

# The behavior of nonfumigant nematicide-stressed, unstressed and wild populations of *Pratylenchus vulnus* cultured on grapevines and bean plants

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## SUMMARY

Several stock cultures of *Pratylenchus vulnus* were kept on Thompson Seedless grapevines. These stock cultures were separated into groups and each group was stressed for five years with subnematicidal doses of the nonfumigant nematicides carbofuran, oxamyl and phenamiphos. One half of each population group was then released from stress for one year (unstressed). Nematodes from each of the stressed and unstressed populations were cultured on bean plants. All the stressed and unstressed nematodes developed lower population levels than did the wild population. However, the percentage of each nematode population found in the root tissue (as opposed to soil) was lowest in the wild population. The initial population structures of various nematodes stages was used as a character. Based on this character, each of the various populations displayed distinct differences when cultured on grapevines. These differences tended to be masked when the various populations were cultured on bean plants. Unstressing appeared to alter population levels and population structures. However, this varied with the specific nematode population and specific host. The characteristics of population levels, percent adults found in root tissue and percent of the total population found in root tissue were closely correlated ( $r = 0.992$ ).

## RÉSUMÉ

*Le comportement de populations de Pratylenchus vulnus sensibilisées à un nématocide non fumigant, désensibilisées, et sauvages, élevées sur vigne et sur haricot*

Plusieurs élevages de masse de *Pratylenchus vulnus* ont été maintenus sur vigne « Thompson seedless ». Ces élevages ont été divisés en groupes dont chacun a été sensibilisé pendant cinq années à des doses sublétales de produits nématocides non fumigants : carbofuran, oxamyl et phénamiphos. La moitié de chaque groupe a été maintenue sans stress pendant une année. Les nématodes de chaque groupe stressé et non stressé ont été cultivés sur haricots. Tous les nématodes stressés et non stressés ont développé des niveaux de population plus faibles que ceux de la population sauvage. Cependant, le pourcentage de chaque population de nématodes trouvée dans le tissu racinaire (par opposition au sol) était le plus faible dans la population sauvage. La structure de population initiale de diverses populations de nématodes a été utilisée comme caractère. Sur la base de ce caractère, chaque population a présenté des différences distinctes lorsqu'elle a été cultivée sur vigne. Ces différences ont tendance à être masquées lorsque les différentes populations ont été cultivées sur haricots. Le relâchement a semblé modifier les niveaux de population et les structures de population. Cependant, cela a varié selon la population de nématodes spécifique et l'hôte spécifique. Les caractéristiques des niveaux de population, du pourcentage d'adultes trouvés dans le tissu racinaire et du pourcentage de la population totale trouvée dans le tissu racinaire ont été étroitement corrélées ( $r = 0.992$ ).

advisors. Their dealings with plant-parasitic nematode problems places much emphasis on the "economic threshold" level. Resulting control programs are frequently staggered. This may result in a field being treated for a couple of years, followed by a lag period and then treated some years later.

The economic importance of the plant-parasitic nematodes *M. incognita* and *P. vulnus* is well recognized. As mentioned earlier, when stressed with nonfumigant nematicides for over three years, these species displayed a number of behavioral changes. However, a realistic approach to characterizing the responses demands the practical considerations of behavioral change persistence. This study was conducted to test the stability of some behavioral changes by comparing stressed, unstressed and wild populations. It was also designed to characterize the complex nature of nematode-host-nematicide interactions.

### Materials and methods

*Meloidogyne incognita* : Unstressed population stock (Yamashita & Viglierchio, 1985). Unstressed stock pots were further expanded by inoculating two month old French Colombard grapevines with J 2 larvae. After two years, without subnematicidal stressing, the stock cultures were extracted for J 2 larvae. However, the number

tures were salvaged by sterilizing egg masses and inoculating emerged J 2 larvae onto Murietta tomato plants. These were left to rebuild for later testing.

