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VIEWPOINT

Standardization of Reporting Procedures for Nematicide Efficacy Testing: A Research and Extension Perspective[1]

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Abstract: Nematicide tests reported in the Annals of Applied Nematology from 1991 to 1995 were reviewed and evaluated for 24 criteria. Most criteria such as soil type, nematode density, cultivar planted, test location, and nematicide applied were reported in more than adequate detail. Soil moisture content and temperature conditions during the test, field history of pesticide use, agronomic-horticultural production practices, and measurements of yield were reported less adequately. Many reports dealing with fumigant nematicides and application by irrigation had inadequate descriptions of rates and application methodology. Although areas for improvement exist, overall the published works in Annals of Applied Nematology are well-reported experiments. Pressure exists from several elements of nematology to "standarize" reporting procedures and test practices. Due to the diversity of crops, nematodes, nematicides, edaphic and environmental conditions that affect nematicide fate, nematode activity, plant growth, and subsequently nematicide efficacy, creation of a completely standardized format is improbable. More accurate reporting of some test criteria rather than standardizatioon will allow better comparison between tests when results do not concur and allow future researchers to duplicate application rates and methodologies to determine the sources of discrepancies between tests, including environmental variations.
Key words: application, calibration, dosage, experimental design, nematicide, nematode control agent, nematode management.

The Industry Committee of the Society of Nematologists has worked for years to standardize reporting test results involving nematode control agents. The initial result of this effort was a standardized form (not published) that listed the criteria required for a highly detailed report using standardized terminology. The goal was to make reports uniform and "complete," with the ultimate goal of making it easier to compare and evaluate differences in results between tests. A large impetus for this project, started in 1989, was to create a form that could easily be used and transferred via the rapidly developing electronic mail and data presentation systems. Due to the protracted development interval for this form, most agrichemical companies developed their own formats before completion of the Industry Committee's form. A second problem was that the subject matter was far too diverse to create one comprehensive form that would not prove to be of unmanageable size and complexity.

This article is intended to provide some of the guidelines included in the Industry Committee's standardized form. Although

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the Industry Committee's report was meant to be used for reports on all nematode control agents, we are focusing on reports dealing with nematicides. In addition, we focused on reports submitted to the Supplement to the Journal of Nematology, the Annals of Applied Nematology (AAN). A list of criteria that will constitute a comprehensive report is provided (Table 1), as are suggestions for articles that serve as examples or sources of more in-depth information on measuring and reporting these criteria. The last 5 years of AAN have been reviewed and evaluated as to how well each article met all criteria. Due to the large number of articles, we evaluated only those that dealt directly with nematicide testing. However, most of the criteria are applicable to all field testing whether for host plant resistance, crop rotation, use of biocontrol agents, or nonconventional control practices. Our goal was not to embarrass any authors who failed to report major criteria but rather to characterize information content to identify areas for improvement. We also recognize technological, time, and fiscal constraints associated with data acquisition and reporting.

One of the driving forces in this ongoing attempt to standardize nematicide test results is the growing number and type of people and organizations using this information. Only a clear statement of the objectives and accurate reporting of methodologies employed in the studies will allow maximum use and comparison of databases generated. As extension nematologists, we are responsible for developing and implementing chemical control strategies for nematodes in various crops. A clearer understanding of the sources of variation in nematicide test results, including differences in nematicide application rates and methodologies reported by other scientists, will allow development of improved nematode management strategies.

TABLE 1. Numbers of articles dealing with nematicides in Annals of Applied Nematology from 1991 to 1996 that contain each of 24 criteria.

Criteria	Numbers of articles reporting: Yes	No
Appropriate description of plot size[a]	22	2
Statistical design and analysis[a]	24	0
% sand, silt, clay, organic matter in soil[a]	20	4
Soil pH[a]	17	7
Soil type[a]	21	3
Cultivar(s) planted[a]	19	5
Fertilizer[a]	12	10
Tillage practices used	10	11
Plant stand[a]	18	6
Local recommendations	11	12
Pi of the nematode[a]	19	5
Race of the nematode pathogen present	6	10
Yield[a]	17	2
Plant symptoms	12	9
Cropping history of the field[a]	7	16
Pesticide history	0	23
Insecticides applied	6	17
Herbicides applied	11	12
Soil temperature at the time of nematicide application[a]	3	21
Soil moisture at the time of nematicide application[a]	11	13
Seasonal temperatures	3	21
Seasonal moisture	13	11
Nematicide rate[a]	20	4
Nematicide application methodology[a]	15	9

[a]Criteria deemed necessary for nematicide efficacy testing reports.

