Expl Agric. (2001), volume 37, pp. 473–494
Printed in Great Britain

WHAT IS AN INTEGRATED PEST MANAGEMENT 'STRATEGY'? EXPLORATIONS IN SOUTHERN MALAWI

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(*Accepted 21 May 2001*

SUMMARY

The concept of an integrated pest management (IPM) strategy is explored using case-study evidence from smallholder agriculture in southern Malawi. The conventional concept of strategy as a 'plan' is contrasted with the use of strategy as a game, as a performance, and as an accident. This pluralistic view is echoed in recent literature on business strategy. A typology is developed that relates farmers' choice of IPM strategy to the predictability of crop losses, the stability of the crop environment, and farmers' knowledge of pests. Some implications for IPM are explored. Where conditions favour 'adaptive' rather than planned IPM strategies, formal experimentation to verify farmers' strategies may be an inefficient use of resources. Where the crop environment is volatile and several pests attack the crop simultaneously, there may be limited scope to increase the adoption of IPM strategies by improving farmer knowledge of pest biology. Addressing the interactions between pest and crop management is critical in making IPM relevant for resource-poor farmers. A deeper understanding of farmers' management strategies is required to frame meaningful recommendations.

INTRODUCTION

Writers on integrated pest management (IPM) use the word 'strategy' in various ways. They may use it to distinguish the philosophy of IPM, based on the ecological principle of containing pest* populations at levels that do not cause economic injury, from alternative approaches such as complete reliance on natural forces or on prevention and eradication (Glass, 1976). Within an IPM context, strategy is also used to refer to the 'broad guidelines for the best way to tackle a particular pest or disease problem', such as the choice between biological control or host-plant resistance (Conway, 1984). Finally, the term 'strategy' (often with the qualifier 'management') is used to describe specific techniques or methods of control against a particular pest. The early literature (Conway, 1984; Apple and Smith, 1976) describes these as 'tactics' but the term 'management

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* *Pest* refers here to any organism harmful to humans, whether insect, disease organism, weed, rodent, or other.

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strategy' is now more common. An *integrated* strategy usually refers to some optimum combination and use of all known management strategies whereby farmers are offered a choice of chemical, biological, and physical controls that may reinforce each other or work together to manage a particular pest.

The focus of this paper is on 'management strategies'. In crop protection, the definition of a management strategy includes the following five elements. One, it involves a decision or a selection between alternatives. Two, a strategy is rational, in the sense that it can be formalized into a logical sequence. Three, it has a threshold at which it becomes economically optimal. Four, a strategy can be verified empirically by statistical methods. Lastly, to qualify as an IPM strategy, it should not harm the environment, wildlife, or human health.

This definition of an IPM strategy may bear little relation to farmers' pest management in practice, whether pre- or post-IPM (Norton, 1976). This is especially true for resource-poor farmers in less developed countries where the variation found in rainfed farming systems favours flexibility over planning, the measurement of economic thresholds may be problematic, and where farmers' knowledge of pest biology is usually limited. Farmers in sub-Saharan Africa have developed a wide array of pest management strategies. In this paper, the authors explore the meaning of 'IPM strategy' for smallholder agriculture. The use of strategy as a 'plan' is contrasted with its use as a game, as a performance, or as an accident. Drawing on recent management theory, a simplified typology of 'IPM strategies' based on the level and predictability of crop losses, the stability of the farming environment, and farmers' knowledge of pests, is offered. In conclusion, some implications for research into IPM with resource-poor farmers are discussed.

The argument is illustrated by case-studies of farmers' pest management strategies made by the Farming Systems IPM (FSIPM) Project (Orr *et al.*, 1999a;b;c), which evaluated numerous IPM strategies for the major field pests of four staple food crops widely grown by smallholders in southern Malawi. The general objective of this article, however, is not to advise farmers on pest management for these crops. Instead, it is to make this advice more relevant for farmers by attempting to clarify what is meant by an IPM 'strategy'. Thus, the article is not concerned with IPM recommendations *per se* but with the process by which researchers arrive at these recommendations. Readers who wish to know more about the technical merits of the various IPM strategies mentioned in this article are referred to the reports in Ritchie (2000).

THE STUDY AREA AND TARGET PESTS

The project operated in the poorest region of one of the world's poorest countries. With a *per capita* income in 1998 of $ US 197, Malawi ranks among the bottom five nations in sub-Saharan Africa (World Bank, 1998). In the Blantyre Shire Highlands Rural Development Project, the two Extension Planning Areas in which the project operated were classed as among the poorest in Malawi

(Moriniere *et. al.*, 1996). Poverty reflected high population density (300 persons km^{-2}), small farm size, and low maize (*Zea mays*) yields (< 1 t ha^{-1}) caused by limited application of inorganic fertilizer and continuous cultivation without fallowing or rotation.

The Blantyre Shire Highlands form a natural region of rolling or flat upland plains 600–1200 m asl. The farming system revolves around maize, grown in the single wet season between November and April. On upland fields, maize is normally intercropped with pigeonpea (*Cajanus cajan*) and beans (*Phaseolus* spp.). Further south where showers prolong the growing season, relay planting of beans and field pea (*Pisum sativum*) is common. On low-lying fields in the valley bottoms (*dambos*), farmers use residual moisture to follow maize with several crops of sweet potato (*Ipomoea batatas*) and field pea. On *dimba* fields, situated near a stream or well, farmers grow early maize and may also grow a variety of high-value vegetables throughout the year.

Farmers in the project area ranked whitegrubs, termites, and *Striga asiatica* among the most important pests of maize; bean stem maggot (*Ophiomyia* spp.) as the most important pest of beans; fusarium wilt as the most important pest of pigeonpea, and sweet potato weevil (*Cylas puncticollis*) as the most important pest of sweet potato (Orr *et al.*, 1997). Experience with on-farm trials over three crop seasons revealed that while individual farmers might suffer high crop losses from these pests, the average level of losses was low. For the project area as a whole, aggregate crop losses from pests were estimated at 15 % of the value of food crop production, of which half was caused by *Striga* and other weeds (Mwale *et al.*, 2000). Low average crop losses in the study area during the life of the project made it difficult to identify effective IPM strategies. Consequently, while the project successfully developed IPM recommendations for whitegrubs and fusarium wilt, it was unable to make recommendations for other pests, either because further research was required (*Striga*, bean stem maggot) or because the strategy proved to be ineffective (sweet potato weevil).

