are shown on bars.

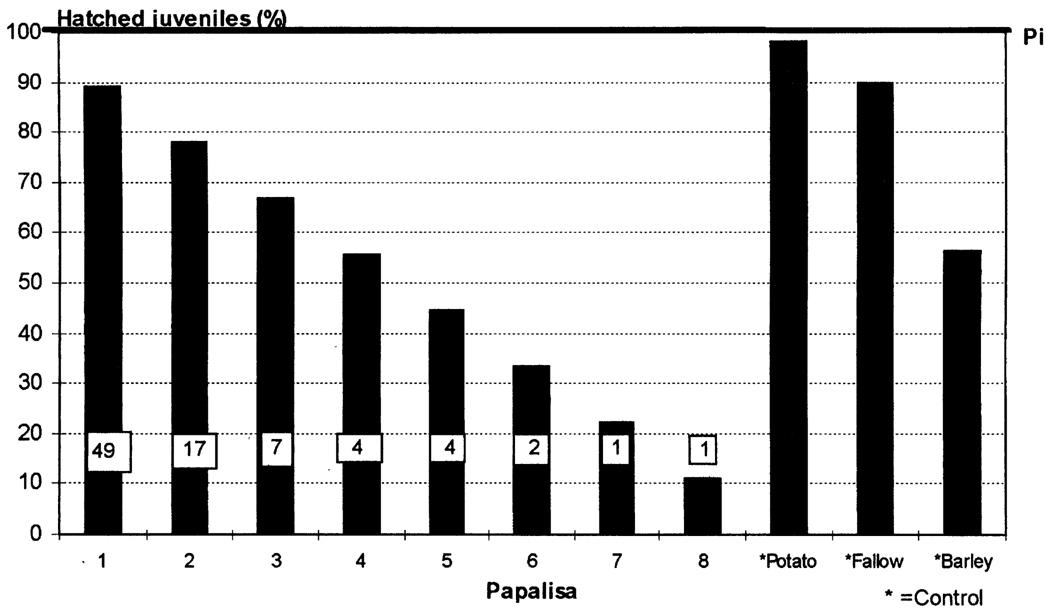

Fig. 3. Percentage of hatched juveniles of *Globodera* spp. in 85 lines of *Ullucus tuberosa* (papalisa) in relation to three control treatments. Numbers of lines comprising each response group are shown on bars.

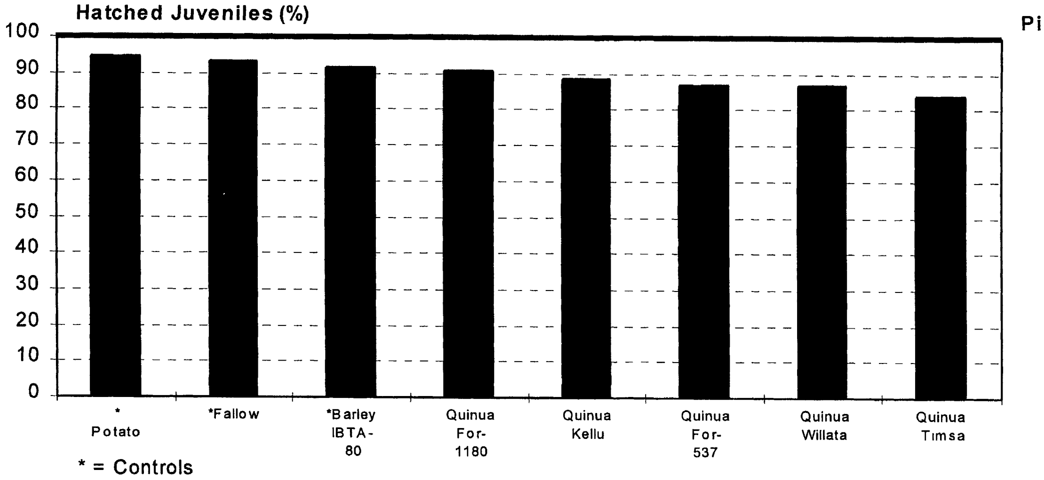

Fig. 4. Percentage of hatched juveniles of *Globodera* spp. in five lines of *Chenopodium quinoa* (Quinoa) in relation to three control treatments.

DISCUSSION

Traditionally, crop rotation has been based on the use of different crops (i.e., cereals, legumes, corn, roots and tubers, etc.) defined as non-hosts to PCN. No nematode reproduction occurs on those crops, and there is a natural decline of the nematode population density in the soil, quite similar to the one in fields under fallow (Franco *et al.*, 1998). However, the results of this study show that crop host status should not be the only relationship of interest between PCN and different crops, because some genotypes within these non-host crops also produced effects similar to those of trap crops and antagonistic crops.

