Application Techniques to Meet the Requirements of IPM, IRM and Transgenics

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ABSTRACT

Farmers continue to treat cotton with insecticides more than most other crops due to the wide range of insect pests that infest plants at different stages of their development. Excessive use of chemical control, especially with poor timing and inefficient application has led to major problems of insecticide resistance in several countries. While reducing the number of insecticide sprays against lepidopterous pests, the introduction of transgenic crops expressing the Bt toxin gene has not eliminated the need to use insecticides. Improved application allows minimal use of insecticides to reduce the impact on beneficial species while still maintaining economic yields. The paper discusses how CDA and other application techniques allow farmers to improve integration of chemical control, including weed management, within IPM programmes and assist in resistance management, especially with increasing use of transgenic crops.

Introduction

Cotton with a flowering period extending over several weeks, is a very attractive crop to a wide range of insect pests and in consequence has been treated with many different types of insecticides. This has led to major problems of insecticide resistance in several cotton growing countries where small-scale farmers use manually carried sprayers. In most of these cases, a relatively dilute spray is applied, usually in over 200 litres of water per hectare, from knapsack sprayers with a hydraulic nozzle held above the crop. Some farmers have used trombone type sprayers. Most of the spray is deposited on the upper surfaces of the top leaves with very little reaching the bracts surrounding young flower buds within the crop canopy. In consequence control of bollworms is poor, so when farmers see larvae still feeding on their crop, they re-spray with the same equipment. Often the same insecticide active ingredient is used, even if a product with a different trade name is used. As the larvae are older, a higher dosage would be required, partly due to their larger size, but also because the insect would have developed its own enzyme systems to cope with toxins in its food. In many situations farmers have sprayed over 20 times during a season, sometimes using tank mixes of 2 - 4 different insecticides and often at higher than the recommended dosages (Armes and Raheja, 1997). Mangan (1997) refers to an average of 22.8 sprays applied on cotton in Wenshang County in Shandong, China.

The small farmer, constrained by a lack of capital, usually purchases the cheapest sprayer available. In India, this was the manually operated syringe sprayer, but more recently and elsewhere in Asia, locally manufactured lever-operated knapsack sprayers, fitted with a lance and single cone nozzle have been used. Hameed (1996) measured a droplet size in excess of 450µm VMD with a flow rate of >1.5 l/minute with a locally available knapsack sprayer with assessments of coverage confirming poor or non-existent coverage of underleaf surfaces and very little penetration into the lower part of the crop canopy. Hameed's data showed that with this sprayer, deposition declined on the upper surfaces of leaves from 6.25 droplets/cm^2 on upper leaves to <1 droplet/cm^2 on the lower leaves. Some farmers have, however, invested in motorized knapsack sprayers which are considerably more expensive, but then to offset the higher costs often attempt to treat several rows with each passage through the crop. Application with this equipment improved upper surface coverage on the upper leaves due to a much reduced droplet size, but penetration through the canopy and on the underside of leaves remained poor (Hameed, 1996).

The poor distribution of insecticide within the canopy might suggest that there are uncontaminated refugees so that any selection for resistance should be counteracted by dilution with susceptible insects. In practice, this does not occur because of the continual exposure of the insects on plants that have extremely small amounts of insecticide deposited from high-volume low-concentration sprays. Thus as the plant grows, lower surfaces may retain a very small proportion of the spray deposit, applied when the plant was smaller, but insufficient to kill the more susceptible early instars. This exposure leads to selection of resistant populations.

Spray Coverage

The hypothesis is that if coverage of the sprays throughout the part of the canopy in which bollworms occur is improved, higher mortality of the early instars is achieved; in particular the first instar larvae are controlled prior to their penetration of the buds and bolls. If the dosage applied is kept low and just sufficient to kill these young larvae, then with normal degradation of the insecticide deposits, the amount remaining on leaf surfaces will be less than if a full dosage was applied over the top of the crop, and in consequence reduce the selection pressure for resistance. This effect is accentuated, as the farmer will not observe the larger bollworms when young larvae are killed, so there will not be the pressure to re-spray so frequently.

To improve application with hydraulic sprays requires droplegs or 'tailbooms' to place nozzles between the rows and within the crop canopy so that the spray is directed upwards between the layers of branches and the droplets are deposited on the bracts, petioles and other surfaces on which the first instar larvae walk from egg hatch to penetration of a bud or boll. This is not a new concept, having been recommended in the early 1960's (Tunstall *et al.*, 1961, 1962, 1965; Tunstall and Matthews, 1961,1963, 1965; Matthews and Tunstall, 1965), and enabled relatively low amounts of insecticides to be applied in Central Africa. However growers have neglected the technique. Successful use of droplegs requires more complex equipment and with tractor-mounted sprayers, guards in front of each dropleg are needed to ensure that in its passage through the crop, it does not do mechanical damage to the crop. With droplegs fitted with multiple nozzles directed up into the crop, volumes can be kept at about 200 l/ha for fully-grown crops by using hollow cone nozzles applying 200ml/minute at 3-bar pressure. Clearly for this system to operate attention is needed to inter-row spacing (preferably 90 - 100cm), plant spacing within the row and choice of variety so that stems do not fill the inter-row and impede passage of the sprayer. Row spacing in Asia is generally narrower, possibly as weed growth is less once the canopy meets across the inter-row.

