Expanding the IPM toolbox: Visual bioassays for assessing root health and soil nematode infestations

Beth K. Gugino*, George S. Abawi, and John W. Ludwig, Department of Plant Pathology,
Cornell University, NYSAES, Geneva, NY 14456

Increased incidence and severity of root diseases caused by soilborne pathogens have contributed to poor soil quality and health, reduced yield, and lower profitability of vegetable production in New York. Plant roots are the ultimate integrators of their surroundings, thus they are good indicators of soil health, in general. We have been using a soil bioassay with bean to visually assess the soil suppressive capacity of target fields and implemented sustainable soil management practices against soilborne pathogens (root health). A minimum of 4 soil samples are collected per field or management practice, planted to bean, and root health (root rot severity) is rated after 4-6 weeks on a scale of 1 (no disease symptoms, healthy) to 9 (>75% of roots affected and at various stages of decay). Similarly, on-farm visual soil bioassays with lettuce and cowpea were developed for assessing soil infestation levels of the root-knot (*Meloidogyne hapla*) and lesion (principally, *Pratylenchus penetrans*) nematodes, respectively. The severity of root-galling and lesions caused by *M. hapla* and *P. penetrans*, respectively on roots is a measure of the level of soil infestation, which is also rated on a scale of 1 to 9. Thresholds have been developed for several crops (onions, carrots, lettuce) for guiding management decisions. These soil bioassays provide cost-effective tools that can be readily integrated into IPM programs for various crops for managing soilborne pathogens on as needed basis and for assessing the general soil suppressive capacity. The participatory training of interested growers and other personnel is currently on-going.

Introduction

The intensive production of vegetable crops in New York and the Northeast region has contributed to reduced soil quality and resulted in lower crop productivity and farm profitability. Among the causes are soil compaction, crusting, low organic matter, increased pressure and damage from diseases, weeds, insects and other pests as well as a lower density and diversity of beneficial organisms (Figure 1). These constraints have increased the interest of growers and other land managers in assessing their soil health status and in implementing sustainable soil management practices.

Figure 1. Lack of surface cover resulting in soil erosion, crusting and nutrient leaching (a). Soil compaction as a result of harvesting practices (b). Inappropriate crop rotation increases root diseases and other pests. Observe normal bean roots in left square and severely damaged roots in right circle (c).

Healthy and productive soils are expected to have a high density and diversity of active beneficial organisms and low levels or the absence of pests, including root pathogens. Thus, a simple method was needed to determine the root health or the capacity of the soil to suppress root pathogens. Beans are known to be susceptible and a good indicator of several root pathogens including *Rhizoctonia*, *Pythium*, *Thielaviopsis*, *Fusarium* and others that are also of major importance to most vegetables grown in New York. In addition, root rot diseases are a major production problem on dry and snap beans in New York, often causing significant yield losses. A greenhouse soil-indexing procedure utilizing a susceptible snap bean variety was previously found to be effective in assessing the potential severity of root rot development in soil samples from targeted fields. Thus, this procedure has been found to be adequate in documenting the differences of root health status of soils under various management practices or production systems.

Figure 2. Healthy roots grown in healthy soil (a) versus unhealthy roots grown in unhealthy soil (b).

Besides soilborne fungal pathogens, nematodes, primarily the Northern root-knot (*Meloidogyne hapla*) and lesion (*Pratylenchus penetrans*), are a major constraint to the production of vegetables including carrot, onion, potato, lettuce, etc. Crop growth in heavily infested fields is often patchy and uneven. Carrots infected with *M. hapla* become forked, stubby, hairy, and develop galls on the fine roots and on the carrots themselves. Infected onions exhibit stunting, delayed maturity, larger necks and smaller bulbs. Onion roots show small galls or root-thickening and extensive branching. Lettuce plants become stunted and produce small, loose and often unmarketable heads. Distinct and large galls are formed on infected lettuce roots (Figure 3). Overall yield losses on bean have been associated with heavy *P. penetrans* infestations. Crop rotation with a non-host crop such as corn, wheat, sudangrass or oats against *M. hapla* or the use of antagonistic cover crops such as rapeseed, sudex, or ryegrass against *P. penetrans* although effective at reducing infestation levels, are generally not cost-effective especially on high value organic soils. Chemical nematicides are also effective but are costly and often applied unnecessarily. Soil bioassays with lettuce and cowpea were developed to enable the visual assessment of *M. hapla* and *P. penetrans* infestation levels, respectively along with the use of crop specific economic thresholds to determine if either biologically or chemically-based management is needed.