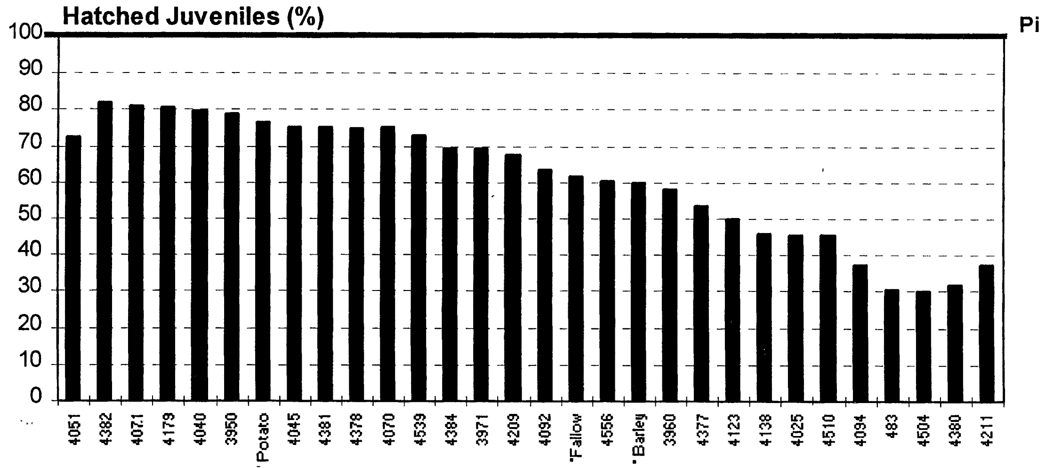

Fig. 5. Percentage of hatched juveniles of *Globodera* spp. in 27 lines of *Tropaeolum tuberosum* (Isaño) in relation to three control treatments.

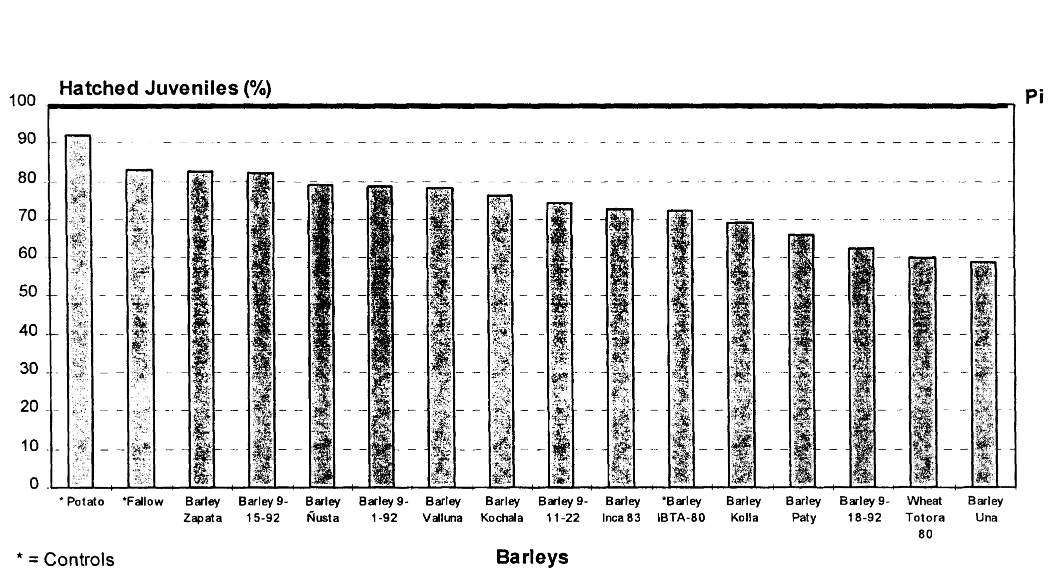

Fig. 6. Percentage of hatched juveniles of *Globodera* spp. in 13 lines of *Hordeum vulgare* and one line of *Triticum sativum*, in relation to three control treatments.