*Pratylenchus vulnus* : Unstressed populations were started and later expanded into a total of four stock pots per population. The method was the same as for *M. incognita*. After the first two years of stressing, the cultures were repotted onto young Thompson Seedless grapevines. This was done with an inoculum of about 1,000 mixed-stage nematodes. Sterile autoclaved soil and pots were used in all cases. After the fourth year of stressing, one half of the stock cultures were removed from monthly subnematicidal stressing. Two stock culture pots from each stressed population were removed from monthly treatment. These were expanded to four pots per population by inoculating two month old Thompson Seedless grapevines with an aliquant of 500 mixed-stage nematodes (extracted from soil and root

maticidal stressing : Carbofuran at 0.002 mM; Oxamyl at 0.005 mM; Phenamiphos at 0.0016 mM.

After one year, the unstressed populations were inspected for nematode numbers and found to be too low for conducting a full-scale greenhouse test (as was done

for *X. index*). As a result, all stressed and unstressed stock cultures of *P. vulnus* were extracted for population level inspections. Because of the low nematode numbers found, a test was designed to compare population level and structural changes. The phenamiphos-stressed population levels were found to be extremely low and this population was omitted from the tests. Nematodes from stressed and unstressed cultures were first evaluated for population structure. That is, the percent contribution from each nematode stage was recorded. Criteria used to distinguish J 2, J 3, J 4 and adult stages were outlined by Chitambar (1983). Adults were easily distinguished. Larval stages were separated mostly by size comparisons and when necessary supplemented with observations on the development of the genital primordia.

Two week old Kentucky Wonder bean plants (in 500 cm<sup>3</sup> styrofoam cups), were inoculated with an aliquant of 340 mixed-stage nematodes from each stock population. Being a more suitable host than grapevines, the beans were selected here to accelerate population increases. Five cups were inoculated for each stressed and unstressed population. Another five cups were inoculated with nematodes taken from a wild population culture. The inoculated beans were maintained in a greenhouse and watered twice daily with half strength Hoagland's solution. This test did not involve the application of nonfumigant nematicides. Rather, the various populations were allowed to develop on the beans in the

the test. A randomized complete block design was utilized.

Following 40 days of growth, the bean plants were harvested. Nematodes in soil were extracted using 246  $\mu$ m and 38  $\mu$ m sieves. Roots from each plant were cut into 1 cm pieces and misted for five days. The suspension from the soil and roots were evaluated separately. Each nematode suspension was brought up to 50 mls and three 2 ml aliquants were evaluated for J 2, J 3, J 4 and adult population numbers. The total population numbers, their structure and percent distribution in the soil vs. roots were recorded for analyses. Population number differences between various stock cultures were evaluated following a Log<sub>10</sub> (X + 1) transformation. Analysis of the population structure and percent nematodes in roots was conducted following an arcsine transformation. Mean comparisons were conducted using Duncan's Multiple Range test. An upper level of significance of 5% was used in these analyses. Relationships between stock population and nematode

### Results

The low stock culture population levels made it necessary to conduct tests with *P. vulnus* differently

