THE ROLE OF PESTICIDES IN SE ASIAN RICE IPM: A VIEW FROM THE MEKONG DELTA

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Summary

Pesticide application remains an important component of rice pest management in Việt Nam and responsible use should be integrated back into a strategy of good agricultural practices. Crucial skills that need to be fostered include: better product selection with safe and efficient application; the role of action thresholds must also be re-considered.

Introduction: the realities of rice IPM

Rice is arguably the world's most important crop by consumption: especially in SE Asia, where 618 million people (11.7%) currently live in 3.3% of the World's land area[1]. According to the Food and Agriculture Organisation (FAO) of the United Nations, it is the third most important crop in terms of agricultural commodity trade (after sugar and maize). Việt Nam is currently the world's fifth largest producer (after China, India, Bangladesh and Indonesia) but is usually one of the top two rice exporting countries. Threats to rice production include losses due to pests (insects, diseases, weeds and rodents). It has been estimated that losses due to pests in tropical Asia are approximately 37% – equivalent to 120–200 million tonnes (Savary *et* al., 2000; Oerke, 2006).

My interest in rice pest management started with work for FAO 35 years ago in Việt Nam, in partnership with the Plant Protection Department (PPD) of the Ministry of Agriculture and Rural Development (MARD) and the National Institute of Plant Protection. In the early 1980s, the country was still recovering from prolonged war and food was very scarce. At that time agricultural inputs, optimised seeds, fertilisers and pesticides, were effectively rationed and one aid programme, co-funded by the Swedish International Development Cooperation Agency (SIDA) provided some $10 million for crop protection supplies.

In those days as now, the key insect pest was the brown plant-hopper (BPH), *Nilaparvata lugens and* diseases – rice blast, *Magnaporthe grisea*, especially in the spring crop and sheath blight, *Rhizoctonia solani* in the summer season. Methyl parathion and lindane were widely available insecticides, but effective controls of fungus diseases were in their infancy. The phenomenon of insecticide-induced resurgence of insects such as BPH was understood only by a few scientists in Vietnam, and had only been identified in the west for less than a decade (Heinrichs, 1979). The roles of our team included providing for crop protection supplies (with specific instructions to 'avoid toxic pesticides', which I interpreted as no products in WHO class 1), carrying-out field trials to identify appropriate alternatives and encouraging the Government to adopt pesticide registration and quality control schemes (Bateman, 1985). Crop protection activities were carried out on a commune basis, especially in the north and operationally, application with motorised mistblowers was considered most appropriate (see page 2).

By the end of the 1980s, it had become widely understood that successful insect control was best achieved in the context of integrated pest management (IPM) and over the following decade this strategy, scientifically based on conserving NE (predators, parasitoids and pathogens: see below), became the general foundation for good agricultural practices in rice (Gallagher *et al*., 2000). In addition, farmers should:

- grow a healthy soil and crop;
- observe their field regularly (*e.g*. soil, water, plant, pests and natural enemies);
- strive to become experts themselves.

This IPM strategy was enthusiastically officially adopted in Vietnam and other SE Asian countries, but I will argue here that real IPM is not is not being widely practiced by farmers for a number of reasons. Possibly the first of these has been a failure to appreciate the importance of, and engage with, pesticide companies, retailers and others whose business is pest management.

There appear to be 'two narratives' on pesticide use, where pesticide science is almost entirely left to industry. Agro-chemical companies and retailers for their part, are increasingly understanding the 'tragedy of the commons' risks: where the over-exploited common resource here is an ability to manage key diseases, that could ultimately threaten rice production. All stakeholders in crop protection, including farmers and the various associates in the pesticide supply chain, have a common interest in maintaining the sustainability of effective pest management: including the responsible use of pesticides.

[1] Excluding Antarctica

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Classic, radiating patches of 'hopper burn' caused by the brown plant-hopper (BPH), taken in 1983. Damage then death to rice occurs when many individuals feed on the phloem: 'hopper-burn', can develop in quite regular circles as expanding populations radiate out from initial parent insects.

