Pesticide Research at Silwood Park

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Work on insecticides, especially pyrethrins used to protect food supplies, had begun at Imperial College at Slough under J.W. Munro in the 1930s. Apart from the pioneering work on protecting stored produce, there was much activity during, WWII to assess insecticides, including, DDT, to combat disease-carrying insects. Drs Page and Lubatti, who had been very involved in the development of fumigation techniques, continued this work after their move to the Field Station at Silwood Park. Frank Call and others studied the distribution of fumigants in soils, ships and warehouses (Pace & Lubatti, 1963). With the discovery of new insecticides and new statistical techniques, much attention was given to the study of bioassay techniques by Robert Blackith and the distribution and pick-up of deposits by insects (Lewis, 1954, Lewis & Huches, 1957; Gratwick, 1957a,b). Continuing the interest in protecting stored grain, Geoff le Patourel has developed the activity of sorptive dusts to reduce the amount of insecticide needed and reduce residues and selection for resistance (Permual & le Patourel, 1992). Sorptive dusts, whether combined with insecticide or not have also proved very effective against cockroaches, especially in ducting of air-conditioning systems.

Interest in aphids led to studies of the effects of applying granular formulations in soil (Way & Scopes, 1968, Critchley, 1972), and integration of chemical and biological control (Way *et al.*, 1969). Much of John Galley's work has been with pesticide degradation and mobility of systemic compounds in plants, particularly in relation to nutrient sinks developed by aphid colonies (Galley, 1974), but other varied topics include the stability of pesticides in hen-house litter (Galley, 1972) and control of the museum beetle *Anthrenus sarnicus*. Newer insecticides such as abamectin (Christie & Wright, 1990) and the acylureas (Fisk & Wright, 1992) have been the focus of studies with *Spodoptera* spp. and *Plutella*, especially the latter, with resistance to most insecticides (Fauziah & Wright, 1991). These studies now include multi-trophic interactions between the crop, pests and their natural enemies (Furlong & Wright, 1993; Wright & Verkerk, 1995).

Application technology and overseas links

Interest in the development of application equipment (Higgins, 1945; Higgins & Green, 1947) resulted in the setting, up of the Colonial Spraying Machinery Pool in 1955. Later known as the Overseas Spraying Machinery Centre, it is now called the International Pesticide Application Research Centre *(IPARC)*. An early innovation was a sprayer developed by Jake Siddorn. It was fitted with a bicycle lamp and sensor to detect the presence of cabbage plants and avoid spraying the caps between plants; a forerunner of the detectors now used on some orchard sprayers. Evan Thornhill provided assistance by spraying broom plots at Silwood, in one of the first experiments to assess long-term effects of a pesticide on insect populations (Waloff & Richards, 1977). Similar help was given to Dick Southwood who wanted to sample insect populations in silver birch trees. Initially a knapsack mistblower was used to project a non-persistent pyrethrin insecticide into the trees so that the insects fell on a large sheet under the trees. Later this technique was adapted by using a thermal fogger.

In the immediate post-WWII era, there was a very strong, influence on the development of Silwood from the Colonial Office, who wanted people trained to go out to the tropics. This led to the development of the D.I.C. course in Applied Entomology - the forerunner of the M.Sc. course started in 1966. Many of these Silwood trained entomologists were recruited to serve overseas. No doubt influenced by the applied ecology taught by Drs Walter Jepson and Nadia Waloff, one of the first outcomes of my joining John Tunstall (also ex-IC) on the Cotton Pest Research Scheme in the Federation of Rhodesia and Nyasaland was an early appraisal of the different control options (Tunstall *et al.,* 1959). This indicated that careful use of chemical control "in conjunction with other forms of control" could lead to high yields of cotton, long before the concept of integrated pest management was promoted in the USA. Studies on chemical control (Matthews, 1966) led to the use of scouting to determine the timing of spray applications (Matthews & Tunstall, 1968) and different insecticides depending on which bollworm species was dominant (Tunstall & Matthews, 1966). This programme limiting the use of each insecticide to a part of the season was recommended throughout the region prior to the resistance management programme that was introduced in Australia in the 1980s.