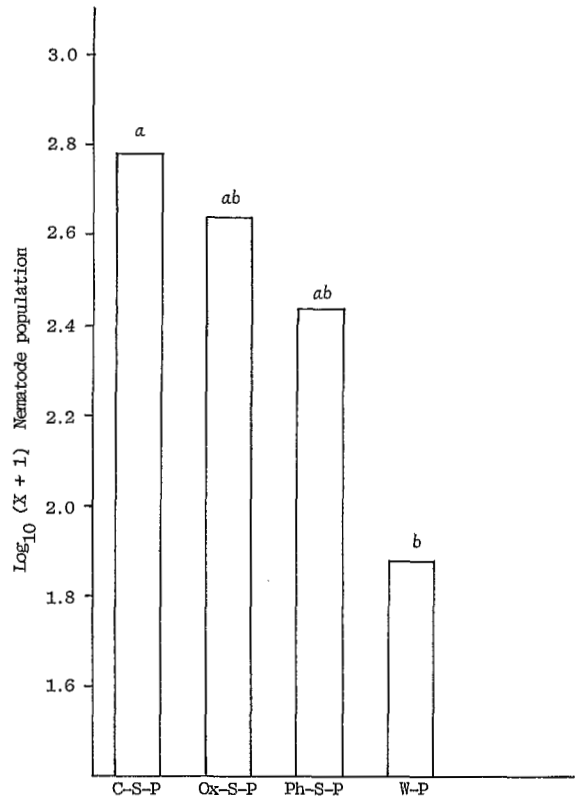
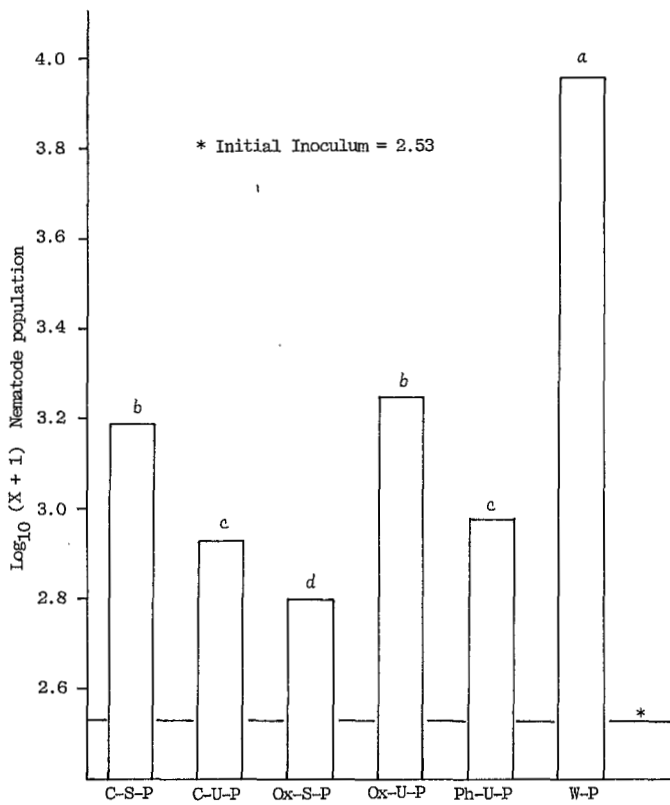


Fig. 1. Mean nematode numbers from various populations of *Pratylenchus vulnus* cultured on bean plants for 40 days at 25°. Means not followed by a common letter are significantly different at an  $\alpha$  level of 5 % or less.

Fig. 2. Mean nematode numbers from stressed and wild populations of *Pratylenchus vulnus* cultured on Thompson Seedless grapevines for 60 days at 25°. Means not followed by a common letter are significantly different at an  $\alpha$  level of 5 % or less.

