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Spray application to cocoa pods and other small targets using cone nozzles

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Summary

Cone nozzles are usually considered most appropriate for applying insecticides and fungicides to complex surfaces. Smallholders in cocoa growing areas commonly buy spraying equipment fitted with variable atomisers that produce indeterminate sprays (*i.e.* a range of droplet size spectra). Because they are infinitely variable, the spray pattern cannot be duplicated and farmers often have difficulty deciding which setting to use. With wide variations in configuration and pressure accurate calibration is impossible, so there are large variations in both spray angles and droplet size spectra. Larger droplets are highly likely to "run-off" the crop, contaminating both the operator and the environment. Simply replacing variable nozzles with standard cone nozzles is an imperfect solution since they are designed and recommended for row crops, and typically produce a wide angle (>60°) of spray.

A USDA sponsored a research programme included a survey of cone nozzle configurations with a view to optimising dose transfer efficiency to cocoa pods, flowers and branches. Spray tracer studies to estimate residues on cocoa pods showed that nozzles that emitted a very narrow spray angle at low flow rates achieved substantially better deposits on pods than normally supplied equipment. Although these nozzle configurations are not usually fitted for mechanised agriculture, suitable nozzles can be made up from standard sprayer parts. Inclusion of pressure regulating valves may further improve reliability, but increase costs to cocoa farmers.

Narrow-angle cone nozzles are being assessed in a series of both insecticide and fungicide field trials in Latin American, W. African and S.E. Asian cocoa. They may be suitable for a number of other situations where efficient spray deposition is required on smaller biological targets, such as branches and individual fruit.

Key words: application efficiency; cone nozzle; droplet size spectra; cone angle; pesticide deposition; cocoa; *Theobroma cacao*

Introduction

Cocoa has been described as a "virtuous crop". There is an increasing appreciation of its value for: land rehabilitation, maintenance of biodiversity and provision of sustainable incomes in less developed regions. Like other crops though, it can be attacked by a number of pest species including fungal diseases, insects and rodents. Most cocoa farmers are small-holders, who usually minimise inputs for pest and disease management, and may do nothing when cocoa prices are low. However, when deemed cost-effective, pesticides are used in all three major cocoa growing areas (Latin America, W. Africa and S.E. Asia). Although low-volume spraying with motorised mistblowers was specifically developed for cocoa (Clayphon, 1971), much pesticide application takes place using low-cost, manual, (hydraulic) knapsack sprayers. Some authors (*e.g.* Pereira, 1983) believe that mistblowers are now unsuitable for small-holder farmers, due to their capital cost and the maintenance required for 2-stroke engines.

Critical cocoa pod diseases include black pod, *Phytophthora spp* (especially *P. megakaryia* in W.Africa) and *Moniliophthora roreri* (frosty pod rot in Latin America) – which both have the capacity to reduce yields by up to 80%. Farmers spray for *Phytophthora spp.* on a regular basis, since copper compounds and fungicides such as metalaxyl are effective and relatively cheap (Evans & Prior, 1987). In S.E. Asia, the cocoa pod borer (CPB: *Conopomorpha cramerella*) is commonly the most critical pest problem in the crop, and in Sulawesi (where most cocoa is grown at present) it is thought to cause 20-30% yield losses. All three of these problems have spread in recent years, and are sometimes described as 'invasive species'.

Current research into improved application methods aims to: (a) provide practical and economic techniques to reduce the use of chemical pesticides and (b) to improve the effectiveness of experimental microbial and chemical control agents that may have a lower environmental impact. The central hypothesis behind this work is that dose-transfer efficiency can be improved by optimising spray deposition onto what are normally slender biological targets (thus lowering the cost to the farmer). In the case of CPB, the biological spray target has been defined by Day *et al*. (1994) and during their one week-long period of egg laying, includes the pods themselves (as with the pod diseases). Adult CPB moths also prefer to roost on branches during the day, and typically prefer horizontally inclined, less than 50 mm in diameter and relatively free from epiphytes.