Silwood was involved in other contributions to the cotton programme from Derek Camplon (Campion & Outram, 1967), George Murdie (Murdie & Campion, 1972) and Jim Marks (1978), and notably with Brenda Nesbitt and others at the Tropical Products Institute (now part of the Natural Resources Institute) to identify the pheromone of *Diparopsis castanea (*Nesbitt *et al.,* 1973)

Sprayer development

Another influence from Silwood was the modification of knapsack sprayers by adding a rear-mounted vertical boom behind the operator, the "tailboom" (Tunstall *et al.,* 1961) and this concept was extended to tractor equipment (Tunstall *et al.,* 1965). In addition to improving, the distribution of spray through the crop canopy, the knapsack tailboom was shown to reduce operator contamination (Tunstall & Matthews, 1965).

Unfortunately one of the difficulties in getting spraying adopted by the many small-holding farmers, particularly in Malawi, was the problem of durability of the sprayers. Farmers were sharing equipment so it was used much more intensively than on the research station. Testing techniques had already been developed and specifications for equipment used in vector control published by WHO (Anon, 1964), so work was carried out at Silwood on the testing of lever-operated knapsack sprayers (Matthews *et al.,* 1969). This led to the design of the CP3 sprayer by one of the UK manufacturers, Cooper Pegler.

ULV sprays

During this period at Silwood, discussions on the problem of water supplies on many small-scale farms with Edward Bals of Micron Sprayers led to the evaluation of the hand-carried spinning disc sprayer, the ULVA, applying up to 2.5 litres of oil-based insecticide spray per hectare. This was the first research on ultra-low volume (ULV) spraying on field crops and showed that farmers could achieve the same yields as those using, the knapsack sprayers (Matthews, 1973). The ULV technique was most widely adopted in francophone Africa from 1975 onwards (Cauquil, 1987), but subsequently the cost of UL formulations has led to a return to the use of water-based formulations applied at 10-15 litres per hectare, originally studied by other former Silwood entomologists in Malawi (Mowlam *et al,* 1975; Nyirenda, 1986). Recent studies at Silwood have examined the extent of operator contamination when using- spinning disc sprayers in comparison with knapsack equipment (Thornhill *et al.,* 1996).

Droplet sizing

Measuring spray droplets had always been so laborious that despite the importance of knowing more about spray droplet spectra, little had been done at IC following the work of Fraser (1958), working, in the Chemical Engineering Department. However, in 1978 ODA provided funding to purchase a Malvern particle size analyser, originally developed at Sheffield for Rolls Royce to study atomisation of fuels in Jet engines. This equipment allowed much more rapid characterisation of the different nozzle types. Combellack and Matthews (1981) examined the spectra of cone and fan nozzles at conventional spray volumes, while Hejne (1978) characterised a new spinning-cup which we developed with Edward Bals to allow larger volumes to be applied by rotary atomisation from a tractor-mounted sprayer, and Hewitt (1992) examined atomisers used in armyworm and locust control.

Other laser equipment had been developed for measuring droplets in clouds, but results with temporal sampling differed from spatial sampling, with the Malvern equipment. To assess differences between these and other methods of measuring spray droplets, a sample of nozzles was sent to several laboratories. The data obtained (Arnold, 1987) suggested that comparison of spectra would be easier, if each laboratory calibrated with a series of reference nozzles. This system was adopted by the British Crop Protection Council to define different spray qualities and provide more guidance on selection of nozzles to minimise the risk of spray drift (Doble *et al.,* 1985). This "Spray Quality" system was included in the Code of Conduct for applying pesticides and has now been more widely adopted in Europe and the USA, with additional data from wind tunnel studies (Miller *et al.,* 1993).

With concern about spray drift, dysprosium/neutron activation analysis (at the Imperial College Reactor Centre – previously CARE - Silwood Park) was used to trace spray (Dobson *et al.,* 1983). Another study in collaboration with Volrath at Oxford confirmed that the smallest droplets drifting in the environment are efficiently filtered out by the fine strands of spiders' webs (Samu *et al.*, 1992). To reduce shrinkage of water droplets, studies on adjuvants included effects of oil on evaporation (Wodagenah & Matthews, 1981), rainfastness of deposits to improve *Plutella* control on cabbages (Taylor & Matthews, 1986) and droplet spectra (Barnett & Matthews, 1992). Another focus was on using an electrostatic charge on droplets to improve deposition on crops (Matthews, 1981).