Survey of the Literature

Before recommending changes to the currently accepted criteria reported in nematicide tests, it is necessary to document the current standard. Each of the 144 articles in the AAN for volumes 23 to 27 was reviewed for subject matter and experimental methodology. For 24 articles the primary subjects were nematicide efficacy, environmental fate, or application technology. Each of these articles was evaluated for the presence of 24 criteria taken from the checklist developed by the Industry Committee in its rough draft of a standardization form and from several articles or chapters on conducting nematicide tests (5,8,13,22,24,36). Criteria identified as important are reported in Table 1. The following is our review of the methods presented in the AAN articles for the last 5 years.

Criteria Reported Adequately

Test identity: Many of the items listed as important by the Standarization Committee are required by JON editorial policy and therefore were more than adequately reported in the articles reviewed. These included: (i) identity of the researcher and cooperators, (ii) test identification-titles and key words (useful for searchers of the literature and(or) electronic data bases), (iii) use of standard (metric) units, and (iv) objectives.

Test site location: The norm for AAN is to state in what county or at what experiment station or, in some cases, on whose farm the test was run. The original intent of geographic location was to provide insight into soil type and weather conditions at a test location. Improved reporting of soil type and environmental conditions is probably more important than the use of new, high-technology systems such as Global Positioning.

Plot description: Two of the 24 tests used field microplots. The remaining studies used field plots, with 17 using some form of irrigation. All of the authors gave adequate descriptions of plot size including information such as number of rows per plot, row width, row length, or, in the case of experiments dealing with trees, shrubs or vine crops, and the number of plants per plot. The importance of describing field production practices relates to the ability to translate application rates expressed per linear unit of crop row to a field (hectare) rate.

Statistical design and analysis: All of the authors gave some report for this criterion. As previous Viewpoint authors (22) have pointed out, whether or not these statistical analyses are totally appropriate is in many cases up for discussion. The biggest improvement needed in design and analysis has always been for everyone to meet with a statistician to design an experiment, not just analyze the data. An extensive review of plot design and analysis is available (23).

Soil characterization: Soil properties can affect nematicide efficacy either directly by determining the direction and rate of movement of nematicides, degradation rates, and subsequent exposure time of nematodes to the nematicides or indirectly by affecting the susceptibility of the nematodes to the chemical. Soil properties also indirectly affect test results by their effects on plant growth, rooting patterns, and plant health. Therefore, accurate reporting of the physical soil environment is critical to interpreting test results. Most reports included the majority of this information. Twenty-one of the 24 reports included soil type. The standard for information on soil type descriptions is the USDA Handbook Number 436 (1). All but seven reports included soil pH and all but four reported percentages of sand, silt, and clay contents of soil. Only six did not report organic matter content. However, the method of obtaining this information was not reported. In fields with highly variable soils, samples should be obtained and reported by plot or block. Protocols or procedures for soil testing and guidelines for proper reporting of soil physical properties are given by Nesmith and Averre (24).

What was not reported for almost all tests was the depth to hard pans or subsoil layers. In the highly eroded agricultural soils in which many tests for annual field crops are conducted, the classic soil descriptions do not accurately apply. Factors that are critical in determining nematicide movement such as soil moisture (saturation point, field capacity, wilting point), temperature, permeability, and bulk density were seldom reported.

Plant genotype: Only 5 of the 24 articles failed to report the genotype (cultivar) used. In the case of perennial crops, the rootstock was generally reported. In the future, as more and more genetically diverse material is created through biotechnology, it may be necessary to provide more detailed descriptions of planting material and status of resistance to a broader array of pathogens present in the field. Some resistance genes, such as those for *Meloidogyne incognita* in tomato (25) and cotton (7), are not effective at high soil temperatures, emphasizing the need for more detailed information regarding prevailing environmental conditions.

Planting descriptions: The planting date was almost always given and in most cases depth of planting was reported for annual crops. Eighteen of the 24 papers gave actual stand or target stands. Nematodes and nematicides as well as disease complexes involving nematodes and fungi can greatly affect crop stand. Seedling diseases that are known to be exacerbated by nematodes were rarely mentioned. Phytotoxicity from either the test agent(s) or other pesticides was not reported. Severe phytotoxicity can result in reduced stands even in situations where the compound had nematicidal action (39).

