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Forum article

MONETARY VALUE ESTIMATES OF NEMATODE PROBLEMS, RESEARCH PROPOSAL AND PRIORITIES: THE RICE EXAMPLE IN SOUTH AND SOUTHEAST ASIA (1)

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Because research expenses are increasingly considered as short-term investments, research is more and more problem- and output-oriented. Monetary values of expected outputs, amounts of investment and time frames necessary to achieve objectives are used by decision makers to set research priorities. Nematologists do not escape this trend. Some may be tempted to support their research proposal by providing the monetary values of the problems they propose to address. Others who consider these estimates as extrapolations based on fragmentary information, are, for ethical reasons, reluctant to provide them. The objective of this paper was to test the usefulness of monetary value estimates to set research priorities concerning rice-parasitic nematodes.

It is estimated that a 65 % increase of the world rice production will be needed by 2020 to meet the projected population growth. For South and Southeast Asia (S-SE A), the increase needed is estimated at about 100 % (Anon., 1989). For a nematologist, a research objective would be to increase the productivity and sustainability of the different rice ecosystems in S-SE A by controlling rice nematode parasites.

With the exception of the ufra disease *(Ditylenchus angustus)* and, to some extent, of the root-knot nematode (*Meloidogyne* spp.), rice farmers cannot suspect nematode problems. Nematologists have to rely on evaluations provided by scientists to estimate the economic importance of rice nematodes. There are strong discrepancies between published estimations of the economic importance of nematodes in rice production. Sasser and Freckman (1987) estimated the loss due to nematodes at 10 % of the world rice production. They based their estimate on the replies of 371 nematologists from 75 countries to a questionnaire. Herdt (1991) estimated this loss at less than 1 % in Southeast Asia. His estimate was based on the advice of a USA scientist panel. Obviously, these two groups of scientists had different sources of information.

Evaluations of the potential economic importances of rice-nematodes

More than 100 species of plant parasitic nematodes have been found associated with rice (Fortuner & Merny, 1979; Gerber *et al.*, 1987). Bridge *et al.*, (1990) listed 27 species known or suspected to cause yield loss in rice. The most prevalent in S-SE A were *Aphelenchoides besseyi, Ditylenchus angustus, Hirschmanniella* spp., *Meloidogyne graminicola.*, and *Pratylenchus* spp.

A. besseyi, causal agent of the " white tip " disease, still causes yield losses in some countries (Rahman & Miah, 1984). However, simple control methods and sources of resistance and tolerance are available (Fortuner & Orton Williams, 1975; Bridge *et al.*, 1990). This nematode is no longer a problem in the USA where it has been controlled by a combination of hot water treatments of seeds and use of resistant cultivars (Hollis & Keoboonrueng, 1984). It may be difficult to develop cheaper and safer methods of control.

The four other nematode genera or species are widespread in S-SE A. To estimate their economic potential on the rice production in the area, it is necessary to consider the yield losses they can cause and their distribution in the different rice ecosystems. Rice is cultivated in five major rice ecosystems: irrigated, rainfed lowland, rainfed upland, deepwater, and tidal wetland. For each ecosystem, the relative contribution to total rice production, the major nematodes and estimates of their frequency of occurence are shown in Table 1. The potential economic importance (PEI), or estimated percentage of the total rice production lost because of damages caused by each of the four nematodes in S-SE A, was estimated as: $PEI = 100\ (P) \times (Ai) \times (Yl)$, where:

P = % of total rice production of the ecosystem(s);
Ai = % of the area infested with the nematode; and
Yl = % estimated yield loss caused by the nematode.

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Table 1. Relative contribution to the total rice production, major nematode genera and their estimated frequency of occurrence by rice ecosystem in South and Southeast Asia.

Ecoststem	% of total rice production	Major nematode genera found in the ecosystem	% of fields infested
Irrigated	73	*Hirschmanniella*	> 90
		Meloidogyne	1
Rainfed	17	*Hirschmanniella*	> 90
		Meloidogyne	25
Deepwater and tital wetland	5	*Hirschmanniella*	> 90
		Meloidogyne	20
		Ditylenchus	10
Upland	5	*Pratylenchus*	60
		Meloidogyne	30

D. angustus, the causal agent of ufra disease, mostly occurs in deepwater rice. It is present in India, Bangladesh, Myanmar, Thailand, and Vietnam (Bridge *et al.,* 1990). Calting *et al.* (1979) reported a 20 % yield loss over 20 % of the deepwater area in Bangladesh. This may be a high estimate for Thailand where the distribution of this nematode is limited, and for Vietnam where the progressive abandonment of deepwater rice in favor of irrigated rice has induced a drastic reduction in ufra occurrence (Cuc & Prot, 1992 *a*). However, it is the only estimate available. Using it, the PEI for *D. angustus* was :