METHODOLOGY

By the third and final season of the project, groups of farmers with high and fairly consistent levels of crop damage from termites and whitegrubs had been identified. These farmers were used as key informants on management strategies for these pests. For termites, all 11 farmers who participated in a termite trial in 1998–99 were interviewed. With respect to whitegrubs, 26 farmers were interviewed, including all nine who had participated in a whitegrub trial in the same year, three farmers who had also experienced problems with whitegrubs, and 14 farmers who had used seed dressing with Carbaryl as an IPM strategy. Information on management strategies for bean pests were derived from interviews with 11 farmers participating in on-farm trials who were representative of five household groups identified through an earlier cluster analysis (Orr and Jere, 1999). Also interviewed were three non-participating farmers who used early-maturing varieties, and four market traders at two local markets for information about prices.

Using a short checklist, interviews were conducted individually with farmers. Specimens used to aid pest identification included five species of termites, seven species of whitegrubs, and specimens of adult *Ootheca,* and *Alcidodes.* Since farmers attribute damage from whitegrubs to other causes, large colour photographs showing symptoms at various stages of plant growth were used to aid identification. To avoid confusion, samples of 10 common varieties of beans were used in discussion of bean pests. Interviews regarding termites were made in March, two months before the harvest of mature maize, when damage was clearly visible. Unfortunately, time constraints meant that interviews for whitegrubs were made in April, whereas most damage occurs after planting in December, while interviews for bean stem maggot were made in August, after the harvest of intercropped beans in March and the relay-crop in May-July.

STRATEGY AS A PLAN

The whitegrub pest complex in the study area consisted of at least seven species belonging to five genera (Mzilohowa, 2000). Crop losses from this pest reached high levels in the Chitera *dambo* in Mombezi EPA, where the species *Heteronychus licas* was found. Farmers distinguished between damage caused by the adult beetle (known in the local Chichewa language as *matono*) and larvae (*mbozi zoyera*). The adult beetle damaged the seed or seedling below ground, resulting in non-emergence or wilting of the plant soon after emergence. Damage occurred during the first few weeks after planting and before first weeding. Larvae also damaged the seed; usually the plant emerged only to wilt and die between the first and second weeding.

To reduce crop losses from the adult beetle, a small group of innovative farmers treated maize seed with Sevin (Carbaryl) WP formulation (85 %). Since farmers did not prime maize seed, this technique was used exclusively as a pest management strategy against whitegrubs. Seed was soaked overnight, drained, and then mixed with the insecticide at rates of between 7 and 14 g kg^{-1} of seed. Adopters claimed that, by killing whitegrubs at the initial stage of plant growth, seed dressing increased emergence and reduced wilting of emerged plants. However, its use was confined to fields in the Chitera *dambo*, and targeted at the adult beetle; it was not used as a strategy against whitegrub larvae.

Farmers had some concept of what constituted ‘serious’ damage from whitegrubs. Several specified the number of non-emerged or wilting plants they looked for in judging the severity of damage, but these damage levels could not be measured accurately since they were not assessed in terms of area but by the number of ridges or planting stations affected. Farmers regarded any damage as ‘serious’ since they automatically sowed new seeds or transplanted seedlings to replace lost plants. This low damage threshold may reflect the land constraint in the study area that encouraged farmers to maximize the plant stand.

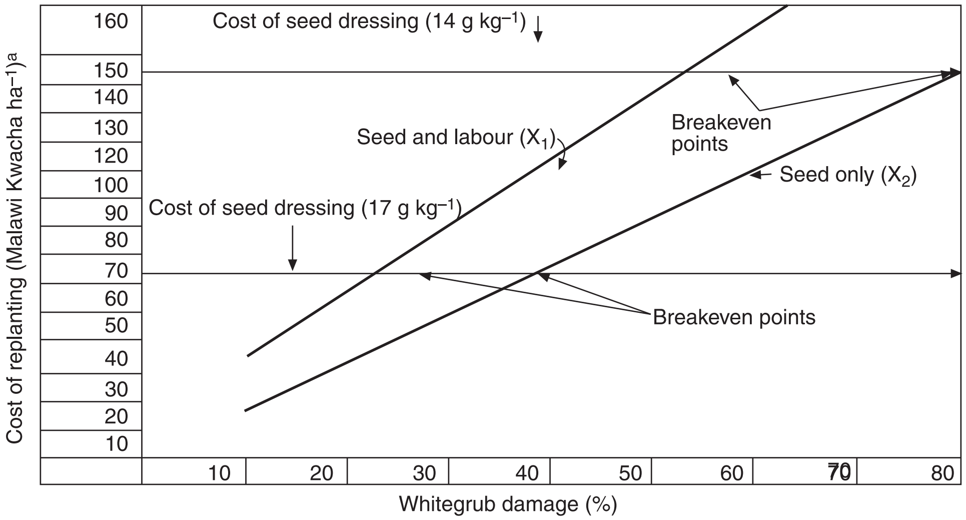


Fig. 1. The economics of seed dressing maize with Sevin, Chitera dambo, 1998–99 season. The regression equations were: $Y = .22 + 2.56\ X_1$ for seed plus labour; and $Y = 0.22 + 1.81\ X_2$ for seed only, where Y = cost (Malawi Kwacha) and x is whitegrub damage (%). Note: [a]45MK = US$1 in 1998–99.

Figure 1 shows the parametric budget for seed dressing and replanting for different levels of crop loss. (Farmers did not usually replant after applying Carbaryl). Two cost lines are shown, for seed only and for seed plus labour. The regression equations were:

$$Y = 0.22 + 2.56\ X_1 \qquad \text{for seed plus labour}$$
$$Y = 0.22 + 1.81\ X_2 \qquad \text{for seed only}$$

Where Y = cost (Malawi Kwacha) and X is whitegrub damage (%).

Solving these equations to give the breakeven level of damage gave values of 28% and 56% when Carbaryl was applied at a rate of 7 g kg^{-1}, and 40 % and 80 % when Carbaryl was applied at the rate of 14 g kg^{-1}. Thus, there was no financial advantage to farmers to seed dress maize seed with Carbaryl when damage was less than 30 %. Usually, the minimum acceptable rate of return for innovations is 100%, or a 2:1 return (CIMMYT, 1988). Therefore, farmers would be unlikely to adopt seed dressing with Carbaryl as a pest management strategy until damage from whitegrubs reached 60% or more. Since seed dressing can be applied only before planting, any decision to use Carbaryl was based on farmers' experience of damage levels in previous seasons.