Only two papers dealt with perennial crops such as trees, vines, shrubs, etc. The susceptibility of perennial crops can be greatly affected by production practices. Reports should include background information on winter injury, pruning date, rootstock, and the presence of chronic disease complexes such as peach tree short life. Production practices such as liming (type applied) and size of the transplant hole often will affect a nematode problem on a perennial crop such as peach (40).

Growth stage descriptions: Although preplant and at-plant applications of nematicides are most common on annual crops, the use of post-emergence treatments is common on perennial and increasing on many annual crops. Post-emergence application methods include soil drenches; broadcast, banded, or directed sprays; and root dips prior to transplanting. Plant growth stage, overall plant health, and soil zone or plant part treated should be well defined for post-emergence applications. Most field crops such as cotton (20) and soybean (10) have well-defined systems for reporting growth stage. Accumulation of growing degree days at the time of application, if models are available, and effects of any at-planting treatments up to that date should be documented. Post emergence is the primary time of application for some nematicides such as oxamyl, and excellent results can be obtained. However, results tend to be highly variable and appear to be affected by general plant health, environmental conditions, plant age, leaf area, and age (9,12,26). Environmental conditions that should be reported for foliar sprays include wind conditions, air temperature, relative humidity, and leaf surface moisture. The tolerance of plants to transplanting varies with age, and the interval between treatment and exposure to the nematode can affect efficacy with oxamyl, especially for foliar treatments (12,26).

Chemical applied: All papers reported this criterion. If a registered product is used, its trade name as well as the common chemical of the active ingredient should be given. In cases with chemicals such as phenamiphos or carbofuran with multiple fomulations (granular [G] vs. liquids [EC]), the formulation applied should be identified. The carrier solution used to dilute and deliver liquid nematicides and any spray adjuvants or spreader-stickers should be well defined for properties such as pH and other mineral constituents.

Measuring nematode population responses: Almost all authors gave some indication of initial nematode density and subsequent changes, but only 6 of 16 gave race when it would have been appropriate. Reports on efficacy of nematicides should document not only changes in yield, but also the change (reduction) in nematode population density that may or may not be a major contributing factor to observed yield increases. Barker et al. (3) have outlined, in detail, methodology and data needed to document changes in population densities. Appropriate methods and timing of sampling will vary with combinations of nematode, crop, and nematicide tested. As they state, "Sampling is frequently the weakest link in field evaluations of nematicides." Care should be taken to choose the correct sampling site, method, time, and intensity. Degree-day or hour models or those that are based on "physiologic time (cumulative heat units above the activity threshold required to complete a life cycle)" (11,18) are seldom used but can be helpful in determining the appropriate sampling time.

Soil samples should always come from the root zone whether on annual or perennial crops, and the sampling zone, especially for perennial crops, should be reported accurately. P_i should be established for each plot and all counts should be reported as nematodes (or eggs) per volume of soil or gram of root weight. Differentiation of live vs. dead nematodes can be an issue and should be taken into account. Extraction techniques should always be thoroughly reported. If possible, extraction efficiency should be determined and reported for each extraction method used. Nematodes occur in polyspecific communities, and it is important to report all nematodes present, not just the target organism. Most tests involved naturally infested fields. When plots were artificially infested, the culturing of the inoculum such as age and source of cultures and the host plant was well reported, but inoculum viability and field infestation methodology were often poorly defined.

Measuring yield and plant response: Criteria measuring yield and plant response have been described previously (27). All but two of the papers reviewed gave adequate descriptions of yield, but few reported plant symptoms of infection such as root lesions or galling. Yield measurements can include gross weights as well as reductions in grade, quality, color, or other aesthetic parameters. Authors should be sure that yield reports are appropriate for each crop studied. Yields of field crops such as soybean and corn need to be standarized to moisture content. Seed cotton yields should be converted to lint yield by ginning samples; in many cases, fiber quality measurements are appropriate. Failure to adjust samples to appropriate criteria may mask differences in maturity and obscure nematode effects. Examples where effects on quality and(or) maturity are more important than gross yield include root-knot nematode on potato (32) and chile pepper (38) and reniform nematode on pineapple (34). Use of methyl bromide on high-value vegetable crops not only can increase yields but also can increase economic returns by allowing more uniform fruit maturity and allowing total harvest with fewer pickings (25).