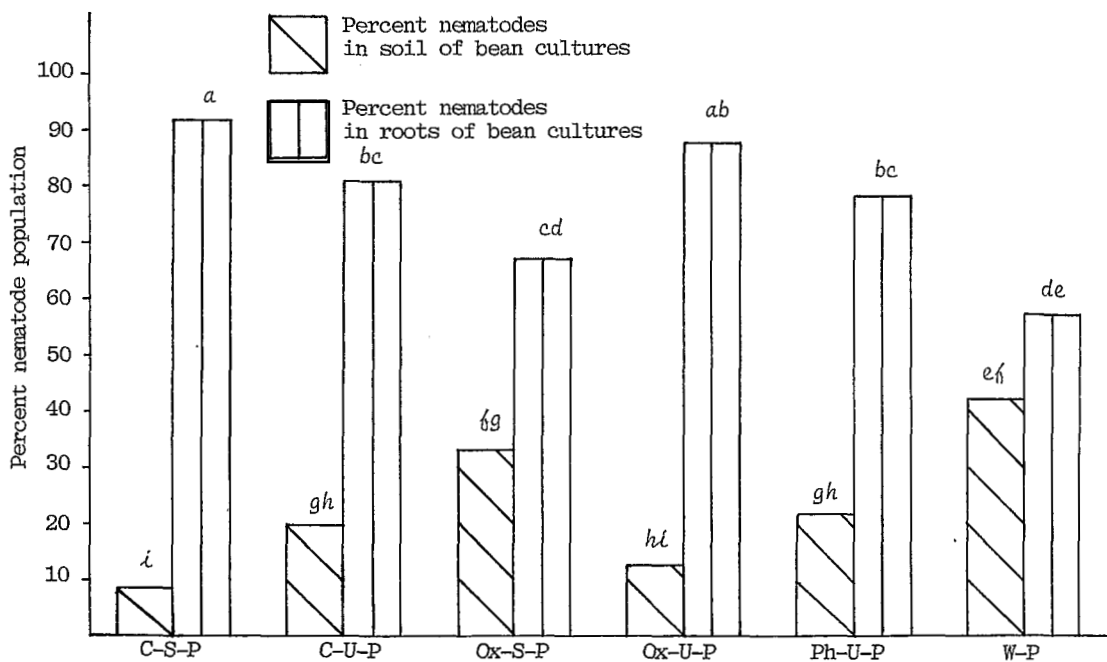


Fig. 3. The percentage of each *Pratylenchus vulnus* population found in the soil and roots of bean cultures. Means not followed by a common letter are significantly different at an  $\alpha$  level of 5 % or less.

Table 1

Population levels from stressed and unstressed stock cultures of *Pratylenchus vulnus* reared on grapevines

<i>P. vulnus</i> population	Mean population levels per culture pot	Duncan's MRT
Stressed population :		
C-S-P	7 050	A
Ox-S-P	2 667	B
Ph-S-P	45	D
Wild	520	C
Unstressed population :		
C-U-P	3 425	a
Ox-U-P	1 108	b
Ph-U-P	340	c
Wild	520	c

Numbers represent the mean nematode levels from four stock culture pots. At the time of population level inspections the stressed populations had received monthly subnematicidal stressing for 60 months. The unstressed populations has been released from stress for 12 months. Means not followed by a common letter are significantly different at an  $\alpha$  level of 5 % or less.

Table 2

Comparisons between stages of *Pratylenchus vulnus* from parent stock populations cultured on grapevines

<i>P. vulnus</i> population	Nematode Stages			
	Ƴ 2	Ƴ 3	Ƴ 4	A
C-S-P	31 <i>de</i>	41 <i>c</i>	19 <i>hi</i>	9 <i>j</i>
C-U-P	10 <i>j</i>	55 <i>b</i>	26 <i>efg</i>	9 <i>j</i>
Ox-S-P	23 <i>fgh</i>	34 <i>d</i>	28 <i>ef</i>	15 <i>ij</i>
Ox-U-P	21 <i>gh</i>	61 <i>a</i>	14 <i>ij</i>	4 <i>k</i>
Ph-U-P	14 <i>ij</i>	50 <i>b</i>	23 <i>fgh</i>	12 <i>ij</i>
W-P	8 <i>jk</i>	43 <i>c</i>	41 <i>c</i>	8 <i>jk</i>

Means represent the percent representation of each nematode stage within each population cultured on grapevines. Means not followed by a common letter are significantly different at an  $\alpha$  level of 51 % or less.

from those conducted with *X. index* (Yamashita & Viglierchio, 1985). The immediate tests with *P. vulnus* did not involve treatment with nematicides. As a result, detection of differences between stressed, unstressed and wild populations relied upon the following observations :

Differences in population levels of nematodes.

Comparisons between nematodes stages from parent

stock populations cultured on grapevines and bean plants.

Comparisons between populations : total percentage of nematodes extracted from bean roots and soil.

Comparisons between the percentages of each nematode stage extracted from bean roots.

Interrelationships between total population levels, percent adults in the roots and the total percent of nematodes found in the roots.

The following abbreviations will be used throughout the paper :

C-S-P	=	Carbofuran-Stressed Populations
Ox-S-P	=	Oxamyl-Stressed Population
Ph-S-P	=	Phenamiphos-Stressed Population
C-U-P	=	Carbofuran-Unstressed Population
Ox-U-P	=	Oxamyl-Unstressed Population
Ph-U-P	=	Phenamiphos-Unstressed Population
W-P	=	Wild Population

## DIFFERENCES IN POPULATION LEVELS OF NEMATODES

Population levels of each stock culture population are summarized in Table 1. Each value represents the mean population level of four stock culture pots. The initial inoculum used to start the stressed populations was different from that used to start unstressed populations. As a result, the means of the stressed and unstressed populations were analyzed separately. At the time this population inspection was conducted, the stressed populations had been maintained for five years. The unstressed populations were exactly one year old.