It is highly probable that the excessive use of broad-spectrum insecticides, which kill the natural enemies (NE) of insect pests, increased plant-hopper outbreaks. This is called pesticide-induced resurgence.

Addressing these problems has been the subject of a project co-financed by *CropLife International* and *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ), where key messages in responsible use are to be demonstrated by PPD specialists at provincial and district levels, the extension services and farmer organisations and local retailers. According to MARD, there are around 22,000 pesticide stores across the country but only 80% of these are licensed and there are "inadequacies in pesticide advertising and labelling, while many farmers still continue to ignore basic instructions on their use" (http://www.dtinews.vn/en/news/018/26217/poor-monitoring-allows-pesticide-abuse-to-continue.html). Improvements can only be achieved through training and education of **all** stakeholders and this project is perhaps pioneering: by including the development of know-how of retailers, besides the generally-agreed need to support farmers.

A survey in Đồng Tháp Province and a Curriculum for the Mekong delta

In 2015, a survey of both farmers and pesticide retailers in five rice growing districts of Đồng Tháp province identified key gaps in the implementation of IPM. The purpose of this was to identify future training requirements and, where appropriate, policy needs for pesticide supply. Some conclusions were:

Only a small minority of farmers (16%) claimed to practice IPM, despite having undergone IPM training in the 1990s, and most farmers evidently were spraying unnecessarily. Farmers typically apply pesticides 7–10 times per season: often preventatively for diseases or if any insects are present.

There is generally a poor understanding of pesticide science – by farmers, spray contractors, retailers and agricultural colleges: a subject which has been neglected in previous IPM curricula.

Existing pesticide application practices are unsafe and inefficient. Nearly all (>99%) farmers and contractors walk into their own spray, and therefore rely on personal protective equipment (PPE: gloves, face masks, etc.) as their 'first line of defence '. Sprays carried out in the late tillering stage (the main crop protection stage) are at very high volume – commonly >500 L/ha.

The Đồng Tháp survey revealed that rice blast is the principal disease, prevalent in cool and humid conditions during the spring season. *Echinochloa* spp. was among the most important weeds and BPH is the insect pest of greatest concern. Similar levels of BPH were reported by farmers between seasons (92% in Winter–Spring, 84% in Summer–Autumn). The rice leaf-folder, *Cnaphalocrocis medinalis*, is also sprayed with a large number of insecticide products specifically registered for this putative 'pest'.

Responsible pesticide use in practice

In order to address some of these issues, two curricula have been developed, for both farmers and retailers, to be delivered in weekly workshops over a rice cropping season:

Farmers training modules	Retailers training modules
Introduction: rice eco-systems	Introduction to responsible pesticide use
Agricultural inputs: their responsible and economic use	Understanding pesticide products and their labels: giving the best advice to customers
Introduction to IPM: and plant protection measures at the seedling stage	Pesticide application: equipment and calibration
How to be an effective rice doctor?	How to be an effective rice crop doctor?
Importance of natural enemies: IPM decision making during the tillering stages	Pesticide Management
Understanding pesticides and their labels: a buyer's guide	Transportation and storage of pesticides
Responsible pesticide use: maximum tillering stage	Maximising the safe use of pesticides and PPE
Pesticide application and calibration	Better pesticide handling, first aid and conclusions
Decision making during the panicle initiation to flowering stages	
Pesticide Management	
Decision making during milky to ripening stages: avoiding residues	
Pesticide transport, storage, handling, first aid and conclusion	

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Three examples of important natural enemies: (left) a 'generalist' lynx spider predator, *Oxyopes* sp.; (centre) a parasitoid of the rice leaf-folder, *Braconidae*; (right) a pathogen, *Metarhizium* infected BPH. (Photo courtesy Trịnh Thị Xuân, Cần Thơ University)