Criteria Reported Inadequately

Field cropping history and pesticides applied during the test: If authors were judged against Nesmith and Averre's (24) suggestion that information from the last 3 years should be included on "amount and condition of remaining crop residue, crops, weeds, hosts, and flooding history," this is the area that would show the greatest shortcomings. Only 7 of 23 papers reported on crop(s) grown, and none gave pesticide(s) applied in the test site for the previous growing season(s). More than 50% of the papers reviewed did not report on specific herbicides or insecticides used during the test. More than 30% of the papers relied on some variation of the phrase "Local recommendations for production practices were followed" to describe pesticides applied. Identification of not just the cropping history, but of pesticides previously applied, can be of immense value in interpreting results. Failure or reduced efficacy of a nematicide may be a result of accelerated degradation that can occur with all nematicides after repeated applications and can continue to occur for several years after the last application (35). Combinations of herbicides and nematicides can result in either synergistic, antagonistic, or independent effects (33). Widely used herbicides such as sulfonyl ureas (28) recently have been found to suppress plant growth and yields. As more is discovered about the interactions of herbicides, nematicides, nematodes, and plants, it becomes obvious this information will become more critical to the interpretation of test results and the development of effective nematode management strategies.

Nematode interactions: The negative interactions of nematodes with other pathogens and detrimental effects on beneficial organisms is well documented (4,36). A virulent pathogen or a pathogen that forms a disease complex with the nematode studied should be reported if either is present in a test site.

Many products such as aldicarb, carbofuran, oxamyl, and phenamiphos have insecticidal properties, and the presence of pest insects can greatly confound test results when they are used as nematicides. Partitioning the insecticidal vs. nematicidal effects can be difficult and will require enumeration and reporting of insect densities for the experiment (21). Indirect effects also can occur if the insecticide-nematicides disrupt beneficial insect populations, especially on crops such as transgenic Bt cotton that rely partially on beneficial insects for pest-insect management.

Land preparation: The degree to which fields are disced, chisel plowed, turn plowed, or infurrow subsoiled was usually well detailed in published results of row crop experiments. In general, these were more accurately reported than most other agronomic or production-related practices. Fertilizer rates were reported by only 12 of the 24 studies. The term "use of local recommendations" or "standard regional practices" was used in 11 of 24 reports to describe land preparation and production practices for a study.

Soil temperature and moisture: Both of these factors are critical in establishing the relative activity and mobility of soil-applied nematicides (6) as well as nematode activity and plant growth. Both temperature and moisture affect the nematicide transformation rate, such as the oxidation of aldicarb to aldicarb sulphoxide and then to aldicarb sulphone (35). Most researchers do not report soil temperture and moisture unless, in their opinions, heavy rainfall has caused excessive leaching or temperature extremes have altered the "normal" movement of a fumigant in the soil profile. Rainfall during the treatment period can affect soil degradation, leaching, efficacy, and nematicide residue in crop tissues (17).

Almost two-thirds of the experiments were conducted under irrigated conditions. Even for these, the cumulative rainfall and irrigation during each 24-hour interval for the first 4 weeks might be useful. This information, combined with soil texture and tillage practices, could provide a clearer picture of pesticide performance under a diversity of environmental conditions. A graph of rainfall and temperature for the remainder of the growing season also would help in interpreting additional plant stresses that, together with nematode damage and the degree of management implemented, determine yield response to nematode control agents.

Soil temperature is rarely reported, but along with soil moisture may be the most critical factors in determining nematode activity, including life stage, in a given soil and thus susceptibility to nematicide treatment and potential damage to host plants. Soil temperature can be used to calculate degree days and heat units for predicting egg production by a nematode species (37) and to explain differences in penetration and subsequent reproduction for a nematode species between planting dates (31). Soil temperature also can explain infection rate differences between two species of nematodes on the same host, even in the same field, and subsequently why fumigation controls one of the species and not another (32). Degree-day models also can be used to characterize growing conditions and predict yields for crops such as cotton (20). Critical point models also can explain the breakdown of resistance in a resistant cultivar of cotton (7) or tomato (25) to a nematode pathogen such as *M. incognita* after exposure to high temperatures.