Seed dressing illustrates strategy as a plan, or a pre-emptive move where farmers anticipate losses and take steps ahead of time to minimize yield loss. In this instance, four circumstances favoured this form of IPM strategy. First, farmers experienced a high average level of crop losses from the pest, in some cases amounting to the entire crop. Second, the existing management strategy of simply replacing damaged seed proved ineffective; the pest population was so great that it simply consumed replanted seed, in some cases four times over. Farmers thus faced the choice of abandoning maize cultivation or inventing a new strategy. Third, farmers had clearly identified the pest (*matono*) and understood the nature and timing of pest attack. Fourth, a solution could be specified clearly since farmers were already familiar with the practice of dressing seed to prevent damage from weevils in storage and Carbaryl was readily available in unadulterated form from nearby retail stores. Together, these four factors encouraged farmers to switch from an adaptive strategy of damage-limitation to a planned, pre-emptive strategy that at least allowed some yield in the face of potentially devastating losses.

The limitations of strategy as a plan are illustrated by the fact that farmers continued to use seed dressing even when the threat was no longer present. Field trials with seed dressing showed that at the higher dose rate Carbaryl was phytotoxic and severely reduced maize yields (Ritchie *et. al.*, 2000a). An economic evaluation of this IPM strategy showed that at lower levels of damage seed dressing with Carbaryl was uneconomic. When abnormally heavy rainfall in 1997 reduced the whitegrub population in the *dambo*, damage levels fell to less than 2% of plants. Despite the reduced threat posed by whitegrubs in subsequent years, however, farmers continued to dress maize seed despite its harmful effect on yields. By its very nature, a pre-emptive strategy is a cost incurred regardless of the eventual level of pest attack.

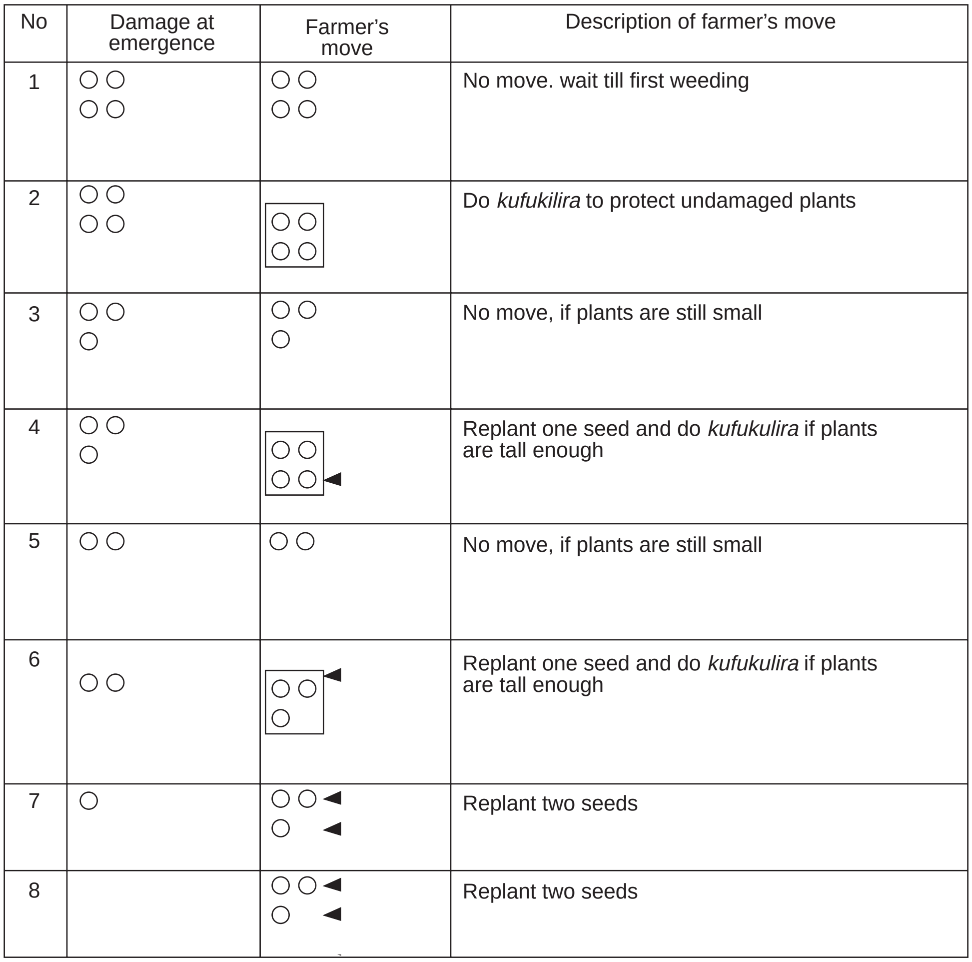
STRATEGY AS A GAME

> '**Game**: A form of contest played according to rules and decided by skill, strength, or luck' (*The Concise Oxford Dictionary*).

Farmers' management practices against whitegrubs also illustrate a very different concept. Traditional control strategies for whitegrubs resemble games in which farmers make fixed moves in response to pest damage. Farmers in the study area had developed games to counter damage from both adult whitegrubs and larvae. In the case of damage from the adult *Heteronychus licas,* the game involved replanting seed whereas, in the case of damage from whitegrub larvae, the game involved transplanting seedlings. By definition, a game has rules. Farmers' responses or moves can be codified to show how these operated for a given level of damage.

The matono *game*

Figure 2 shows how the *matono* game was normally played. Farmers planted four maize seeds at each station. Damage from *matono* was inferred from the number of seeds at each station that did not emerge. With four seeds per station, this gave five possible outcomes (4, 3, 2, 1, 0). If the maize seedling failed to emerge one week after planting, farmers dug up the seed to discover the reason. If adult whitegrubs were found they were killed by hand or with a hoe. Then, because farmers believed that the soil around the original seed had been 'used'



No	Damage at emergence	Farmer's move	Description of farmer's move
1	○ ○ ○ ○	○ ○ ○ ○	No move. wait till first weeding
2	○ ○ ○ ○	○ ○ ○ ○	Do *kufukilira* to protect undamaged plants
3	○ ○ ○	○ ○ ○	No move, if plants are still small
4	○ ○ ○	○ ○ ○ ○◀	Replant one seed and do *kufukulira* if plants are tall enough
5	○ ○	○ ○	No move, if plants are still small
6	○ ○	◀ ○ ○ ○	Replant one seed and do *kufukulira* if plants are tall enough
7	○	○ ○ ◀ ○ ◀	Replant two seeds
8		○ ○ ◀ ○ ◀	Replant two seeds

Fig. 2. The *matono* game: *Heteronychus licas* vs. farmers in Chitera *dambo*
Time: from emergence to first weeding
Moves: up to three moves per player
To start: plant four seeds. . . .
Source: farmers in Chitera dambo, Mombezi EPA, Blantyre Shire Highlands RDP.
Notes: ▭ = *kufukulira*
◀ = replant seed
○ = seed

and would not produce a strong and healthy plant, new seed was planted adjacent and to one side of the original planting hole. Farmers sometimes also scraped the soil from around the planting station to form a *glacis* that prevented access to the seed by the pest. This practice (known as *kufukalira*) was used only after the seedling had reached a certain height (roughly 30 cm) in order to avoid weakening the plant. It was used as a preventive strategy to protect replanted seeds or to protect planting stations with four undamaged plants. This added a further three outcomes, bringing the total to eight.