In developing this curriculum, fears have been expressed that such a course would be 'promoting chemical pesticides'. This emphatically is not the intention, as its role is 'filling in knowledge gaps' required to implement practical IPM. It promotes the use of biological control methods and, perhaps even more importantly, addresses issues such as safety, residues and the real risk of pesticide resistance. In our survey, many farmers are aware of natural enemies (NE) in their fields; more than 80% of farmers believe that they use 'selective pesticides', but there may be some confusion here. A number of fermentation products actually have a very broad spectrum of activity and, by way of illustration, have long been problematical for inclusion in the *Manual of Biocontrol Agents* by its editors. This and other issues are discussed further in the *ASEAN Guidelines Regulation, Use, and Trade of Biological Control Agents*. One problem specifically identified was that poor application practices (failure to achieve efficient dose transfer to target pests) have been a significant constraint to the introduction of biological (microbial) control agents (GIZ, 2014).

The three major groups of NE are predators, parasitoids and pathogens are shown above.

What to do specifically about interventions?

It has been suggested that banning or restriction of pesticide products is an answer, but attempts to do this have evidently failed: partly because the majority of farmers in Asia get their advice on pest control from retailers and training for responsible pesticide use has been neglected.

Insects such as the rice leaf-folder and various species of stem-borers have long been perceived by farmers as 'important pests to control'. Whereas this may be true for stem-borers, when they cause 'white heads' where farmers grow longer-duration, traditional rice varieties, it is most unlikely that chemical controls are warranted for leaf-folders (Matteson, 2000). Nevertheless, with no other guidance, 93% of farmers sprayed, when insects were present.

Action thresholds appear to have been a matter of debate within the IPM programmes with suggestions that those "… developed by researchers are irrelevant and should be discarded" (Matteson, 2000) contrasting with specific instructions by practitioners (Thuy & Thieu, 1992). There was also perhaps an over-emphasis on entomology and the effectiveness of previous IPM programmes may have been reduced by insufficient recognition of the importance of disease management. In practice, the use of fungicides remains crucial for the control of fungi such as rice blast. Viruses such as ragged stunt, which are transmitted by plant-hoppers and in 2006, more than 485,000 ha of rice production area in southern VN were severely affected by viral diseases (known as "yellowing syndrome" and spread by BPH) resulting in an estimated loss of 828,000 tons of rice (Du *et al*., 2007).

Responsible pesticide use addresses not only safety of farmers and spray operators, but also is crucial for maintaining the sustainability of existing effective pest management practices. From a technical point of view, pesticide misuse is risky behaviour: potentially resulting in at least three dangers: residues, resurgence and resistance (3 Rs). The risks of pesticide misuse affect everyone:

- **farmers** – obviously, because of risks to health and loss of ability to control pests; if resistance occurs they may apply higher dosages (increasing costs) until the product becomes useless;
- **pesticide companies and retailers** – because of loss of reputation and if resistance to products occurs, they may lose business from farmers who choose products from other companies;

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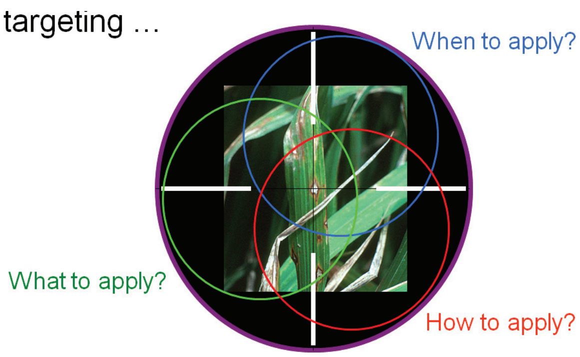
- **consumers** – loss of effectiveness of products diminishes pest control: thus potentially increasing the cost of food and when farmers increase dosages this adds to the risk of residues, exceeding the maximum residue level (MRL).