Nematicide application methodology: The goal should be to duplicate the application rates and techniques, not the equipment. The rate of nematicide applied is one of the most critical factors in a test and generates some of the greatest confusion. It has been reviewed recently (8) and authors are reminded to: (i) clearly state whether reported rates are active ingredient (preferred) or product; (ii) clearly state if rates are for a unit area (g/m^2) or for linear distance (g/m); (iii) avoid jargon when describing application techniques and equipment used and be precise even if it requires more space (diagrams are more than appropriate if the technique is difficult to visualize); and (iv) emphasize if the rate reported is on a broadcast, row, or unit basis (i.e., strips, bands, in-furrow, side-dressed) less than for the total hectare (broadcast application).

Application of granular materials is relatively simple compared to chemigation and fumigation. The carrier (granule) is basically inert, and the primary environmental factor to be measured is soil moisture or rainfall that will directly affect the movement of the nematicide from the granule into the soil. Reporting soil moisture is therefore critical in understanding the efficacy of granular materials. However, some materials such as phenamiphos may be applied broadcast and incorporated even as granular materials (16).

Chemigation, the process of using an irrigation system to deliver water-soluble fertilizers, pesticides, or other pest control agents, in a common practice and is increasingly used in the production of many fruit and vegetable crops (2,14). The types of irrigation systems used vary considerably but can be simplistically categorized as either point or line-source. Assuming a nematicidal concentration in irrigation water, two factors critical in determining the success of chemigational delivery of nematicides involve wetted surface area and wetting depth. Therefore, some indication of the wetted surface area and penetration depth of the water front must be provided to spatially characterize the potential zone of nematode control. For example, metham-sodium treatments were effective for control of *M. incognita* only when at least 50% of the bed width was treated and penetrated to a depth of 45 to 60 cm (30). Surprisingly, this information is seldom reported, despite its extreme importance for the development of management recommendations and to expedite refinements in application procedures and technology.

In addition to observations of wetted area and spatial distribution, descriptions of the design and mechanics of the irrigation system and procedures and timetables for toxicant injection into the irrigation system also should be reported. Concurrent with the views of Apt and Caswell (2) and Lembright (19), we emphasize the need to include the following parameters within the reports of such tests: (i) soil hydraulic conductivity and sorptivity; (ii) discharge rate; (iii) pesticide concentration in irrigation water; (iv) irrigation time; (v) whether the nematicide is applied continuously through the irrigation run or, if not, the amount of water applied before and(or) after application of the nematicide; (vi) type of irrigation and chemical injection system used; (vii) distance between irrigation emission points; (viii) dilution concentration and volume of injected nematicide; (ix) flow rate of the irrigation water; (x) plant proximity to emission sources; and (xi) measures of application uniformity. For chemigation applications involving point source, elevated sprinklers and the degree of overlap in sprinkler coverage also becomes a useful statistic, particularly if soil sampling for efficacy testing predominates from areas of overlap (2× dosage) or if sprinklers do not provide uniform distribution within their circular paths of wetted areas.

Soil fumigants are compounds that are capable of radial diffusion as a gas from a point source and form a distribution pattern throughout the soil profile. The magnitude of their diffusion pattern is regulated by certain environmental and edaphic characteristics of soil. The principal factors affecting soil fumigant performance (efficacy) are soil type, texture, moisture, temperature, organic matter content, nematicide dosage, diffusion characteristics, and application technology (19). Suboptimal soil conditions will, in most cases, limit spatial diffusion of the compound, causing reduction in concentration gradient, treated soil volume, and efficacy. Soil moisture content usually has the greatest impact on restricting fumigant diffusion in soil, and the volume of soil that is effectively treated. All fumigant nematicides that are dependent upon gaseous diffusion are also less effective at low soil temperatures.

With some limitations, the zone of nematode control for both fumigant and nonfumigant nematicides is most strongly influenced by the depth of soil injection or incorporation. Reporting the depth of release of the material, chisel spacing, soil moisture, and temperature are critical. Also critical is whether a tarp (be sure to clearly state the type) or other methods such as water are used to confine the gas to the soil. Defining the concentration of nematicide applied is most complicated for the fumigants, which are applied in a truly 3-dimensional manner and all parameters that regulate fumigant diffusion and influence pest and disease control must be reported. How the application was applied (i.e., formulation, delivery system including equipment used for application) also should be included. Also, include information on any propellant used.