To conceptualize the various effects of intraspecific plant genotypes on the behavior of *Globodera* spp., a series of criteria are presented in Table 2. The first criterion, based on nematode development, defines the general host status of the crop to PCN, where potato and barley are examples of host and non-host crops, respectively. Within a plant species (crop), a second criteria defines the degree of nematode development in different genotypes (lines). Those genotypes in a host crop showing no female development are considered as poorly efficient or resistant, whereas moderately or highly efficient lines are considered as partially resistant or susceptible, depending on the number of new females formed. In a non-host crop where no female development occurs, some genotypes may also stimulate hatching and be invaded by J2, but nematode development to adult female will not be reached. Such lines will reduce numbers of eggs in soil more quickly than will non-host lines that do not stimulate egg hatch. Thus, depending on the intensity of hatching and invasion, the genotypes are considered as highly, moderately or poorly efficient. Those non-host genotypes listed as highly efficient are defined as true "trap crops", which differ from host plants used as "bait crops", where plants must be removed before full female development occurs.

The results obtained in this study with different genotypes of several Andean crops have shown variable effects on PCN populations. For instance, the stimulation hatching effect (trap crop) of lupine lines 80, 98, 9, 75, 39, 79, 21, and 103, or the permanent hatching inhibitory effect (antagonistic crop) of lupine lines 78 and 87, as a response to the presence of root chemical compounds or because lupine roots favored the development of an anti-nematode microbial activity, constitutes the first report of such effects on the activity or behavior of PCN. Lupines are now grown and incorporated as a green manure by some farmers. The practice has resulted both in higher potato yields (Perez, 1996) and lower PCN multiplication rates (Franco, 1991). These effects could likely be improved by the use of those lupine lines found to be most effective as trap or antagonistic crops.

Table 2. Criteria for defining the behavior of plant species and genotypes in relation to the development and reproduction of *Globodera* spp.

		Hatching[z]	Invasion[z]	Development[z]		Reproduction[z]
Between	Within		(J2)	(J3-J4)	Female	Viable cysts
Host	Highly Efficient (Susceptible)	>80*	>80	>80	>80	>80
	Moderately Efficient (Partially resistant)	50-79	50-79	50-79	50-79	50-79
	Poorly Efficient (Resistant)	<49	<49	<49	0-49	0-49
Non-host	Highly Efficient (Trap crop)	>80	>80	>80	0	0
	Moderately Efficient	50-79	50-79	50-79	0	0
	Poorly Efficient (Antagonistic crop)	<49	<49	<49	0	0

[z]Percentage of success in each stage of nematode development in relation to an efficient host plant (i.e. potato).

Among the other non-host Andean crops, although evaluations were not as detailed as with the lupine lines, there is a clear effect on the percentage decline of *Globodera* spp. in response to the hatching stimulus of several genotypes. Genotypes of *O. tuberosa* in groups 1, 2 and 3 can be considered to be highly efficient non-hosts (trap crops) because their hatching stimulus was higher than 80%, with less than 20% of the initial population density remaining in the soil. The most efficient lines in these three groups were: Bol4028, Bol3992, Bol4046, Bol4095, Bol3898, Bol4114, Bol4110, Bol4190, Bol4113, Bol3919, Bol4012, Bol4565, Bol3873, Bol3991, Bol4024, Bol4038, Bol4042, Bol4058, Bol4151, Bol4162, Bol4185, Bol4336, Bol4363, Bol4416, Bol4422, Bol4505 and Bol4511. Genotypes in the other groups were considered as moderately efficient non-hosts because hatching stimulation was 50-80%, leaving a higher residual (unhatched) population density in the soil.

Several genotypes within the other crops also caused high reduction of *Globodera* spp. eggs. Genotypes Bol3975, Bol4213, Bol4388, Bol4395, Bol4389, Bol7003, Bol4322, Bol4479, Bol3963 and Bol4572 in group 1 of *U. tuberosus* were the most promising because they behaved as highly efficient non hosts with a hatching stimulus close to that of potato. Lines in groups 2-4 and 5-8 behaved as non-hosts, but moderately and poorly efficient, respectively.

Within the other crops, all lines of *C. quinoa* (1180, Kellu, 537, Willata and Timsa) and the lines Bol4382, Bol4071, Bol4179 and Bol4040 of *T. tuberosum*, behaved as highly efficient non-hosts (trap crops). Similar behaviour was observed with the variety Zapata and line 9-15-92 of *H. vulgare*, with a residual viability of *Globodera* spp. less than 20%.

This study shows the need to consider the relative efficiency of various non-host crops to reduce populations of PCN in Andean crop rotation plans. Nematode population densities can be reduced more quickly and crop rotation cycles shortened by the use of these crops. However, future research should differentiate the effects of various crop lines on individual species of PCN to determine whether particular crop lines could shift the species composition in fields. Agronomically acceptable lines of non-host crops that function as trap plants will play an important role, in conjunction with resistant potato cultivars, in an effort to reduce nematode population densities to below damaging levels. Such an approach offers a practical means to restore the productivity and increase crop yield on the so called "tired-soils" in the Andean region.

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