Variations in moves

An important variation in the *matono* game was the number of times that farmers were prepared to replant failed sites. Replanting three times was reported as the maximum feasible number. Assuming seedlings require one week for emergence, replanting may have continued up to three weeks after emergence or four weeks after first planting. However, many farmers believed that replanting three times was impractical because of the risk of shading from the maize that had been planted first. In addition, most farmers would have run out of seed by this time. Replanting twice was considered feasible, after which farmers switched strategies and planted seedlings instead of seeds.

In both the *matono* and *mbozi zoyera* games, moves were not planned in advance but were determined by variations in the level of damage farmers inferred from seed that had failed to emerge or observed from plants that had wilted or died. Farmers' pest management strategies for whitegrubs, however, also included an element of foresight and planning. In the *matono* game, *kufukilira* was used as a preventive strategy to protect replanted seed. Also, farmers might anticipate a certain level of damage and make provision for this by planting more seeds per station or, as in the *mbozi zoyera* game, planting nurseries to provide a supply of seedlings for transplanting. Maize seed left over after the first planting was guarded carefully (children were forbidden to roast them) while nurseries might be established in the furrows of the affected fields, or close to the homestead. Some farmers, reasoning that the odds of seeds surviving were higher in their upland fields, planted extra seed there to use as replacements for wilted plants in the *dambo*. Others believed that seedlings raised in nurseries were not strong and produced less healthy plants than those simply transplanted from other planting stations. We did not compare the cost of replanting and transplanting with chemical seed dressing. Obviously, planting and transplanting are costly in terms of seed, labour, and reduced yields from delayed planting. These costs explain why, at higher levels of damage, farmers switched from reactive to planned strategies that involved seed dressing with Carbaryl.

STRATEGY AS A PERFORMANCE

> 'They [the French marshals] planned their campaigns just as you might make a splendid piece of harness. It looks very well; and answers very well; until it gets broken; and then you are done for. Now I made my campaigns out of ropes. If anything went wrong, I tied a knot; and went on.'
>
> The Duke of Wellington (Longford, 1969).

Field surveys in 1991–92 identified 24 species of termites from nine genera in farmers' fields in southern Malawi (Logan *et al.*, 1993). Farmers in our study area identified and named four species. Of these, macrotermes (*chiswe chapa chulu*) was identified as the most severe termite pest of maize because it severed stalks and caused lodging. Termite populations are high because farmers usually incorporate crop residues before planting, a practice they believe enhances soil fertility, and because land shortage discourages rotating maize with grain legumes. IPM strategies to reduce the termite population, therefore, are limited by soil fertility and land constraints.

The project tested an IPM strategy against termites that involved a modified form of weeding known as *kukwezera*. Normally, farmers gave a second weeding by earthing-up soil from the furrow and depositing it on the ridge, smothering weeds beneath a thick blanket of soil. This practice was known as 'banking' or *kubandira*. However, farmers also believed that, by depositing soil around the planting station, banking encouraged termites by giving them easier access to the maize roots. Consequently, farmers who feared losses from termites preferred to use *kukwezera*, a form of weeding in which there was no earthing-up of the planting station and weeds were not buried on top of the ridge but laid in the furrow to dry out, sometimes under a light covering of soil.

Testing the effectiveness of *kukwezera* in on-farm trials proved difficult, however. Macrotermes forage in a wide radius around their nests ($> 8000\ m^2$) and attacks vary in time and space (Darlington, 1982; Lepage, 1983). Even on fields with a history of termite damage, farmers were often reluctant to use the technique. In the project's third and final season, for example, of the 11 farmers who participated five (45%) failed to use *kukwezera* as required by the experimental design. Subsequent investigations produced several reasons why farmers might still prefer to bank rather than use *kukwezera:*

1. 'Banking' was the form of weeding that generally gave the highest maize yields.
2. There was a high risk of weeds re-establishing if they were not buried, particularly in wet seasons.
3. Without banking there was a high risk of fertilizer leaching since ridges might be too low to channel runoff effectively.
4. Low ridges also increased the risk of runoff and soil erosion on sloping fields.
5. Banking reduced the risk of maize plants lodging in high winds.

Except in dry years, termites were not usually visible before farmers had started the second weeding. By this time, farmers might already have banked their fields making it too late for them to use *kukwezera*. Essentially, therefore, *kukwezera* was a planned strategy used by farmers who expected high crop losses from termites in that particular season. Such farmers had decided, in advance, that the cost of banking (high crop losses from termites) exceeded the cost of not banking (lower yields). Other farmers, however, preferred to defer the decision on whether to use *kukwezera* until the last minute, when they were in a better position to evaluate the trade-offs.

The authors were unable to identify any obvious 'rule of thumb' for farmers' use of *kukwezera*. As with whitegrubs, they had no consistent definition of what constituted 'serious' damage. To some it meant even one lodged plant, or enough cobs to provide one meal, to another at least 10 lodged plants in a small area and, to yet another, approximately 150 damaged plants. Thus, the concept of an economic 'threshold' may vary so greatly with farmers' circumstances as to make a generalized threshold level inappropriate (Farrington, 1977). Some farmers on seeing one lodged plant or termites in the field assumed that more damage was imminent and quickly took preventative action before the economic threshold was crossed; they didn't wait.

In a rainfed farming system, decision-making often resembles a 'performance' or a series of adjustments and improvisations in the face of uncertainty (Richards, 1989). For example, farmers expect to weed their maize and plan to allocate labour for this activity. However, these plans may unravel as the season unfolds, with some fields left un-weeded or weeded in a particular way. Weeding decisions are very flexible. In the study area, a separate analysis of farmers' decision-rules for second weeding identified no fewer than 24 criteria for deciding whether or not to bank their fields (Orr *et. al.*, 1998). Farmers synthesized information about events (rainfall, anticipated termite damage, weed growth, expected maize yield) and the relationship between them. For some farmers, controlling damage from termites had lower priority than controlling damage from weeds. In these circumstances, they preferred to bank their fields as usual and use 'adaptive' strategies against termites such as salvaging fallen cobs or tying up lodged maize plants.