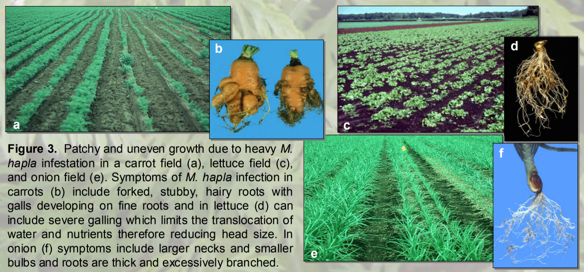


Figure 3. Patchy and uneven growth due to heavy *M. hapla* infestation in a carrot field (a), lettuce field (c), and onion field (e). Symptoms of *M. hapla* infection in carrots (b) include forked, stubby, hairy roots with galls developing on fine roots and in lettuce (d) can include severe galling which limits the translocation of water and nutrients therefore reducing head size. In onion (f) symptoms include larger necks and smaller bulbs and roots are thick and excessively branched.

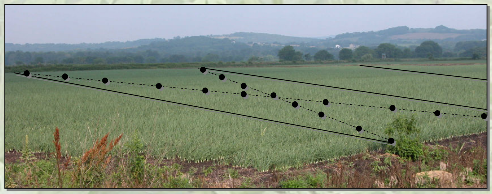
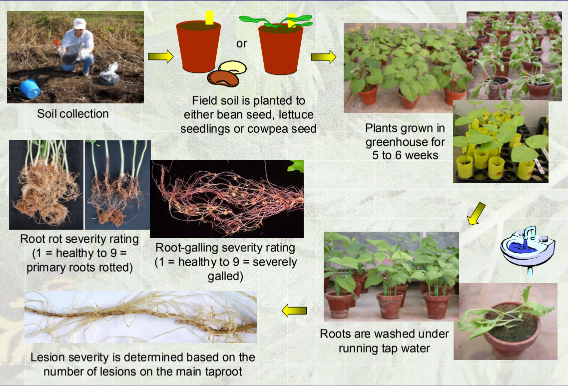


Figure 4. Pattern for sampling a large (20+ acre) onion field for Northern root-knot or lesion nematode. Four soil samples each consisting of 15 to 20 sub-samples were collected from this field in a X-shaped transect. Sub-samples could also be collected in a V or W-shaped transect.

Soil Sampling and Bioassay Protocols

Since the distribution of soilborne fungal and nematode pathogens within a field is patchy and uneven, adequate soil sampling is critical to accurately assess the soil suppressive capacity and/or nematode infestation level of a field or portion of a field. A composite sample per ≤4 acres composed of 15 to 20 sub-samples is recommended. Although increasing the number of samples will increase accuracy, the sampling unit should only be as small as the grower is willing to individually treat whether due to the configuration of the field, size of the sprayer, etc. After the composite soil samples are collected (Figure 4), each soil sample is thoroughly mixed, and placed in two 10-cm pots or other suitable container with drainage holes and planted to either snap beans cv. 'Hystyle' (7 seeds/pot) for the root health bioassay or with 2 lettuce seedlings or California black-eyed pea seeds for the bioassays for root-knot and lesion nematode, respectively. After 4-6 weeks, the plants are carefully removed and washed free of soil under running tap water. For the root health bioassay, the roots are rated for root rot severity on a visual scale of 1 (no visible disease symptoms) to 9 (>75% of hypocotyl and root tissues are diseased or effected, reduced in size and with advanced stages of decay). The severity of the root-galling on the lettuce roots is a reflection of the *M. hapla* infestation level in the soil and therefore is rated on a scale of 1 (healthy) to 9 (>80% roots galled) based on the percentage of roots galled. The rating scale for assessing the severity of lesions on cowpea as a result of lesion infection in currently on-going but will be based on the number of lesions on the main taproot.

Soil bioassays to determine soil suppressive capacity and nematode infestation levels



For the root health bioassay using bean, roots with ratings from 1 to 3 are considered highly functional (healthy), 4 to 6 are moderately healthy, and 7 to 9 are severely diseased (unhealthy). For *M. hapla*, the observed root-galling severity (RGS) has been closely correlated with soil nematode counts made by direct extraction and identification of the nematodes from the soil. This has made it possible to establish threshold severity ratings that can be used as benchmarks to decide on the need for nematode management. If planting onions, an average RGS ≥3 indicates that the sample area will need to be treated either with a chemical nematicide or rotated to a non-host crop. However, for a more sensitive crop like carrot, a sampling area with an average rating of ≥2 should be managed before being planted to carrot.

