

Perspective

Botanical insecticides: for richer, for poorer

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Abstract: Botanical insecticides presently play only a minor role in insect pest management and crop protection; increasingly stringent regulatory requirements in many jurisdictions have prevented all but a handful of botanical products from reaching the marketplace in North America and Europe in the past 20 years. Nonetheless, the regulatory environment and public health needs are creating opportunities for the use of botanicals in industrialized countries in situations where human and animal health are foremost – for pest control in and around homes and gardens, in commercial kitchens and food storage facilities and on companion animals. Botanicals may also find favour in organic food production, both in the field and in controlled environments. In this review it is argued that the greatest benefits from botanicals might be achieved in developing countries, where human pesticide poisonings are most prevalent. Recent studies in Africa suggest that extracts of locally available plants can be effective as crop protectants, either used alone or in mixtures with conventional insecticides at reduced rates. These studies suggest that indigenous knowledge and traditional practice can make valuable contributions to domestic food production in countries where strict enforcement of pesticide regulations is impractical.

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1 INTRODUCTION

The use of plants, plant material or crude plant extracts (botanical insecticides) for the protection of crops and stored products from insect pests is probably as old as crop protection itself.¹ Indeed, prior to the development and commercial success of synthetic insecticides beginning in the 1940s, botanical insecticides were major weapons in the farmer's arsenal against crop pests. The combination of efficacy, speed of action, ease of use and low cost of the synthetic insecticides (organochlorines, organophosphates, carbamates and later the pyrethroids and neonicotinoids) drove many botanicals to near obscurity in most industrialized countries. Twenty years after synthetic insecticides were firmly entrenched in 'modern' agricultural production, documented and suspected issues of widespread environmental contamination, toxicity to non-target organisms and, most importantly, negative effects on human health led to a resurgence in interest in 'natural' means of pest control, including intensified searches for new sources of botanical insecticides.²

While the agrochemical industry has ably met the challenge of producing newer synthetic insecticides with dramatically reduced health and environmental impacts, public perception remains strongly tied to the damaging products of the past, such as DDT. On the other hand, the relative safety of natural

products cannot be assumed – nicotine and strychnine are notable examples of plant compounds acutely toxic to humans – but again public perception can be a persuasive force, even when not well informed.

There is a rich scientific literature based on the effects of plant secondary chemicals on insects, much of it generated in the last 25 years. In contrast, over the period 1980–2000, only a single new botanical insecticide received registration for use in the United States and parts of Europe – neem. The complex triterpenoid azadirachtin, obtained from the seeds of the Indian neem tree *Azadirachta indica* (A. Juss.) (Meliaceae), is a potent insect growth regulator and feeding deterrent, with minimal mammalian toxicity and environmental persistence.³ This product alone spawned a wealth of scientific studies, numerous international conferences and several major volumes of information.⁴ Unfortunately, in spite of the unquestionable enthusiasm of its proponents, neither neem (nor its major constituent azadirachtin) has revolutionized crop protection; in fact its commercial impact has been less than that of the microbial insecticide *Bacillus thuringiensis* Berliner, which at one time itself was hailed as a possible successor to many conventional chemical insecticides. Even in health-conscious California, the use of biopesticides (microbials and botanicals combined) as a proportion of all pesticides used has remained relatively constant

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(at ~0.5% based on pounds of active ingredient) over the past decade.⁵ A second group of botanical insecticides, those based on plant essential oils, have recently been commercialized in the United States, but in terms of market presence they are currently in their infancy.⁶ Some of these may be especially attractive to consumers because the sources of the active ingredients, namely rosemary, thyme, cloves, cinnamon and mint, are in common use as culinary herbs and flavourings.

Another impetus for the discovery of natural insecticides from plants has been their putative value as lead compounds with novel bioactivities for use by the agrochemical industry. However, with the exception of the pyrethroids (based on the natural pyrethrins from *Tanacetum cinerariaefolium* (Trev.) Schultz-Bip., but commercially successful only after a 25 year 'gestation' period), this approach has met with little success.⁷

Reasons often given for the poor market penetration of botanical insecticides, at least for agricultural use, are their relatively slow action, variable efficacy, lack of persistence and inconsistent availability. The challenge of protecting intellectual property based on natural products has also limited commercial development of botanicals. Without question most botanicals have failed to compete adequately against the newest generations of synthetic insecticides (e.g. the neonicotinoids), products of the agrochemical industry that in large measure have successfully addressed the toxicological and environmental shortcomings of their predecessors. In this context, then, where are botanical insecticides of greatest benefit and most likely to be adopted for use in the future?