Conclusions

At least 18 compounds have been used commercially as nematicides most likely beginning in 1881 with Kuhn testing carbon disulfide for control of sugar beet nematode (15). Since 1881 economic, environmental, and regulatory concerns associated with pesticide use have forced the evolution of nematicide testing standards to today's level of complexity and technological sophistication. Environmental parameters such as soil temperature and moisture can be recorded more than once a minute at many locations simultaneously, and the concentration of a chemical in soil or plant samples can be determined to parts per million or even parts per billion in some instances. At the same time, relatively gross error is associated with estimating changes in nematode densities in soil or plant tissues, which is the basic premise of most efficacy trials. The nematicide reports in AAN demonstrate a need for improved reporting of soil moisture and temperature at the times of nematicide application; application methods and rates especially for tests involving fumigants, chemigation, and perennial crops; agronomic and pest management data including pesticides applied, reductions in yield versus quality, and plant growth stages; and growing degree-day models.

Concurrent with our perceived needs for more detailed reporting, we also realize that cost and time involved in the collection of such data could outweigh its value in improved interpretation of results. Costs and access to instrumentation may preclude investigators from collection of many data. The degree of precision we propose in reporting information on application methodology and environmental, edaphic, and plant growth parameters also is likely to create a dilemma with the editors of scientific journals. The current standard is concise reporting of materials and methods. Lengthy, more comprehensive reports may exceed the perceived limits for documentation. Implementing this higher standard, which we believe our science needs, may require reevaluation and change of editorial policy.

Previously, it was common for a researcher to report only information that appeared to impact or explain test results. Although we have limited our comments to nematicide tests in this review, we see even greater potential needs for the reporting of tests using alternative control strategies such as soil amendments and biocontrol agents. In the future, enhancing agricultural production may require that growers integrate several management tactics, including less effective chemicals, to incrementally reduce nematode densities and related plant stresses (29). Each individual tactic will likely be less effective than traditional nematicides.

Difficulties with interpreting nematicide efficacy tests and reported rates of nematicide application in many field trials has prompted the development of reporting standards for scientific publications (2,8, 13). Standards are necessary because pertinent information regarding application technology and production practices (i.e., bed width, row spacing, pesticide placement, and calibration) employed within these tests is frequently omitted or insufficiently described to permit duplication in subsequent experiments or the calculation of the actual row or broadcast nematicide application rate. Similarly, the quantity of active ingredient applied per hectare is frequently unreported. Such formatting will facilitate performance comparisons of particular chemical products and application rates between studies.

Reporting soil and environmental data may ultimately be more useful for relating nematode control and crop performance than the two-dimensional concept of describing application rates of nematicides to the soil surface. Higher standards for reporting soil and environmental characterization data as well as specific cultural practices employed should be considered. For example, the failure or inconsistency to control nematodes between fields and between years with a specific rate of nematicide often is related to change of environmental conditions. Variation in soil texture and profile, precipitation, and production practices strongly influences nematicide efficacy by affecting rates of pesticide movement and dissipation. Nematicide application rates as currently reported define only the amount of material applied to the soil surface rather than the dosage over time to which nematodes in soil are subjected. In reality, the level of pest control achieved is probably more closely related to pesticide concentration in the soil water, outward radial movement which determines total treated soil volume, and residence time of the chemical in the soil than to surface application rate.

Statistics describing the uniformity with which nematicides are applied within a field or orchard may also be desirable. For example, it has been our experience that in many grower field chemigation experiments, irrigation system design and maintenance can significantly affect delivery uniformity of nematicides to target sites. If a uniformity problem is severe, then the net effect is to significantly reduce the overall nematicide application rate to the majority of the treated field. Without an estimate of delivery uniformity, the information derived may lead to erroneous conclusions and invalid comparisons. The calibration process prior to field application of nematicides describes the precision in which the formulated product is distributed over the field and should be reported.

The evolution of nematode management strategies and control agents is rapidly being driven by environmental, economic, and regulatory concerns away from the single application of one highly effective management practice to the continuous integration over time of numerous agents that rely on additive or even synergistic activity to ultimately obtain the same level of control. Developing rational guidelines for the continued use of traditional nematicides and future use of nontraditional control strategies and agents will require extensive documentation of each tactic's performance under diverse environmental conditions. More precise definitions of environmental conditions, rate and placement of the control agent, exposure time of the nematode to the agent, and host plant response to the nematode and the agent are key to developing site-specific recommendations for maximizing benefits of nematode control agents or tactics.

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