As can be seen from Table 1, the consistent order from highest to lowest population levels is : stressed population : 1 : C-S-P; 2 : Ox-S-P; 3 : W-P and 4 : Ph-S-P and W-P; unstressed populations : 1 : C-U-P; 2 : Ox-U-P; 3 : Ph-U-P and W-P. These results appear to coincide closely with the trends observed in Figure 2 (1 : C-S-P; 2 : Ox-S-P; 3 : Ph-S-P; 4 : W-P), which were recorded with four year old stressed populations. In most instances the stressed and unstressed population levels exceeded those of the W-P.

The population levels from six *P. vulnus* populations are summarized in Figure 1. On bean plants the W-P (9,120) reached the highest numbers. This was significantly larger than all other populations tested. However, in an earlier study on stressed populations cultured on Thompson Seedless grapevines (Yamashita, Viglierchio & Schmitt, 1985), the reverse effect was observed (Fig. 2). It appears that the behavior of specific populations of *P. vulnus* is largely influenced by the specific host. On grapevines the W-P level (76) was lowest and significantly below the C-S-P control levels (605).

As mentioned in the material and methods section, the Ph-S-P cultures were found to be extremely low. They were found to be contaminated with root-knot

Table 3

Comparisons between stages of *Pratylenchus vulnus* from populations cultured on bean plants

P. vulnus population	Nematode Stages			
	J 2	J 3	J 4	A
C-S-P	11 fg	22 d	39 b	28 c
C-U-P	9 g	18 e	35 b	38 b
Ox-S-P	9 g	16 ef	39 b	36 b
Ox-U-P	3 h	25 ed	45 a	27 cd
Ph-U-P	7 gh	16 ef	40 ab	37 b
W-P	15 ef	18 e	38 b	29 c

Means represent the percent representation of each nematode stage within each population cultured on bean plants. Means not followed by a common letter are significantly different at an  $\alpha$  level of 5% or less.

Table 4

Comparisons between the change in *Pratylenchus vulnus* juvenile and adult stages as the host is changed from grapevines to bean plants

P. vulnus population	$\Delta$ In nematode Stages : Growth on Grapevines-Beans			
	$\Delta$ J 2	$\Delta$ J 3	$\Delta$ J 4	$\Delta$ A
C-S-P	20 bc	19 c	- 20 ij	- 19 ij
C-U-P	1 f	37 a	- 9 gh	- 29 l
Ox-S-P	14 d	18 cd	- 11 h	- 21 ijk
Ox-U-P	18 cd	36 a	- 31 l	- 23 jk
Ph-U-P	7 e	34 a	- 17 l	- 24 k
W-P	- 7 g	25 b	3 f	- 21 ijk

Numbers represent the difference between mean percentages (% contribution from nematode stages grown on grapevines minus % contribution from nematode stages grown on bean plants). Numbers not followed by a common letter are significantly different at an  $\alpha$  level of 5% or less.

nematodes and the exact cause of the low populations cannot be evaluated at this time. However, it is possible to compare the effects of unstressing with the C-S-P vs. C-U-P and Ox-S-P vs. Ox-U-P comparisons (Fig. 1). Removing the C-S-P (1,445) from stress for one year appears to affect population levels, as the C-U-P (797) is significantly lowered. The opposite effect is seen with the Ox-S-P. Removing the Ox-S-P from stress appears to improve population build-up (Ox-S-P = 603 vs.

order of population levels were found to be : 1 : W-P; 2 : C-S-P and Ox-U-P; 3 : C-U-P and Ph-U-P; 4 : Ox-S-P. However, as mentioned earlier, it is important to consider the host in these evaluations. In an earlier study, using Thompson Seedless grapevines, the W-P levels reached the lowest numbers (Fig. 2).