2 INDUSTRIALIZED ('RICH') COUNTRIES

It is argued here that in the most affluent countries (North America, the European Union, Japan), where human and animal health is paramount, botanical insecticides will be embraced. This will be especially true for consumer or 'domestic' products – those used in and around the home for public health pests (cockroaches, flies, dust mites), ectoparasites (fleas and ticks) on companion animals and garden pests on ornamentals, vegetables and urban trees and landscape plants. Products based on botanicals such as pyrethrum, neem or essential oils are also finding favour for pest management in industrial applications where pesticide residues and bystander exposure risks are least acceptable – hospitals, schools and restaurants, for example. In these contexts, wide margins of safety to high-value animals (horses, domestic cats and dogs) and humans, especially children, are of greater importance than absolute efficacy, i.e. where ready-to-use products mean that application rates and costs per unit area are of lesser concern. In California, more pyrethrum is used for structural pest control and against public health pests than for agricultural uses.⁵ Global production of

pyrethrum is limited and costs have risen in recent years, making it inaccessible to less affluent societies.

In spite of their short residual action, some botanicals are finding use as 'flushing' agents or as 'barrier' treatments. In these applications, efficacy results from behavioural effects (repellence, deterrence) rather than acute toxicity per se. The introduction and rapid spread of West Nile Virus in the United States has sparked renewed interest in fogging of urban areas with adulticides for mosquito abatement; concerns over the safety of malathion, whether well founded or not, may create another significant market opportunity for botanicals. It is worth noting that in the United States certain essential oils as pesticide active ingredients are exempt from EPA registration.⁸ Other jurisdictions (Japan, Korea, EU) are considering reduced data requirements or waivers for products of this type, particularly for use against public health pests where food residues are not at issue.

In these countries, botanicals may find acceptance in agricultural contexts where a premium is placed on user and bystander health, and where there is strong public (consumer) pressure against pesticide impacts on the food supply, water and the environment. Clearly, the best market opportunities for botanicals are for certified organic production of high-value row crops where there are fewer competing products, and in controlled environment (glasshouse) production of vegetables and ornamentals. While the field efficacy of botanicals as stand-alone products may fall short in comparison with conventional insecticides, they can be effective in rotation or in tank mixtures with other insecticides, lessening the total quantities of more persistent products applied over a growing season.

3 LESS DEVELOPED ('POOR') COUNTRIES

A number of factors support the argument that botanical insecticides should be of greatest benefit in developing countries, particularly those in tropical and subtropical zones. In many countries in South-east Asia, Latin America and Africa there is longstanding indigenous knowledge, if not local practice, of using plants and plant extracts for mitigating pests.¹ When economic forces made conventional (imported) pesticides less affordable for cocoa farmers in Cameroon, they turned to using extracts of local plant species, used either alone or mixed with conventional products.⁹ The local plants (e.g. 'banga', *Cannabis sativa* L. and tobacco, *Nicotiana tabacum* L.) were found within cocoa plantations, making them readily available. Following the loss of subsidies on chemical pesticides and fertilizers and devaluation of the local currency, the proportion of growers producing cocoa without the use of synthetic pesticides rose from 6 to 33%.

In a study of damage to cotton by the bollworm (*Helicoverpa armigera* Hübner) in Benin, evaluations by investigators, local research agents and farmers

themselves were consistent in finding that mixtures of conventional insecticides at one-half the recommended rate with extracts of three local plants [neem = *Azadirachta indica*, Senegal mahogany = *Khaya senegalensis* (Desr.) A. Juss., pignut = *Hyptis suaveolens* (L.) Poit.] provided greater efficacy than the conventional products alone at their recommended rate.¹⁰ None of the plant extracts alone provided adequate crop protection. Such a direct demonstration of the utility and value of botanical preparations increased the farmers' confidence in indigenous technology. A field trial in Uganda revealed that treatment of the crop in the field with crude aqueous extracts of local plants (tobacco = *Nicotiana*, rotenone = *Tephrosia* and marigold = *Tagetes*) were equally efficacious to cypermethrin or fenitrothion in reducing emergence of bruchid beetles (*Callosobruchus* spp.) from cowpeas in storage.¹¹ A subsequent study by the same investigators found that rotating sprays of tobacco extract (three applications) and cypermethrin (two applications) on cowpea generated greater economic return than five sprays of either the extract or cypermethrin.¹² In the tobacco-growing areas of western Mexico, multinational corporations are running programmes intended to reduce drastically the quantity of chemical insecticides applied; in this situation, botanicals could become an attractive and effective alternative (Badulescu D, 2006, private communication).