Insecticide machinery pool at *IPARC, Silwood Park*

Electrostatic spraying
Work with the "Electrodyn" sprayer, in collaboration with Coffee of ICI agrochemicals (now Zeneca) developed the concept of a hand-carried electrostatic sprayer to apply ULV formulations. With pre-packaged containers to eliminate farmer exposure to pesticides the "Electrodyn" was used in several countries, notably Mozambique and Brazil (Matthews, 1989; 1990), but the limitations of spray volume, cost of oil dilutent and restricted choice of insecticide to meet resistivity specifications prevented its continued use. Elizabeth Chadd (1985) studied electrostatic sprays for mosquito control in Tanzania and Andrew Harberd (1988) tsetse control in Somalia.

A significant reduction in soil contamination under treated crops allowed greater survival of ground inhabiting predators (Endacott, 1989), but pests within crop canopies may not be controlled when charmed sprays are preferentially deposited on outer leaves unless a turbulent air flow improves canopy penetration.

Effects of small droplets
Meanwhile fundamental studies on effects of droplets of different size on insects on foliage were started by collaboration with the Glasshouse Crops Research Institute, now part of HRI. Mboob (1975) had shown difference between a cold fogger and a mist applicator on glasshouse tomatoes. Subsequently Munthali (1984) using red spider mite *(Tetranychus urticae)* eggs as a sessile target compared different sized droplets and spray concentrations of dicofol in an oil formulation. The reduced amount of insecticide needed with small droplets prone to drift stimulated the electrostatic studies to improve deposition. Abdalla (1984) studied different formulations and Omar (1987; Omar *et al,* 1991) used *Plutella* larvae and Hameed (1996) the highly mobile *Dysdercus* to assess the influence of insect mobility on the effectiveness of discrete droplets. These studies encouraged others to improve the efficiency of sprays by examining the interrelationships between droplet size, spray concentration and formulation. However, hydraulic nozzles continue to dominate spraying throughout the world, increasing concern about lower dosages of pesticides where the sprays can be environmental pollution and to lower dosages of pesticides where the sprays can be more accurately timed.

Application of biologicals
Collaborating with industry, Roy Bateman developed application of thiodicarb for bollworm control (Bateman, 1989). This experience with particulate suspensions was invaluable when the International Institute for Biological Control recruited him to participate in the *LUBILOSA* project (Bateman & Thomas, 1996). There was a need for an alternative method of controlling locusts instead of organophosphate and pyrethroid insecticides. IMI had a strain of *Metarhizium,* collected from locusts, so the question was whether the fungal spores could be applied to locusts in a hot dry environment using the *ULV* technology used with dieldrin. ULV suspension of conidial spores developed at Silwood has been evaluated in locust-affected countries. The technique now needs to be used in ecologically sensitive areas. Recent studies have included foliar sprays of entomopathogenic nematodes (Lello *et al,* 1996).

Operator safety
Although alternative application techniques to hydraulic spraying have been an important part of the research work at Silwood, the knapsack sprayer remains the most widely used equipment in tropical countries. As the operator is much closer to the spray and often gets heavily

contaminated, further work on the design of these sprayers has introduced the "spray management valve" to provide a constant pressure at the nozzle (Craig *et al*, 1993a). This equipment was developed in conjunction with Laurie Down in Australia, together with a disposable container dispenser (DCD), that allows a pre-packed pesticide to be injected close to the nozzle at a pre-determined dilution rate (Craig *et al.*, 1993b). Unfortunately this design has not been commercialised so far, as the returnable container needs to be part of an agrochemical packaging system. If adopted it would provide a greater guarantee that a given pesticide was applied at the correct rate, the only other variable berries the operator's speed of moving through the crop, while greater acceptance of returnable containers would reduce environmental pollution due to discarded pesticide containers.

The work on pesticide application has enabled the unique collection of equipment initiated by Arthur Higgins back in the 1940s to be maintained and provide the ideal forum for training the many course participants who have come from throughout the world to Silwood Park.

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