## COMPARISONS BETWEEN NEMATODE STAGES FROM PARENT STOCK POPULATIONS CULTURED ON GRAPEVINES AND BEANS

In each stock population cultured on grapevines, the largest proportion of nematodes appears to be represented by J 3 larvae (Tab. 2). This is followed by either the J 4 or J 2 larvae, with adults forming the smallest segment of the population. When cultured on beans for 40 days, however, the general structure is seen to change (Tab. 3). The J 4 larvae now form the largest segment of the populations, followed by the adults and J 3 larvae, with the J 2 larvae representing the smallest portion of each population. The larger increase in the proportion of adults is evident in the bean cultures. They form a distinctly larger segment of each bean cultured population than is represented in the grapevine cultured populations. Another effect, which is quite consistent, involves comparisons between the stressed and unstressed populations. When grown on grapevines, there appears to be significant differences in the population structures between C-S-P vs. C-U-P and the Ox-S-P vs. Ox-U-P (Tab. 2). In addition all stressed and unstressed populations appear to have differences in population structure from the W-P (Tab. 2). There is a slight tendency for differences between stressed and unstressed populations cultured on bean plants, as well (Tab. 3). However, these population structure differences are both of lower frequency and magnitude. In earlier studies grapevines were observed to be a less suitable host than bean plant for *P. vulnus* population build-up. These differences might otherwise have been masked when cultured on the more suitable bean host. The populations cultured on grapevines show distinct signs of structural differences. These differences indicate unique characteristic of each population. However, when the same populations are cultured on bean plants, their population structures appear to be more uniform (Tab. 3).

The percent representation of each nematode stage for each population is presented in Tables 2 and 3. The mean differences between the values from grapevine cultures minus the values from bean cultures is presented in Table 4. When populations are extracted from grapevines and cultured on bean plants, the general trend is a distinct increase in J 4 and adult stages (Tab.

Table 5

Percentage of each stage of *Pratylenchus vulnus* extracted from roots of bean plants

P. vulnus population	Nematode Stages			
	J2	J3	J4	A
C-S-P	99 a	94 abc	95 ab	90 abcde
C-U-P	98 a	96 a	74 efgh	78 bcdefg
Ox-S-P	56 ij	59 hij	79 bcdefg	65 fghij
Ox-U-P	77 cdefg	92 abcd	88 abcde	87 abcde
Ph-U-P	99 a	82 abcdef	75 defgh	75 defgh
W-P	48 j	68 fghi	58 hij	61 ghij

Means represent the percentage of each nematode stage

extracted from bean roots (the samples being extracted from the soil). Numbers not followed by a common letter are significantly different at an  $\alpha$  level of 5 % or less.

these general trends is found with the W-P. While other populations decreased in the percent of J 2 larvae, the W-P displayed a significant increase (7).

Within each population the changes that occur in each stage appears to be significant for almost all populations. The only two exceptions are the low degree of change observed with the J 2 larvae of the C-U-P (1) and the J 4 larvae of the W-P (3).

#### COMPARISONS BETWEEN POPULATIONS: THE TOTAL PERCENT OF NEMATODES EXTRACTED FROM BEAN ROOTS AND SOIL

With all *P. vulnus* populations, the great majority of nematodes are found in the roots (Fig. 3). Highest values are found in the C-S-P (92 % from roots) and the lowest values are found in the W-P (57 % from roots). Except for the Ox-S-P (67 % from the roots), all other populations show significantly higher percentages of nematodes found in the roots than the W-P.

In addition, unstraining appears to have affected these values. Percentages of nematodes from roots in the C-S-P are significantly larger than from the C-U-P (92 % vs. 81 %). The effects of unstraining are reversed with the Ox-S-P. Here, the percentage of nematodes found in the roots of the Ox-S-P are significantly lower than found in the Ox-U-P (67 % vs. 87 %).

#### COMPARISONS BETWEEN THE PERCENTAGES OF EACH NEMATODE STAGE EXTRACTED FROM THE ROOTS

Fairly uniform percentages of the C-S-P nematode stages were extracted from bean roots (Tab. 5). However, other populations did show some signs of

variations. Although there are exceptions, the main differences between stages appears to occur with J 2 and J 3 larvae vs. J 4 and adults. All values from the W-P appear to be lower than most percentages from other populations. This is reflective of the low total percentage of W-P nematodes found in roots (Fig. 3). Except for the low percentage (48 %) of J 2 larvae found in roots, all other stages of the W-P appear quite uniform.