The guidelines aim to provide both farmers and retailers practical information on pesticides, including: the selection of pesticides including, where available, integration of non-neuro-toxic and biocontrol agents, efficient pesticide application and responsible promotion of products. The training will emphasize the maintenance and promotion of beneficial organisms in IPM, but also focus on:



- accurate diagnosis of problems and consequent decision making ...
- the responsible use of pesticides or alternative control techniques, when needed;
- choice of appropriate products that are registered for control of plant-hoppers (and/or other rice pests) and rotation of products with different modes of action to avoid build-up of resistance;
- Efficient, timely and safe application: to maximise efficacy and minimize costs and impacts on non-target organisms. Safety comes firstly from avoiding exposure to spray and not reliance on PPE.

Action thresholds: when to intervene

The project has now proposed an action threshold scheme for the main rice pests in the form of a table: to identify when it is necessary to intervene against pests and whether to apply pesticides. Monitoring and management of certain key pests such as BPH, rice blast and rodents are explained further in the modules and relate to the crop stage.

Selection of control agents

The proposed curriculum above includes responsible selection and use of crop protection products and covers important health-related and technical issues such as: Mode of Action (MoA), resistance, resurgence, residues, the importance of pre-harvest intervals (PHI) and efficient application techniques. There is also a general need to strengthen knowledge about pesticides: for example clarifying an apparent confusion, by both store-keepers and farmers, about MoA with dose transfer from spray tank to pest. Participants will regularly be encouraged, in one module in particular, to read and understand product labels: the emphasis being on both safe use and maximising efficacy. The use of biological control agents is especially to be encouraged: by focusing on current constraints such as quality and availability of products and inappropriate application methods.

Application: one of the weakest links

Good application is a core aspect of safe and efficient pesticide use. This is also one of the most neglected aspects of pest management, only very rarely appearing on training agendas in the context of efficient dose transfer to target pests. Most pesticides pass through spray nozzles and, although the subject may seem abstruse, attention to details of the dose transfer process ('spray accountancy') can potentially result in substantial cost savings.

Most (90%) of farmers surveyed in Đồng Tháp owned their own application equipment, 70% owned one sprayer, 25% owned 2 and a few owned 4 or more. Spraying equipment in use was recorded as:

Compression sprayer	0.4%
Side-lever knapsack	13.6%
Motorised hydraulic (mostly 2-stroke engine)	84.7%
Motorised mistblower	1.3%

Motorised hydraulic knapsack sprayers are by far the most common method of spraying rice: note that PPE is being used as a first line of defence against operator contamination.

Box 1. Brown Plant Hopper monitoring

Official recommendations for control interventions are 1500 adults/m^2 (this level may cause hopper-burn), which can be translated to 2-3 insects per tiller. The best method is to scout regularly and avoid build-up of nymph populations: wait for 3rd instar nymphs to appear and only spray chemical insecticides if at least 10 insects per tiller are present (this only applies to 1-3rd instar). Using slow-acting biopesticides such as Metarhizium, there is virtually no risk of resurgence or resistance, so a lower threshold of 2-3 insects per tiller is appropriate: again, treating young 2-3rd instar nymphs is most effective.