PEI (D. angustus) = 100 (0.05) (0.20) (0.20) = 0.2

Hirschmanniella spp. are omnipresent in all flooded rice ecosystems in S-SE A (Bridge *et al.,* 1990; Prot & Cuc, 1990; Jairajpuri & Baqri, 1991; Cuc & Prot, 1992 *b*). Their noxiousness to rice has been demonstrated in inoculation experiments. In pot experiments, an average yield loss of 34 % (31-39) has been observed with initial populations ranging from 100 to 1 200 individuals per plant (Yamsonrat, 1967; Mathur & Prasad, 1972; Babatola & Bridge, 1979; Jonathan & Velayuthan, 1987). With an initial population of 5 000 nematodes per plant, Panda and Rao (1971) observed a 51 % yield loss. In experiments conducted in one-m^3 microplots, Fortuner (1974, 1977) observed a 42 % yield loss when fertilizer was not applied and a 23 % yield loss with adequate fertilization. The control of *Hirschmanniella* spp. under field conditions resulted in 24-36 % yield increases in Thailand (Taylor, 1968) and 17-36 % in the Philippines (Prot *et al.,* 1992 *b*). In India, it is estimated that *Hirschmanniella* spp. cause an average yield loss of 25 % (Jairajpuri & Baqri, 1991). All estimates of yields loss due to *Hirschmanniella* spp. range between 51 and 17 %. We may consider 20 % yield loss as an acceptable estimate, and in half of the fields where *Hirschmanniella* spp. occur their development is limited by antagonistic factors or their effect already compensated by high inputs (Thorne, 1961). Considering these assumptions and the presence of these nematodes in all flooded rice environments, their PEI was :

PEI (Hirschmanniella spp.) =
100 (0.73 + 0.17 + 0.05) (0.90/2) (0.20) = 8.5

M. graminicola is the predominant root-knot species affecting rice in S-SE A (Bridge *et al.,* 1990; Jairajpuri & Baqri, 1991). In India, it is considered as the second nematode rice pest after *Hirschmanniella* spp. with yield losses estimated at 16-32 % (Jairajpuri & Baqri, 1991). Although *M. graminicola* occurs in all rice ecosystems yield losses are more severe in upland and unfavorable rainfed ecosystems. It may also cause yield loss in irrigated rice but only in fields where the soil is not permanently submerged. With the exception of India, yield losses caused by this nematode have not been assessed; however, it is a very strong pathogen and, when it occurs, can cause significant yield loss (Bridge *et al.,* 1990; Jairajpuri & Baqri, 1991). Therefore, an estimate 25 % yield loss in infested fields may be considered. With this assumption and all those made on its frequency of occurrence (Table 1), the PEI for *M. graminicola* was :

PEI (M. graminicola) =
100 {[(.73) (.01)] + [(.17) (.25)] + [(.05) (.2)] + [(.05) (.3)]} (0.25) = 1.9

Pratylenchus spp. occur only under upland conditions. Two species, *Pratylenchus indicus,* which is widely distributed in India, and *P. zeae,* have been reported to cause yield losses in S-SE A. A 34 % yield loss has been observed with low initial number (30/seedling) of *P. indicus* (Prasad & Rao, 1978). With the same nematode, Rao *et al.* (1986) reported yield loss up to 53 %. *Pratylenchus* spp., mostly *P. zeae,* are omnipresent in upland rice ecosystems in Sumatra (Prot *et al.,* 1992 *a*) and the Philippines (Villanueva *et al.,* 1992). Control of *P. zeae* by chemical application (Plowright *et al.,* 1990) and crop rotations (Aung & Prot, 1990) has resulted in 13-55 % yield increases. Yield increase after control of low populations of *P. zeae* (Plowright *et al.,* 1990) and the absence of correlations between initial inoculum and grain yield in pot experiments and under field conditions (Prot & Savary, 1993) suggest that yield loss can occur when detectable populations of *P. zeae* are present. With the few information available, it may be inferred that *Pratylenchus* spp. infest 50 % of the upland rice area and cause an average 30 % yield loss when they are present. Their PEI was :

PEI (Pratylenchus spp.) *= 100 (0.05) (0.5) (0.30) = 0.7*

When the four calculated PEIs are compared, *Hirschmanniella* spp. have the highest economic potential with 8.5 %, followed by *M. graminicola* with 2 %. *D. angustus,* which causes ufra, one of the most devastating diseases affecting rice, has an insignificant estimated effect (0.20 %) on total rice production. Hence, it is a nematode of local importance. *Pratylenchus* spp. also have a low estimated incidence (0.7 %) on this production. It may be of economic importance in upland rice ecosystem, but this ecosystem contributes only 5 % to the total rice production. Are these estimates accurate? What are the factors affecting the calculation of the different PEIs?