STRATEGY AS AN ACCIDENT

The bean pest complex in Malawi comprises no fewer than eight insect pests (Ampofo, 1993). These include the bean foliage beetle (*Ootheca bennigseni*), the striped bean weevil (*Alcidodes leucogrammus*), and beanfly (*Ophiomyia* spp.). Damage from one pest may be minimal one year and devastating the next. In addition, heavy rainfall and the maize canopy create a humid microclimate that encourages the rapid spread of foliar diseases including common bacterial blight, angular leaf spot, *Ascochyta* blight, and Anthracnose. Added to the risk of moisture stress soon after planting that may completely wipe out the bean crop, this creates a volatile crop environment.

Field trials over three crop seasons showed low average levels of damage to beans from insect pests, with the exception of *Ootheca*. This made it difficult to draw firm conclusions about varietal resistance. However, the trials showed that the local variety *Kaulesi* performed significantly better than varieties recommended by the national bean research programme. Circumstantial evidence suggested that higher yield from Kaulesi might reflect early-maturity, which shortened its exposure to pests and diseases. During the main growing season, *Kaulesi* produces fresh beans after 90 days and dried beans by 120 days, a full month before *Chimbamba,* the variety most widely grown in the study area. Of the 11 bean varieties grown by the sample farmers, three (*Nyadanao*, *Mashunga*, and *Nambewe tikhwasule*) had maturity dates similar to or even earlier than *Kaulesi*.

Of the 14 farmers that were interviewed, only three perceived any connection between early maturity and reduced damage from pests. Most said that there was no difference in pest damage between early- and late-maturing varieties, or that it was impossible to tell. Similarly, research in other regions of Malawi has shown that the vast majority of growers were unable to identify bean varieties that were less susceptible to beanfly or *Ootheca* (Malawi Bean Improvement Project, 1997). Among our small sample, the only strategies used to control bean pests were killing by hand, not planting in areas of the field where wilting was common, and crushing the bean foliage beetle in the belief that the smell deterred others.

Rather than as an IPM strategy, farmers grow early-maturing beans to provide nourishment at a time when other forms of 'relish' to eat with maize porridge (*nsima*) are hard to find. February, when these varieties ripen, is traditionally a period when poorer households are reduced to eating weeds, for example *Bidens pilosa*, or wild plants. The importance of early-maturing bean varieties for food supply is captured by their names: Mashunga is nicknamed *Msunga banja* ('Tying the family together') while *tikhwasule* as in *Nambewe tikhwasule* means 'Can be eaten without *nsima*' (maize porridge). Early-maturing varieties also earn a hefty price-premium when sold in local markets. At planting, in late November, the price differential between *Kaulesi* and *Chimbamba* ranged from 40 to 70%. Prices fell after the harvest of the main bean crop in March, but recovered again by the harvest of the relay crop in July. In all three periods, the price differential never dropped below 22%.

In terms of pest management, therefore, farmers who grow early-maturing beans are accidental strategists. Usually, they cannot identify pest damage correctly. Since they do not understand insect reproduction, they see no connection between beanfly and their pupae. They attribute the cracked, swollen stems caused by the pupae to disease or physical causes such as cold or wind (Riches *et al*., 1993). Moreover, beans are attacked by a multitude of pests and damage varies between fields, land types, and seasons. In this crop environment, identifying sources of varietal resistance to beanfly is difficult enough for researchers armed with microscopes, let alone for farmers who simply lack sufficient information on which to base comparisons.

RETHINKING THE CONCEPT OF AN IPM STRATEGY

These analyses of farmers' IPM strategies find echoes in recent writing on business management. 'Strategy' originally entered the IPM lexicon as a borrowing from management theory which, in turn, had adopted the concept from the military (the word derives from the Greek '*strategia*' meaning generalship [Cooper and Argyris, 1998]). Since then, the application of strategy to management has become something of a growth industry. In the process, the concept has evolved so that, by the 1990s, the original view of business strategy propounded in the 1960s was being challenged by a number of new perspectives (Moore, 1992; Segal-Horn, 1998; Whittington, 1993).

Management theory in the 1960s saw strategy as the outcome of centralized planning (Ansoff, 1987). Corporate strategy was the preserve of top management, and businesses were guided by elaborate long-term plans prepared by specialized planning units. However, this view of business strategy assumed a stable market environment. The energy crises of the 1970s shattered this assumption. What was the point of long-range planning if market conditions could change so fundamentally and so quickly? Today, management theory lays much more emphasis on the external forces determining business success. Markets, prices, and competition create a 'turbulent' environment that leaves little scope for formal planning (Ansoff, 1990; Mintzberg, 1994). Frequently, strategies are not 'deliberate' but 'emerge' from the pattern of events in ways that cannot be predicted in advance (Mintzberg and Waters, 1998). The key to business success lies in finding ways to deal with this 'turbulence'. Instead of road maps with fixed routes, firms need compasses that provide them with strategic direction but leave room for flexibility (Whittington, 1993). Management texts in the 1980s stressed the importance of organizational flexibility in staying close to customers and anticipating market trends (Peters and Waterman, 1982).

Again, the 'classical' view of business strategy saw it as the product of rational analysis designed to maximize profits. However, behaviourists who observed managers in practice produced a different view of managerial decision-making. Rather than search for optimal solutions, managers usually accepted the first satisfactory option that presented itself, a form of behaviour known as 'satisficing' (Cyert and March, 1963). 'Satisficing' decisions were sub-optimal, but they satisfied several criteria rather than just one. The anatomy of management decisions also revealed that rational analysis might form only one element in the decision-making process. Decisions were also based on intuition, 'tacit' knowledge that was not easily formalized or (like chess grandmasters) on the recognition of 'patterns' that invited a specific response (Mintzberg, 1994).

Clearly, these insights have implications for the way that researchers conceptualize farmers' management strategies. Resource-poor farmers in developing countries operate in 'turbulent' environments that are highly unpredictable, whether in terms of physical conditions or pest attack. This often renders 'planning' a pointless exercise, but places a high value on 'performance', or flexibility and improvization. This is not to say that farmers never plan, but that they are flexible in how they reach their ultimate objective. In addition, resource-poor farmers are 'satisficers' rather than profit-maximizers (Lipton, 1982). They try to reconcile a number of different objectives, such as risk reduction and food security, with maximizing incomes. Finally, the rationality of farmers' decisions about pest or crop management may be limited. For example, it was not possible to identify farmers' economic thresholds for action against termites or whitegrubs. Researchers, who have more sound information, may be better placed to make these decisions than farmers.