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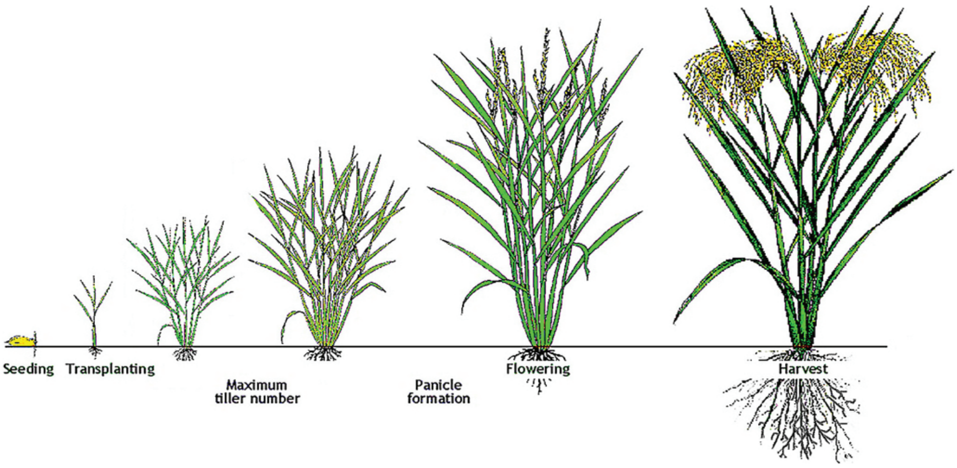
Action thresholds for key pests of rice: with changes during the main stages of crop development.

Crop stage	**vegetative phase: first 40 days**	**40 days (tillering) to booting**	**booting to flowering**	**ripening**	**** last 14 days**
Key: Pesticide application Avoid if possible or unlikely to be effective Do not apply pesticides **Pest:**	 				
Plant-hoppers: BPH, WBPH		2–3 insects /tiller if virus diseases are not present on farm (see box 1).			
BPH, GLH & other hoppers: **virus risk**	ONLY in response to warnings from local authorities (agricultural officers) or when symptoms seen in fields				
Leaf-folder and other leaf feeders *		100 living insects per m^2	40 living insects per m^2		
Stem borers		2 egg masses per m^2 (see parasitism)	one egg mass per 2 m^2	Too late for effective control	
Thrips		**Insecticides mostly ineffective or not economic to control**			
Gall midge					
Panicle rice mite/ sheath rot		**Identify problem** if > 5% flag leaves with lesions (pesticides probably not effective)		Too late for effective control	
Rice blast (with **susceptible varieties**)	Progressive scouting method (in text): increasing signs of lesions on 10% of leaves: 10 leaf samples in 4 sides of the field		Spray max. 2 X for neck blast if disease present and humid	Max. 3 sprays / season	
Bacterial leaf blight		Chemical controls have <u>limited</u> efficacy: only apply at early stage of disease			
Late season pests: especially **rice bugs**			10 insects per m^2: at milky stage (7–10d after flowering)		
Herbicides	If direct seeded				
Golden Apple Snails	GAS: 10 /m^2 if >1 ha				
Rodents	Community strategy at early stage			Not effective	

Notes: *1. The PPD recommends that insecticide sprays are not normally warranted for the first 40 days after seeding. Numerous tests have shown that 50% loss of leaf area (or 'whitening' of leaves with leaf-folder and hispa) causes little crop loss; other defoliators include: cutworms, caseworms, grasshoppers, amongst others.
** observe the pre-harvest interval (PHI): NO pesticides to be applied within 7 days before harvest: and they are probably unnecessary within the last 14 days.

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Striping' along rice fields appears to be a common sight in rice fields and could be related to either a phytotoxic or phytotonic effect relating to uneven application of pesticides, foliar fertilisers, etc. This phenomenon requires further investigation.

Of most significance are the vast majority (99%) of farmers who spray by 'rainbowing' the lance in front of themselves as they walk through the crop. This has two deleterious effects:

- Operators walk into their spray thus contaminating themselves.
- The distribution of dosage across the swath is uneven: some operators are aware of the fact that the central part of the swath is under-dosed, so they attempt to apply extra to this zone, thus further contaminating themselves.