Accuracy of these evaluations

Yield loss estimates are based on inoculation experiments conducted in pots or microplots and on yield increases observed after the control of nematodes under field conditions. Pot and microplot experiments, which are relevant to prove the noxiousness of a parasite and to understand the host-parasite relationships under different conditions, are performed under conditions that differ from those prevailing in the field. Hence they may not provide an accurate estimate of actual yield losses. Because control methods may affect other factors (Cadet & Quénéhervé, 1982; Venugopal & Litsinger, 1984, Baujard *et al.,* 1987) contributing to or constraining yield, yield losses estimated from control experiments are also questionable. Nematodes can be indicators of a complex of productivity factors that have been modified by the metohds used to control them.

For *Hirschmanniella* spp., and *M. graminicola,* the same yield loss estimate has been used in all ecosystems where they occur. This is most certainly not the case, but one may consider that a single estimate is as good as several guesses.

Within an ecosystem, the yield loss caused by a nematode has been considered uniform. But because of the variability within each ecosystem, and because different cultivars are grown in the same ecosystem, this is most certainly inaccurate. Moreover, farmers' cultural practices can reduce nematode effects. This has been taken into account to minimize *Hirschmanniella* spp. PEI. In addition, cultural practices may either decrease or increase nematode damage. For example, *Hirschmanniella* spp. can be controlled by growing the green manure crop *Sesbania rostrata* in rotation with rice (Prot *et al.,* 1992 *b*). However, because *S. rostrata* is a good host for *M. graminicola,* the same rotation applied in rainfed areas where it is present may result in a significant increase in yield losses due to the rice root-knot nematode.

Estimated yield losses have been considered as constant over time. It has been assumed that they will not decrease or increase in the future. What will be the susceptibility of the cultivars of the future? What will be the effects of nematodes when farmers will have to produce 5 tons in fields where they are now producing 2.5 tons?

The area infested by *Hirschmanniella* spp. is relatively easy to determine. They are present in almost all rice fields that are flooded for a period of time. For *M. graminicola* and *Pratylenchus* spp., the paucity of the information is such that the rules of thumb have been followed.

The contribution of each ecosystem to the total rice production has been considered constant. A significant extension of the irrigated area is doubtful; it may even decrease because of loss of land due to increase in population and urbanization. Moreover, decrease in water availability and its increasing cost may further reduce the irrigated area.

The contribution of each ecosystem to the total rice production had a tremendous effect on the estimation of the potential economic importance of each nematode. The poorer rice farmers are those living in the less favorable rice ecosystems. A strong emphasis on irrigated rice has strong equity implications. Environmental factors also have to be considered. For example, it may be necessary to improve the productivity and the sustainability of the upland rice ecosystem to reduce the slash-and-burn practice that contributes to soil degradation. Control of upland rice nematodes may become important when equity and environmental issues are considered.

The PEIs calculated above are easy to criticize. However, considering the research objective chosen, these PEIs indicate an order of priority between the different nematodes suspected to affect rice production in S-SE A. When the four PEI are added, the percentage of yield loss due to these nematodes in rice is estimated at 10.5 %, a figure close to the estimate (10 %) given by Sasser and Freckman (1987). More than 260 millions tons of rice are produced each year in S-SE A, a 10 % loss would represent 26 millions tons or 5.2 billions US dollars. It may be argued that it is impossible to base a global yield loss estimate on a few inoculation and control experiments. However, inoculation experiments have repeatedly proven their noxiousness to rice. Moreover, dozens of nematode control experiments conducted in different S-SE Asian countries have resulted in yield increase averaging more than 20 % without additional fertilizer input. Considering that nematode control can affect other factors, the results indicate that there are constraints in the soil that may reduce rice production by 10 %, but can be manipulated to increase it. Nematodes can be one of these constraints and it may be worthwhile to consider them.

Conclusions

This attempt clearly indicates that, from a deontology point of view, it is risky to attach estimates of monetary values just to make a research proposal attractive to decision makers. However, it indicates that nematodes are of potential economic importance to rice production in S-SE Asia and hence are a viable subject for research. It also indicates an order of potential economic importance of the different rice diseases induced by nematodes. However, this order of importance depends more on the contribution to total rice production in the agroecosystem in which the nematodes occur than on the level of damage they cause. This attempt also clearly indicates that collaborative studies with agronomists, soil scientists and plant pathologists are needed to understand the role of nematodes on the productivity and sustainability of rice ecosystems, nematode management, and how to compensate for their effects.

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