Figure 3 illustrates how the influence of three important variables might determine farmers' choice of IPM strategy. The Y-axis shows the predictability of crop losses, which form a continuum from 'stable' to 'volatile'. The parameter assumes that crop losses from pests are high enough to justify the introduction of IPM strategies to reduce pest damage, and that the issue is what type of strategy is

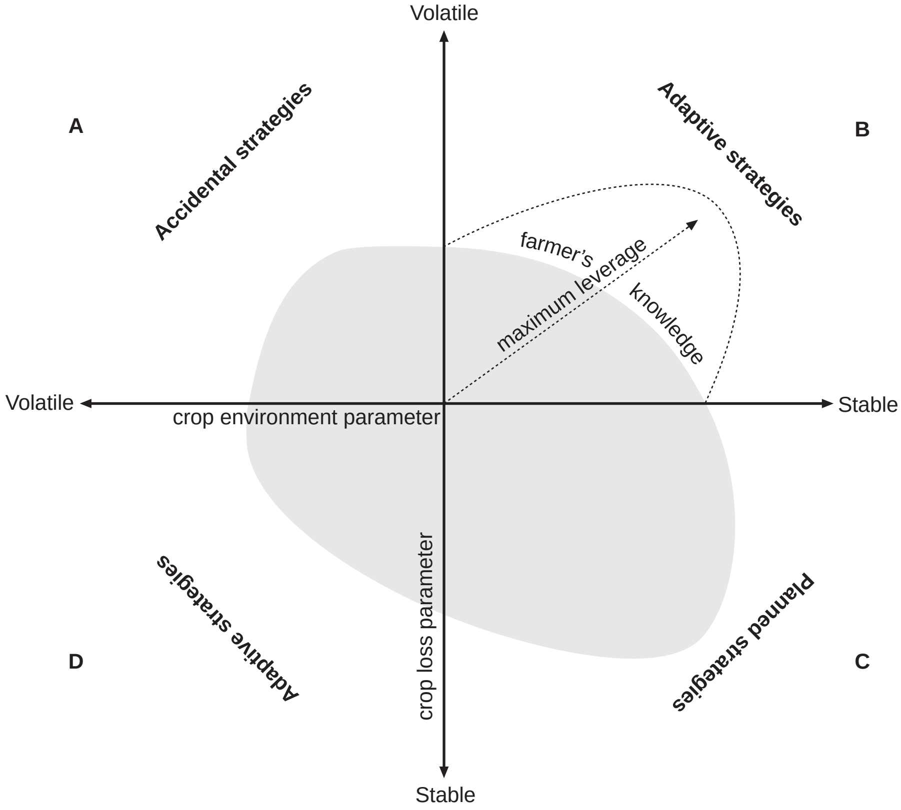


Fig. 3. Classification of farmers' pest management strategies.

appropriate. The X-axis shows the predictability of the crop environment, which forms a second continuum from 'stable' to 'volatile'. The 'crop environment' is defined here as the set of physical and climatic variables that determine final yield. The sphere in the centre of the two axes represents the variation in farmer knowledge of pests that, *ceteris paribus*, is associated with each combination of variation in crop losses and in the crop environment.

Figure 3 allows the identification of four distinct types of farmers' IPM management strategy:

1. In quadrant A, where both the crop loss and crop environment parameters are volatile, management strategies will tend to be accidental. Under these conditions, 'turbulence' in both parameters may prevent farmers from acquiring sufficient knowledge about pests to develop effective pest management strategies.
2. In quadrant B, where crop losses are volatile but the environment is reasonably stable, farmers will favour 'adaptive' management strategies. These conditions are the most suitable for the use of 'threshold' measures made in response to pest attacks as and when they occur. Given the stability of the crop environ-

ment, these strategies are effectively low-risk. Farmer knowledge of pests is high because of low turbulence in the crop environment that makes it easier for them to identify pests and the mechanism of pest attack.

3. In quadrant C, where both the crop loss and crop environment parameters are stable, farmers will adopt 'planned' management strategies. These are pre-emptive strategies made without any estimate of the actual level of pest attack. Knowledge of pests and causal mechanisms is highest in this quadrant.
4. In quadrant D, where crop losses are stable but the crop environment may be volatile, farmers will also favour 'adaptive' management strategies. Unlike in quadrant B, however, the greater volatility of the crop environment means that these strategies carry higher risks. These conditions favour the adoption of 'schedule' measures (for example calendar pesticide sprays) that are employed before or during pest attacks. They may also limit farmers' knowledge of pests.

The authors stress the limitations of this classification. It is not a management decision-model. This would require more variables than can be shown on a two-dimensional matrix. In particular, it would require information about the range of strategies available, their outcomes, and the farmers' objectives and degree of risk-aversion (Norton, 1982; Norton and Mumford, 1993; Mumford, 1981). Rather than analysing the decision-making process, Figure 3 classifies these decisions into different types in terms of two relevant criteria. Also possible are alternative classifications of IPM strategies based on the nature of control mechanism (for example, biological or cultural) or on farmers' prior knowledge of pest attack (for example, threshold measures, schedule measures, or calendar measures) (Norton, 1982). Furthermore, the criteria for classification in Figure 3 are not based on some objective measure of the variability of crop losses and the crop environment, but on farmers' perceptions. Two farmers with the same pest problem but with different perceptions of risk might choose different types of strategy. Similarly, the same farmer might use more than one type of strategy against the same pest, for example by integrating planned and adaptive strategies.

Despite these limitations, the typology does capture important features of the IPM strategies discussed above:

- *Planned strategies: stable crop losses and crop environment, good farmer knowledge of pests*. In the case of chemical seed dressing with Carbaryl, farmers had clearly identified the whitegrub pest, and the crop loss parameter was stable, with farmers experiencing high losses. Similarly, where farmers expected a stable level of damage from termites, they used the planned management strategy of *kukwezera* to keep soil and weeds away from the maize planting station. These circumstances favoured the development of farmer strategies that were planned ahead of time (quadrant C).
- *Adaptive strategies: volatile crop losses, stable crop environment, some farmer knowledge of pests*. Where crop losses from whitegrubs were less predictable, farmers had developed adaptive strategies such as seed or seedling replacement, or the cultural control known as *kufukulira*. A reasonably stable crop environment (just

after planting) and good farmer knowledge of the pest allowed the development of effective adaptive strategies (quadrant B). Similarly, where crop losses from termites were less probable and the planned strategy of *kukwezera* carried high risks, particularly in wet years, farmers preferred to use adaptive strategies (salvage, tying-up lodged plants) rather than change their method of weeding (quadrant D).