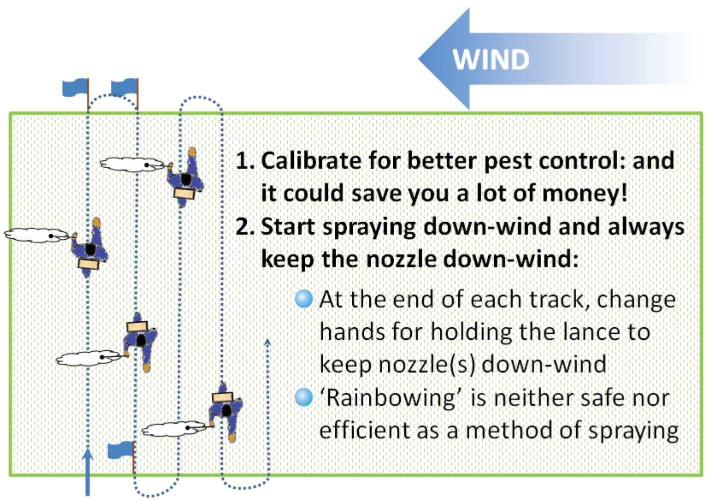
The dosage pattern across a swath, using a 5-nozzle boom configuration (typically, there may be 3–8 nozzles with motorised hydraulic sprayers), has been simulated using a simple model (see figures). More studies are needed to evaluate actual deposition: both in the crop and on the operator. However, evidence that this might be a real issue, requiring further investigation, is the commonly observed 'striping' in rice fields: that is regular sight and easy to photograph.

At present the operator is not only exposed to the spray directly in front and from sprayed foliage, but also from spray emitted from nozzles upwind of the body. A well-established engineering solution to this problem is to mount the nozzles on a boom behind the operator. Not only could this significantly reduce dose variation across the swath, but it should (more importantly) dramatically reduce exposure to pesticides, since the operator constantly walks away from the spray created. Alternatively, if 2-stroke engines are practicable, the use of motorised mistblowers could be actively encouraged; with low flow rate settings, these are capable of achieving much lower volume application rates (VAR: the number of litres likely to be applied per hectare), with <100 L/ha a realistic prospect.

Calibration of equipment is essential to avoid over- or under-dosage of pesticides: both of which are potentially harmful; in the case of spraying this means assessing VAR. With very high volumes of spray being applied by farmers, (i) tank mixtures are very dilute, (ii) low dosages may reach the biological target and (iii) the work rate is low. Each application at 400–800 L/ha requires carrying one tonne of water or more from a clean source to the fields of a typical (2 ha.) holding. A further consequence of using high VAR and work-rate is that farmers tend to combine products in tank mixtures (including 'preventative sprays'): rather than targeting specific pests as found in the field, which is a basic component of IPM.

Smaller-scale spraying equipment is almost invariably fitted with locally-manufactured hollow cone nozzles, which although easy and cheap to manufacture, may not be optimising dose transfer to the target pest. Unfortunately, the >54% of farmers using variable cone nozzles cannot calibrate their sprayers accurately since flow rates vary with the nozzle setting (Bateman *et al*., 2010). Over the last 30 years, research has led to the design of improved nozzles to meet International standards for hydraulic nozzles, including colour coding to indicate flow rate. Vietnamese farmers are unable to benefit from this R&D: a state of affairs that will continue until spraying equipment with ISO 8169 compliant nozzle holders is made available. The capacity to fit nozzles "manufactured to international standards" is identified in the FAO *Guidelines on the minimum requirements for agricultural pesticide application equipment* (FAO, 2001). Unfortunately, it can be difficult to find equipment that complies with these requirements in many parts of the ASEAN Region.

Safety of application is often discussed, but for decades now, emphasis has been placed on the use of PPE. Important though this is, it must be the last line of defence with emphasis on avoiding exposure to sprays, *etc*. and unfortunately avoidance of exposure is under-emphasised. Avoiding exposure simplifies PPE requirements and training messages for safe and efficient spraying should include:



Conclusions: Delivering IPM Messages

With such an important crop, strategies for good management perhaps inevitably become rather political in nature, with