An alternative approach has been the use of an air-sleeve along the boom to provide a curtain of air that entrains the spray droplets and penetrates down through the crop canopy. In practice the success of this technique with cotton will depend on the crop variety, spacing and agronomic situation. With lush plant growth, especially with excess nitrogen applied, too narrow row spacing or large leaves, the barrier to penetration down through the crop is extremely high once the plants meet across the rows. Under these circumstances deposition of spray in the lower part of the canopy and on the lower surfaces of leaves is poor. Recent research in Israel is investing other forms of air-assistance which involves releasing spray in the inter-row (Gan-Mor *et al.*, 2000; Grinstein *et al.*, 2000).

In small-scale farms in Africa, adoption of ultra-low volume spraying with hand-carried spinning disc sprayers, capable of controlled droplet application (CDA), used natural air turbulence to distribute spray within the crop canopy, but unless movement of leaves occurs during spraying underleaf coverage remains minimal. The technique has proved robust and effective, presumably to some extent because oil-based UL formulations were more rain-fast and applications once started were generally on a calendar schedule to protect new growth during the critical boll development phase of the crop. The cost and limited choice of UL formulations has led to a change to very low volume (VLV) spraying technique using conventional formulations diluted in 10 litres of water per hectare, so that the farmer has greater flexibility in choice of chemical in relation to pest infestations. Studies by Clayton (1992a, b) indicated that changing from ULV to VLV using an ULVA + sprayer (Clayton *et al.*, 1993) with a larger droplet size (100 - 120μm instead of 50 - 70μm VMD) can improve penetration to lower leaves. Hameed (1996) reported limited droplet assessments using a spinning disc sprayer and obtained better deposition in comparison with the knapsack sprayer as used by the farmer (Table 1). Underleaf coverage remains poor except in the upper canopy where movement of leaves is induced by the wind. The VLV technique has become adopted extensively in West Africa as it allows farmers to treat their crops rapidly when required (Cauquil and Vaissayre, 1995) and 1.9 million hectares are now treated annually using this technique (Anon, 1998).

So far, in contrast to the situation in India, Pakistan and China, where insecticides have been applied as dilute sprays in large volumes, there has been no major problem due to insecticide resistance in Africa. Whether this is due to differences in application technology is not known, but overall better distribution of more concentrated droplets has provided consistently effective control of bollworms with relatively few applications, on average 4 - 5 per season. Other factors undoubtedly influence the resistance situation. In West Africa, spray schedules have been much more regulated and the market for pesticides has been controlled. In contrast, outside Africa, pesticides are readily available in villages and thus more pesticides are used on vegetables and other crops to control *Helicoverpa armigera* and whiteflies on other host plants. This contrasts with the situation in most African countries, where cotton is the principal crop on which insecticides are applied and where large areas of maize and other cereals are untreated.

Application Technology and Resistance Management

If insecticide resistance is to be managed, improved application, using droplegs or CDA technology in addition to area-wide control on the range of active ingredients available to farmers is required, to ensure greater mortality of pests and thus reduce the motive for repeating sprays as frequently as twice a week. If this is to be effective then farmers should re-examine some of their agronomic practices. It may be that a slightly wider row spacing would allow better utilization of insecticides without any impact on yield. If weed control is a factor, herbicide application, albeit another input, should be considered as it would reduce weed competition over a wider area at a critical period of crop establishment and by lessening disturbance of the soil, allow greater survival of certain natural enemies located in the soil. In irrigated crops, ridging would also assist survival of soil inhabiting natural enemies during irrigation along the inter-rows. Weed control using low volume CDA spinning disc sprayers, has already increased in West Africa as availability of labour and the cost of manual weeding make chemical control economically more attractive to farmers (Martin and Gaudard, 1997).

It might be argued that the introduction of genetically engineered cotton varieties containing the gene for the *Bacillus thuringiensis* toxin, effective against lepidopterous pests should overcome the problems of spray application. While it is true that the Bt gene is effective against certain species of lepidoptera, initial data has shown differences between bollworm species. In the USA control of *Helicoverpa zea* on some farms was less than *Heliothis virescens* and this has led to Bt cotton being sprayed. Furthermore a proportion of the acreage allocated to non-Bt cotton will also require spray treatments. In addition, the absence of broad-spectrum insecticides for bollworm control has led to an upsurge of sucking pest populations in some areas. In Africa, apart from effects on jassids, aphids and whiteflies, this could increase the importance of cotton stainers, *Dysdercus* spp., that have been minor pests in areas where insecticides have been used.

The growing of cotton varieties resistant to a particular herbicide has other complications. It might be argued that application is easier, but there is considerable concern by the public that technologies should not increase use of chemical controls. Overuse of one type of herbicide will lead to a change in the weeds present and select for resistance, so the use of these new varieties does require caution. Furthermore the amount of herbicide applied and timing of its application should be carefully considered to optimize use of a minimal dosage.

Conclusions

Application technology tends to be forgotten, as agrochemical companies tend to leave the decisions regarding how insecticides and other pesticides are applied to the user. Experience in Africa has shown that it is better to provide definitive recommendations on the application technique to be adopted and encourage the cotton processing companies, the ginneries and others involved in the industry to make the required equipment inputs accessible to farmers.

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Table 1. Spray droplets deposited on leaves and VMD measured using magnesium oxide coated slides in cotton in farmers' fields Pakistan.

Sprayer	Droplet size (VMD)	Number of droplets on upper surface/cm^2		
		Top leaves	Middle leaves	Lower leaves
Knapsack	690	6.25	2.75	0.75
ULVA+	125	58.5	35.5	17

Source: Hameed, 1996