- *Accidental strategies: volatile crop losses and crop environment, poor knowledge of pests*. The volatility of crop losses and of the crop environment, combined with their limited knowledge of this pest, made it difficult for farmers to develop effective management strategies for bean stem maggot. Farmers who grew early-maturing beans (an IPM strategy identified by researchers) were not consciously practicing pest management. Improving farmer knowledge of the links between early maturity and yields would allow cultivation of early-maturing beans to become a planned strategy, but the turbulence of the crop environment would make it difficult for farmers to observe this link for themselves.

SOME IMPLICATIONS FOR IPM

If it is accepted that farmers' choice of IPM strategy is determined by the stability of the crop loss parameter, the stability of the environment, and by their knowledge of the pest in question, this has several important implications for research with resource-poor farmers.

Verification of IPM strategies

All the management strategies tested by the FSIPM Project (seed dressing, varietal resistance, cultural controls such as *kukwezera*) were 'plans' that could be tested in on-farm trials using a pre-determined experimental design. This design assumes some level of stability in the level of crop losses and in the crop environment. If these assumptions are not met, however, then the use of planned strategies is not likely to be appropriate.

For example, despite three seasons of field trials it was not possible to demonstrate that the farmer management strategy of using *kukwezera* against termites was statistically superior to the normal weeding practice of banking (Ritchie *et. al.*, 2000b). This was largely because of the unpredictable nature of damage from this pest. On the other hand, the trials showed that in the absence of termites *kukwezera* reduced maize yields. Except in situations where they expected high losses from termites, therefore, farmers preferred to use 'adaptive' management strategies like salvage. Where crop losses from pests are low and unpredictable, as in southern Malawi, farmers may prefer generally to use adaptive IPM strategies.

While it is possible for researchers to evaluate farmers' adaptive strategies through field trials, this may be an inefficient use of scarce resources. First, since adaptive strategies are designed to cope with random, low-level attacks, they are less amenable to verification using standard experimental designs and conventional tests of statistical significance. Second, if adaptive strategies are used primarily in situations where crop losses from pests are low, the benefits from these strategies are likely to be relatively small. Third, if these adaptive strategies are already widely known and used by farmers, there is little justification for on-farm trials to provide recommendations.

A parallel approach adopted by the project was to document the range of management strategies farmers used against a particular pest and the conditions in which they might use them. For example, the farmer practice of *kukwezera* against termites was described and illustrated together with the other weeding techniques used by farmers in the study area. Written up as a leaflet for Field Assistants, this would sensitize frontline extension workers to the range of farmers' pest management strategies and also illustrate why the blanket recommendation that farmers bank their fields at second weeding might not always be appropriate. This reversal of roles (farmers as teachers) is an essential part of participatory research and extension.

Knowledge as leverage

Research with resource-poor farmers has revealed important gaps in their knowledge of crop pests (Bentley, 1989; Riches *et al.*, 1993). Since IPM is knowledge-based, successful implementation has been critically dependent on improving farmers' identification of pests and knowledge of pest biology, particularly the lifecycle of the pest, its breeding behaviour, and the conditions that encourage growth in the pest population. Developing farmers' knowledge of pests is a form of leverage that provides a rationale for the adoption of IPM strategies.

The scope for leverage depends partly on the nature of the pest. Farmers know most about pests that are easy to observe and that they perceive as economically important, such as termites or whitegrubs. They know least about pests that are difficult to observe, such as beanfly, and may regard them as unimportant (Bentley, 1992). The scope for leverage depends also on the stability of the crop environment. Where it is easy for farmers to distinguish damage caused by pests and damage attributable to the crop environment, the level is high. Where the nature of the pest and the crop environment combine to make this distinction difficult, however, the scope for leverage is more limited.

The returns from improving farmer knowledge are greatest, therefore, in quadrant C where both the crop loss and crop environment parameters are relatively stable. Witness the success of IPM in crop monocultures such as cotton or irrigated rice. By contrast, in quadrant A where both the crop environment and losses are volatile, increasing farmer knowledge is unlikely to improve the adoption of IPM strategies. The bean pest complex is a good example. Bean growers in the Central African Highlands cleverly manipulate the crop environment to create a microclimate that reduces the risk of crop losses from pests, yet they cannot identify resistant varieties (Trutmann *et al.*, 1993). Bentley (1992) classes important but difficult-to-see bean diseases as 'enigmas'. Some enigmas are perhaps best left alone. Even with improved knowledge, it is questionable whether farmers could identify varietal resistance in the face of multiple pests and a volatile crop environment. Reduced damage from, say beanfly, would be subsumed by a myriad of other influences on yield. In this situation, farmers need alternative rationales to adopt IPM strategies. In southern Malawi, for example, a recommendation to promote early-maturing bean varieties might focus on the benefits from timely food supply and a price premium rather than reduced losses from pests.

Where farmers use adaptive strategies, the returns from improving farmer knowledge of pests may vary. Where the crop environment is relatively stable (quadrant B), returns are likely to be higher than where the environment is more volatile (quadrant D). This is because adoption of an IPM strategy depends not only on farmer knowledge of the pest in question but also on the perceived risk of adoption. Litsinger (1993) provides an example from wetland rice cultivation in the Philippines. In years following a good harvest, when farm households were food secure, farmers were more prepared to take risks and base their insecticide application on threshold measures. In years following a poor harvest, however, when households were not food secure they were more risk-averse and continued to use a calendar spray regime.

Interactions between pest and crop management

The number of possible interactions between pest and crop management is large (Meerman *et al.*, 1996). Some interactions are positive-sum, where synergy means that the whole is more than the sum of the parts. In southern and eastern Africa the major constraint on maize yields is poor soil fertility, a condition exacerbated by the high relative cost of inorganic fertilizer (Kumwenda *et al.*, 1997). In this context, IPM must be viewed as part of a wider strategy to secure and raise the productivity of staple crops grown by resource-poor farmers. For example, some strategies to reduce yield losses from *Striga* also address the underlying problem of poor soil fertility. These include the use of green manure crops such as *Tephrosia vogelii*), that may be undersown with maize, or the use of trap crops (groundnuts, soybean) that trigger premature emergence. In the study area, where one in eight fields was severely infested, the economic value of damage from *Striga* was estimated to be three times higher than the combined losses from termites, whitegrubs, and bean stem maggot (Mwale *et al.*, 2000). Thus, successful IPM strategies for *Striga* would have a major impact on crop yields and farmer incomes. Other interactions are zero-sum, where the gains from better pest management are cancelled out by losses elsewhere. As has been demonstrated, the IPM strategies of seed dressing with Carbaryl against whitegrubs and *kukwezera* against termites both reduced maize yields. Trade-offs are an implicit element of strategy. 'The essence of strategy is choosing what *not* to do' (Porter, 1998).