Selected Results from the Various Bioassays

Table 1. Root-knot nematode infestations in 14 vegetable fields were determined by direct extraction from the soil and the lettuce bioassay in fall 2004 shortly after harvest and in spring 2005 prior to planting. The results of the visual lettuce bioassay suggested that only 5 out of 10 and 6 out 14 fields sampled in fall 2004 and spring 2005, respectively, needed to be treated prior to being planted to onion based on a RGS threshold of RGS ≥ 3 for onion. Differences in management recommendations between the fall and spring sampling are currently being addressed in a soil storage trial to determine the effect of collecting the soil samples in the fall, storing them over winter and then conducting the bioassay in early spring prior to planting. This is the most desirable situation for our collaborating growers.

Field Code	Soil Type	Nematodes extracted per 100 cc soil		Lettuce Bioassay Root-Galling Severity*		Need to Manage?	
		Fall 2004	Spring 2005	Fall 2004	Spring 2005	Fall 2004	Spring 2005
Wayne 1	Organic	30	60	2.0 ± 1.0	3.0 ± 1.7	No	Yes
Wayne 2	Organic	8	30	2.1 ± 1.0	2.4 ± 0.6	No	No
Oswego 1	Mineral	45	0	3.3 ± 1.7	1.8 ± 0.8	Yes	No
Oswego 2	Mineral	98	110	2.3 ± 0.9	3.4 ± 0.8	No	Yes
Oswego 3	Mineral	15	10	1.1 ± 0.3	2.1 ± 1.3	No	No
Oswego 4	Organic	20	30	2.5 ± 0.9	2.8 ± 0.8	No	No
Oswego 5	Organic	45	30	3.9 ± 1.8	5.2 ± 1.0	Yes	Yes
Yates 1	Organic	115	50	3.1 ± 1.7	3.6 ± 2.1	Yes	Yes
Yates 2	Organic	320	0	3.9 ± 0.9	6.6 ± 0.5	Yes	Yes
Yates 3	Organic	440	50	5.8 ± 1.3	6.0 ± 1.0	Yes	Yes
Orange 1	Organic	n/a	0	n/a	1.2 ± 0.3	n/a	No
Orange 2	Organic	n/a	0	n/a	1.4 ± 0.6	n/a	No
Orange 3	Organic	n/a	0	n/a	1.6 ± 0.7	n/a	No
Orange 4	Organic	n/a	0	n/a	1.4 ± 0.5	n/a	No

* Root-galling severity is rated on a scale of 1 (no galls, healthy roots) to 9 (> 80% of roots galled). For example, a rating of 2 and 3 refers to 1-3% and 4-6% of root system being galled, respectively whereas a rating of 4 refers to 11-25% of the root system being galled. Sample means and standard deviations are presented.

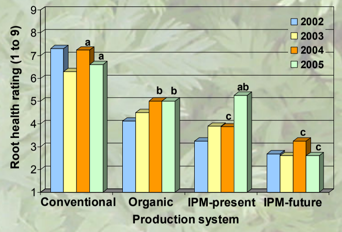
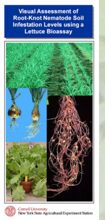


Figure 5. Average root health ratings for bean plants grown in soil collected from four different production systems at the IPM experimental research site in Geneva, NY from 2002 to 2005. The conventional system was managed using 'typical' grower management practices, the New York farm organic certification standards are used to manage the organic system, management in the IPM present system follows Cornell IPM production guidelines while the IPM future system also included year long soil-building crops into the rotation. In spring 2006, all the plots will be planted to beans in order to make yield comparisons. Bars within the same year with different letters are significantly different according to Fisher's LSD P<0.05.

Conclusions

The visual soil bioassay with lettuce and/or cowpea is a simple and cost-effective method for determining soil infestation levels of *M. hapla* and/or *P. penetrans* and deciding on the need for their management. Often it is not cost effective to rotate with non-host crops and nematicides are expensive and environmentally unfriendly, so these soil bioassays will enable growers to conduct their own on-farm nematode infestation assessments and determine the need for management, if any. The successful utilization of this method will promote the management of this nematode on an as needed basis, thus reducing crop loss and increasing profitability. Training sessions on conducting the soil bioassays are currently on-going and a user friendly brochure describing the bioassay protocols has been developed. The soil bioassay for assessing the soil suppressive capacity is currently part of the Tier I soil health assessment protocol that is currently being finalized and will soon be available to growers on a fee-for-service basis.



Acknowledgements

We would like to thank the vegetable extension educators and collaborating vegetable growers for their many contributions in validating and promoting this research and outreach effort. Also, the financial support of the NE-SARE, NYS/CU IPM, RAMP/USDA Programs NAPIAP and NE-PIAP, and the Regional Nematology Project (NE-1019) is greatly appreciated.