Unstraining appears to affect these values in the C-U-P and Ox-U-P quite differently. With the C-U-P unstraining significantly reduces the percentage of J 4 larvae found in bean roots (95 % vs. 74 %). However, unstraining appears to increase the percent of J 2, J 3 and adults in the Ox-U-P (J 2 - 56 % vs. 77 %; J 3 - 59 % vs. 92 %; A - 65 % vs. 87 %). These effects of unstraining on changes in percentage of nematode stages found in roots (Tab. 5) were believed to be correlated to the

However, no significant correlations were detected. Thus, the reduction or increases in the percent of nematode stages found in bean roots (C-U-P and Ox-U-P) are believed to be a result of unstraining effects.

#### INTERRELATIONSHIPS BETWEEN TOTAL POPULATION LEVELS, PERCENT ADULTS IN THE ROOTS AND THE TOTAL PERCENT OF NEMATODES FOUND IN THE ROOTS

When observing the population data (Fig. 1) and the total percent of nematodes in bean roots (Fig. 3), certain correlations were apparent. The most striking of these was the observation that the highest and lowest population levels (W-P and Ox-S-P; Fig. 1) both had the lowest percent of nematodes in bean roots (W-P = 57 %, Ox-S-P = 67 %; Fig. 3). Populations with intermediate levels of nematodes (Fig. 1) appeared to have intermediate percentages of nematodes found in bean roots (Fig. 3).

Several correlation and regression analysis studies of these observations proved to be incomplete. However, use of a third character (the percent adults in bean roots) provided for a highly significant multiple correlation coefficient ( $r_{yx_1, x_2} = 0.992$ ). The  $\text{Log}_{10}$  of the total population level ( $x_1$ ) and the arcsine transformed percent adults found in roots ( $x_2$ ) were used as characters of each population. These two characters were found to account for more than 98 % of the variability in the total percent of nematodes found in bean roots ( $y$ ). The regression equation proved to be a near perfect fit ( $y = 30.77 - 6.844 x_1 + 0.892 x_2$ ).

## Discussion

#### DIFFERENCES IN POPULATION LEVELS OF NEMATODES

The general pattern of population levels seen in stock cultures (Tab. 1) and from control pots of an earlier test

(Fig. 2) appear to be manifestations of true population character differences. There are other possible explanations but these do not coincide with past and immediate test results. For example, population levels of a related species, *Pratylenchus penetrans*, were increased in the presence of certain species of fungi (Edmunds & Mei, 1966; M. & M. K., 1969).

different.

It is common knowledge that certain hosts are better suited for some plant-parasitic nematodes. A host range study for *P. vulnus* gave indications that this species did not behave differently (Jensen, 1953). When cultured on grapevines, the W-P levels reach a low 76 nematodes per

with the Ox-S-P and Ox-U-P (Fig. 1). Here, releasing the nematodes from oxamyl stress appears to contribute towards a slight reversion to wild-type (Ox-S-P at 631 vs. Ox-U-P at 1,778), although the fitness of the Ox-U-P on bean plants cannot match the fitness of the W-P (Ox-U-P at 1,778 vs. W-P at 9,120). Since *P. vulnus* is known to reproduce by amphimixis (Roman & Triantafyllou, 1969),

#### COMPARISONS BETWEEN NEMATODE STAGES FROM PARENT STOCK POPULATIONS CULTURED ON GRAPEVINES AND BEANS

When carrot callous tissue cultures are inoculated with mature females and males of *P. vulnus*, the various stages appear as follows; J2 at nine days from inoculation; J3 at eleven days from inoculation; J4 at seventeen days from inoculation; adults at eighteen days from inoculation (Chitambar, 1983). In spite of small time requirement differences for each stage development, the structure at equilibrium should be relatively balanced with higher representations from J2 and adults. This is so, because: *i*) Adults have a longer life span than all other stages, *ii*) A certain percent of J2 larvae will be found accumulating in the soil and without invading the roots may remain in a J2 state. This structure trend was observed with *P. vulnus* cultured on carrots for 90 days (Marban-Mendoza & Viglierchio, 1980).