Lastly, IPM strategies usually have to meet both pest and crop management objectives. Overlooking this interaction may lead to the non-adoption of IPM recommendations. For example, in Malawi the pigeonpea variety ICP 9145 is more resistant to fusarium wilt than are local cultivars and it also gives higher yields. Adoption rates, however, never exceeded 15–20% of the area planted to pigeonpea (Subrahmanyam, 1996). This is explained partly by poor seed supply. However, when it comes to pigeonpea farmers are 'satisficers', preferring varieties with a number of desirable traits rather than just one. Its taste, seed colour and difficulty in de-hulling make ICP 9145 unpopular with growers and the processing industry. Field trials demonstrated that farmers preferred the newer variety ICP 00040, which was desirable with respect to these traits, even though it was no more resistant to wilt than ICP 9145 and in fact suffered more severely from damage by podborers (Ritchie *et al.*, 2000c). In the language of marketing strategy, this emphasized the importance of designing an IPM strategy that was consumer-led rather than product-led.

The research process

In Asia, the Green Revolution permitted large increases in farmer income with little need for improvements in the efficiency of crop management (Byerlee, 1987). In Africa, where infrastructure is less developed and input:output price ratios are higher, increases in farmer income are likely to need *both* Green Revolution technology and more efficient crop management. In this context, farmers' management strategies assume a new importance for the research process.

First, there is a need for greater understanding of these strategies. Even in low-input smallholder farming systems, as in Malawi, management strategies can be complex, reflecting an intimate knowledge of the crop environment and its attendant risks. The logic may not be immediately obvious to outsiders. To uncover this logic, it is essential that researchers spend more time learning from farmers. Without greater knowledge of why farmers do what they do, it is difficult to suggest improvements in efficiency. Thus, for example, recommendations on the timing of fertilizer application in maize cultivation must take account of farmers' preference to avoid basal application of fertilizer and to delay topdressing until the maize is well established because they want to be sure that their investment will not be wasted. This highlights the importance of a farming systems research perspective, where the central points of reference are the objectives of the farm household. Thus it is important to see IPM in a household context in order to understand the rationale for farmers' pest management strategies. Farmers' choice of early-maturing bean varieties, for example, reflected a concern for household food security rather than for the avoidance of crop losses from bean stem maggot.

Second, this understanding should be reflected in more appropriate recommendations. Frequently, researchers make prescriptive recommendations that ignore the complexity of the crop environment and the need for flexibility. In Malawi, for example, traditionally there has been one blanket recommendation for the fertilizer rate for hybrid maize. Only recently have researchers developed conditional recommendations based on soil texture, the relative price of urea and maize, and whether production was for home consumption or sale (Benson, 1998). Tailoring recommendations more closely to the farmers' objectives and to the crop environment should result in a more efficient use of scarce resources.

Lastly, the search for more effective pest management strategies requires greater realism about the scope for *integrated* strategies. In practice, most crop enterprises cannot justify the cost of sophisticated IPM systems (Apple and Smith, 1976). Smallholder agriculture is also handicapped by limited technical options. Although farming systems in Malawi are complex, agriculture remains rainfed and hoe-based, with little cash available to invest in crop protection. In these circumstances, farmers effectively lack a menu of pest management options for specific pests. Weeding, for example, is done with a hoe because herbicides are expensive and, unlike the situation in dryland regions of Zimbabwe, farmers do not use draught animals that would allow the use of cultivators. This limits the scope for truly integrated pest management strategies and directs research towards flexible, single strategies that are tailored carefully to farmers' circumstances.

CONCLUSIONS

The monolithic view of management strategy as a planned, wholly rational activity is clearly inappropriate in IPM. Resource-poor farmers operate in a 'turbulent' environment that favours improvisation over pre-determined plans. Such adaptive strategies make limited use of formal economic thresholds or rational analysis, but seem to rely more on intuition or 'tacit' knowledge that is not easily codified. Consequently, strategy is a multifaceted concept that assumes different guises in different contexts. No single definition of an IPM strategy does full justice to the variety of crop protection measures used by resource-poor farmers.

Farmers' choice of management strategy is influenced by their knowledge of the pest in question, the level and predictability of crop losses, and the stability of the crop environment. They usually develop 'planned' strategies in situations of high, predictable losses, while 'adaptive' strategies are generally found where losses are lower and less predictable. In situations where farmers' knowledge of pests is deficient, the variability of losses and the volatility of the crop environment may preclude the development of effective IPM strategies, although farmers may inadvertently use such strategies.

Formal experimentation has a limited role in the verification of IPM strategies for resource-poor farmers. Standard on-farm trials are effective in evaluating 'planned' or pre-emptive strategies (seed dressing, resistant varieties), provided that the pest is actually present. Experience in southern Malawi suggests, however, that farmers favour 'adaptive' rather than 'planned' strategies. This is because pest attacks vary in time and space, and because pest management is subordinate to the farm household's wider objectives of achieving food security or earning cash income. The prevalence of adaptive management strategies makes the task of formal experimentation difficult, since strategy becomes a performance that cannot be predicted in advance. Moreover, since adaptive strategies are a response to low and unpredictable losses, the cost of 'verification' is unlikely to be justified, particularly if these strategies are already known and widely used by farmers. In such circumstances it may be more beneficial simply to document what farmers are doing and why. This will generate useful knowledge for researchers and extension workers and temper the assumption that, in the absence of planned, pre-emptive strategies, farmers must inevitably experience high crop losses from pests.

Improving farmers' knowledge of pests is often a precondition for the adoption of certain management strategies. The scope for improving knowledge is greatest where the pest is visible and a relatively stable crop environment allows farmers to develop planned or adaptive strategies. Where the pest is less easy to observe and the crop environment is more volatile, it becomes more difficult for farmers to judge the effects of IPM strategies and, also, there may be higher risks attached to the use of economic thresholds. In these situations, alternative rationales must be found to promote the adoption of IPM strategies.

Lastly, it is unreasonable to separate the design of IPM strategies from broader crop management objectives. In southern Africa, IPM for staple foodcrops is more relevant when viewed as part of a wider effort to address the problem of poor soil fertility. In addition, experience in southern Malawi illustrates the importance of modifying IPM strategies to ensure they also address the broader requirements of the market.

Acknowledgements. The authors thank A. Larkin, the library staff at the Natural Resources Institute (UK) and J. Darlington, for supplying literature. Gratitude is expressed also to D. Cooter, C. Riches, and two anonymous referees for helpful comments, without incriminating them in the contents. The authors are solely responsible for any remaining errors and omissions.

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