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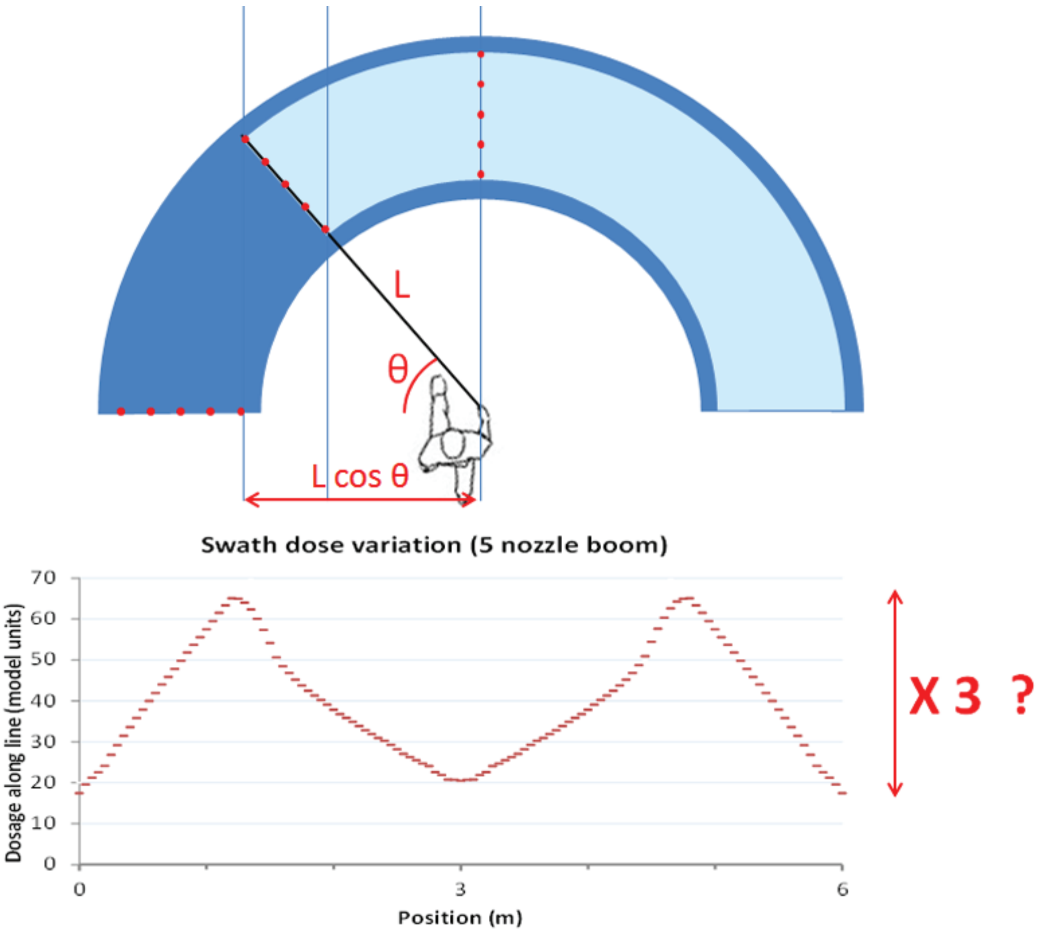

A 'cosine model' estimated dose variation over a 6m swath, created by a 3m lance fitted with 5 nozzles being waved to and fro, at an even velocity in front of the operator, assuming constant forward speed. In fact, the boom is slowed-down and reversed at the end of each side-stroke, so this accentuates the deposition at the two sides, relative to the centre. The actual values of the dosage units would depend on the flow rate of the nozzles and forward speed.

perverse consequences at the technical level. In many rice-growing countries (besides VN) it is possible to identify where improvements may be made to pest management practices. There are a number of common issues, that sometimes become conflated and adopting an 'anti-pesticide' stance is not helpful: much better, surely, to adopt a set of rules where pesticides are truly used judiciously and as a last resort, on the understanding that a preventative approach is the basis of IPM. Over the coming years we intend to put this into practice.

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