All stock populations of *P. vulnus* (stressed, unstressed and wild) were cultured on Thompson Seedless grapevines under similar conditions for more than one year (stressed for five years; unstressed for one year; wild for five + years). This should have allowed existing populations to reach an equilibrium in their structure. The consistently large J3 representation of all grapevine cultures indicates that the J3 to J4 transition may be slightly affected on this host (Tab. 2). The disruption of this transition seems to be overcome when the populations are cultured on bean plants. A differential effect of the host on specific stage development may in part indicate the unique physiology of each stage. The greater degree of differences seen both within and between grapevine cultures (as opposed to bean plant cultures) is indicative of the specific interactions of each population and each stage with that particular host. The monthly subnematicidal treatments in stressed cultures adds to the complexity and specificity of these interactions during the natural selection process. Being a less suitable host than bean plants, the grapevines contribute to the expression of existing differences between populations and even between stages within a population.

#### COMPARISONS BETWEEN PERCENTAGES OF NEMATODES EXTRACTED FROM ROOTS

The ability for a *P. vulnus* population to parasitize the root system can be inferred from evaluating the total percentage of nematodes extracted from the roots. Studies conducted with a related species, *Pratylenchus penetrans*, have correlated suboptimal conditions of both

roots to soil (Patterson & Bergeson, 1967). With corn, for example, the number of *P. penetrans* adults extracted from the soil was inversely correlated to the population extracted from the roots (Miller, Boothroyd & Mai, 1963). Under the conditions of this experiment, the total percent of nematodes extracted from roots was found to be correlated to both the population levels and the percent adults extracted from the roots. The correlation and regression in three variables and the regression equation were used mainly to help characterize the different populations. The subcharacter of percent adults extracted from roots was used to help facilitate this characterization. The correlation and regression studies do not in themselves propose cause and effect relationships.

Unstressing appears to decrease the percent of J4 larvae in the C-U-P (Tab. 5; J4 — 95 % to 74 %) while increasing the J<sub>2</sub>, J<sub>3</sub> and adult stages in the Ox-U-P (Tab. 5; J2 — 56 % to 77 %; J3 — 59 % to 92 %; A — 65 % to 87 %). These changes are related to the effects of unstressing in the reductions of the C-U-P (Fig. 1; C-S-P at 1,549 vs. C-U-P at 851) and the increases in the Ox-U-P (Fig. 1; Ox-S-P at 631 vs. Ox-U-P at 1,778). The effects of unstressing on increasing the Ox-U-P appear to be more typical of a gradual reversion to wild-type. The opposite effect with the C-U-P, however, may further indicate the complexity of the nematode-host-nematicide interaction. Specificity of the interactions is hinted at strongly in both cases, since only certain nematode stages are observed to change in the percent extracted from bean roots. While the lower populations (Fig. 1) in the Ox-S-P stages may in part reflect a reduced ability to invade roots (as indicated by the low percentage of J2, J3 and adult stages extracted from bean roots; Tab. 5), the lower population levels of the C-U-P (Fig. 1) may be more closely related to other physiologically based factors such as reduced fecundity (as indicated by the similarities in percent of nematodes extracted from roots; Tab. 5).

#### Conclusive statements

It appears that releasing the C-S-P and Ox-S-P from subnematicidal stressing changes the characters of those populations. While unstressing increases production in the C-U-P, the population levels of the Ox-U-P are increased. The increase in the Ox-U-P appears to be partly attributable to an increased ability to invade the



root system. The decrease in the C-U-P appears to be related to more complex physiologically based factors such as reduced fecundity.

The specific behaviors of all stressed and unstressed populations are strongly influenced by the specific interactions between the nematode-host-nematicide. Behavioral changes even at the level of specific nematode stages attests to the specificity of these interactions.

A very important practical consideration for agriculture may lie in the area of crop rotations or alternate cropping. Stressed and resistant populations of *P. vulnus* were found to reach significantly higher population levels than the W-P on grapevines (Yamashita, Viglierchio & Schmitt, 1985). When stressed, unstressed and wild populations were cultured on Kentucky Wonder beans, however, the W-P reached population levels that were more than five times the levels reached by other populations. While the W-P seems to retain a greater capacity to adapt to new hosts, the specific selection process seems to have narrowed this capacity in both stressed and unstressed populations. Furthermore, removal of the C-S-P from carbofuran stressing appears to remove an element necessary for its normal growth. A grower, who has

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