While economic benefits from the use of locally prepared botanicals are encouraging, the greatest benefit from the use of these materials may well be in terms of human health. The vast majority of acute human poisonings from pesticides occur in developing countries; in some regions they are a major cause of mortality (a relatively rare event in western Europe or the United States).^{13,14} For example, the potato-growing areas of Carchi, Ecuador, have among the highest reported rates of human pesticide poisoning in the world.¹⁵ Farmers frequently used highly toxic insecticides, yet few had any knowledge of the dangers of those products and they received no warnings from vendors. In many developing countries, farmers are illiterate or speak only indigenous dialects, whereas pesticide labels are printed only in the official national language. Only 20% of farmers had received training on the safe use of pesticides, and few used protective equipment. This scenario is likely played out in numerous developing countries where alternative crop protectants, including those produced from indigenous plants, are available. It could easily be argued that the benefits to human health from the use of botanical insecticides in tropical agriculture vastly outweigh those to the affluent consumer in Europe or the United States using botanicals in their homes or on their pets. Additionally, rural communities in developing countries could benefit financially by becoming involved in the cultivation and extraction of plants to produce botanical insecticides. As previously noted, certain plant compounds such as nicotine and rotenone are acutely toxic to humans – in the pure

form. However, the health risks associated with these compounds are largely mitigated through the use of crude plant preparations in which the concentrations of these substances typically range from 1 to 5%. Ideally, such local production of plant extracts would be standardized and regulated to ensure product safety and efficacy, but this may be an unrealistic expectation in many of the poorer regions of the world.

4 CONCLUSIONS

In this paper it has been suggested that botanical insecticides should prove most beneficial in two contrasting applications, one for affluent consumers and the other for farmers in developing countries. Apart from economic considerations and potential health benefits, another important force driving botanicals into these disparate markets is the regulatory environment. Regulatory approval in industrial nations has become so costly and time consuming that only multinational agrochemical companies have the resources to satisfy regulatory requirements for their insecticides to see widespread agricultural use.¹ As a consequence, botanicals will only see use on food crops in niche markets such as certified organic production or in controlled environments. On the other hand, regulation, or at least enforcement of pesticide regulations, in developing countries is generally more relaxed, particularly for domestic food production. While it might appear irresponsible to advocate the use of unregistered crop protectants for which health hazards have not been rigorously established, there is reasonable evidence to suggest that, with few exceptions, crude botanical preparations at worst pose no greater risk to human health than conventional insecticides and indeed are probably of substantially lower risk. Moreover, indigenous knowledge often extends beyond the potential efficacy of endemic plants as crop protectants to include their toxicity to users. This may well represent a case where our highly technological society can learn that long-established agroecological practices have a role to play in food production in the twenty-first century.

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REFERENCES

- 1 Thacker JRM, *An Introduction to Arthropod Pest Control*. Cambridge University Press, Cambridge, UK (2002).
- 2 Regnault-Roger C, Philogene BJR and Vincent C (eds), *Biopesticides of Plant Origin*. Lavoisier, Paris, France (2005).
- 3 Isman MB, Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annu Rev Entomol* 51:45–66 (2006).
- 4 Koul O and Wahab S (eds), *Neem: Today and in the New Millennium*. Kluwer, Dordrecht, The Netherlands (2004).

- 5 CDPR, *2005 Summary Report, Indexed by Chemical*. [Online]. California Department of Pesticide Regulation (2005). Available: http://www.cdpr.ca.gov/docs/pur/pur05rep/05_pur.htm [14 December 2006].
- 6 Isman MB, Plant essential oils for pest and disease management. *Crop Prot* **19**:603–608 (2000).
- 7 Isman MB and Akhtar Y, Plant natural products as a source for developing environmentally acceptable insecticides, in *Insecticides Design Using Advanced Technologies*, ed. by Ishaaya I, Nauen R and Horowitz R. Springer-Verlag, Berlin, Germany, pp. 235–248 (2007).
- 8 USEPA, *25b Minimum Risk Pesticides*. [Online]. US Environmental Protection Agency. Available: http://www.epa.gov/opbtpd1/biopesticides/regtools/25b_list.htm [14 December 2006].
- 9 Coulibaly O, Mbila D, Sonwa DJ, Adesina A and Bakala J, Responding to economic crisis in sub-Saharan Africa: new farmer-developed pest management strategies in cocoa-based plantations in Southern Cameroon. *Integ Pest Manag Rev* **7**:165–172 (2002).
- 10 Sinzogan AAC, Kossou DK, Atachi P and van Huis A, Participatory evaluation of synthetic and botanical pesticide mixtures for cotton bollworm control. *Intl J Trop Insect Sci* **26**:246–255 (2006).
- 11 Kawuki RS, Agona A, Nampala P and Adipala E, A comparison of effectiveness of plant-based and synthetic insecticides in the field management of pod and storage pests of cowpea. *Crop Prot* **24**:473–478 (2005).
- 12 Opolot HN, Agona A, Kyamanywa S, Mbata GN and Adipala E, Integrated field management of cowpea pests using synthetic and botanical pesticides. *Crop Prot* **25**:1145–1152 (2006).
- 13 Forget G, Goodman T and de Villiers A (eds), *Impact of Pesticide Use on Health in Developing Countries*. International Development Research Centre, Ottawa, Canada (1993).
- 14 Ecobichon DJ, Pesticide use in developing countries. *Toxicol* **160**:27–33 (2001).
- 15 Yanggen D, Cole DC, Crissman C and Sherwood S, Pesticide use in commercial potato production: reflections on research and intervention efforts towards greater ecosystem health in northern Ecuador. *EcoHealth* **1**:72–83 (2004).