Cone nozzles are most appropriate for applying insecticides and fungicides to complex surfaces such as branches and dicotyledonous foliage (Matthews, 1974). Many locally-available sprayers are fitted with variable cone nozzles that produce an infinitely variable range of droplet sizes and flow rates (*e.g.* Bateman, 2003). They are arguably a contributory factor to reported poor or variable fungicide efficacy, and a capacity to make recommendations based on fixed geometry nozzles would be highly desirable. Nozzle manufacturers understandably focus on tips that are likely to be used in their principal markets (*e.g.* on tractor booms at pressures up to 2 MPa) with cone angles that are typically in the region of 80° (*e.g.* Combellack & Matthews, 1981). When used on the narrow spray targets described above, 80° nozzles inevitably result in considerable wastage of pesticide. Jollands & Jollands (1984) appreciated that more targeted application of fungicides, on cocoa trunks and pods, could achieve better control of black pod (*P. palmivora*) with careful selection of cone nozzles. Substantially reducing volume application rates (VAR) to as little as 65 l/ha, using a TX2 'Conejet' with a 67° cone angle, had no effect on yield and significantly reduced the spread of black pod lesions. However, Matthews (1974) pointed out that low flow rate nozzle tips with narrow orifice sizes are prone to blockage, especially with tank mixtures containing particulate material (by design or otherwise), and were not necessarily the most practical solution in the hands of smallholders that had received little or no training.

Combined with the fact that nozzles are obtained from a number of manufacturers, the task of extension personnel is therefore complex, and it is probable that no single "cocoa nozzle" formula is universally applicable. The objective of current work is to place data on cone nozzle characteristics in the public domain, focusing especially on settings that are likely to be useful for cocoa farmers (and perhaps also similar slender crop targets). This is being supplemented by field evaluations in a number of trials in all three major cocoa growing regions.

Nozzle characterisation

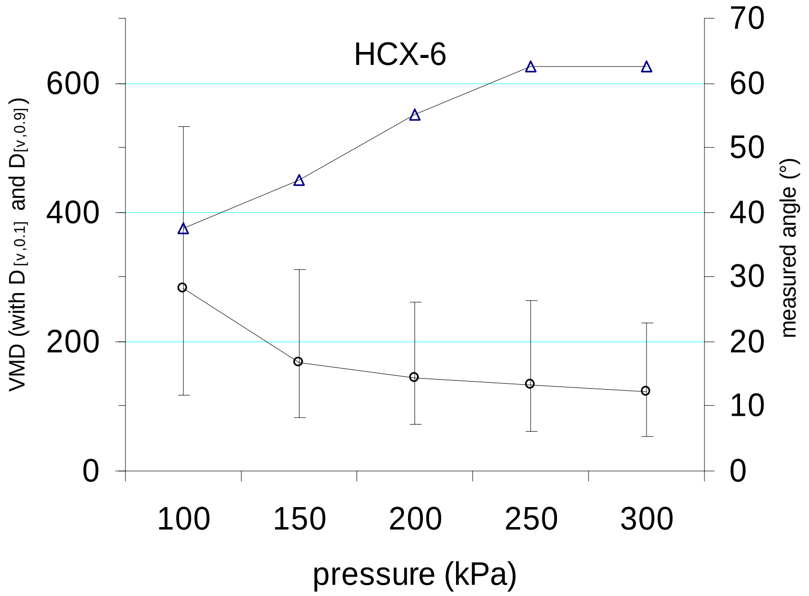
Cone nozzles are available in a number of forms including:

1. Standard (integral) hollow cone tips (*e.g.* Spraying Systems: 'ConeJet' and 'VisiFlo'TX range; or Hypro Lurmark 'HollowTip': HCX series). Spraying Systems produce 'TY' nozzles that form a narrower 65° cone.
2. Full (or solid) cone tips: are manufactured for spot applications: *e.g.* the Hypro Lurmark 'FulcoTip'.
3. Separate disc and swirl plates: described by an arcane coding system (Bateman, 2004) and produced by both of the above manufacturers.
4. Other proprietary cone nozzle designs are fitted as standard to certain manual sprayers (*e.g.* an orifice plate and swirl mechanism incorporated in the nozzle body: as fitted to many Chinese sprayers).
5. Variable cone nozzles that can be set from a fine hollow cone spray to a jet.

Bateman (2004) surveyed of the spray output from a number of potentially useful cone nozzles from two manufacturers: within a low range of flow rates and cone angles. Droplet size spectra were measured with a Malvern 2600 PSA (Malvern Instruments Ltd., Spring Lane South, Malvern, Worcestershire, UK), fitted with an 800 mm lens along the guidelines of BCPC protocols (see: www.dropdata.net/bcpc_ewg/index.htm). Disc and swirl plate nozzle combinations were mostly selected since these appear to be the most cost effective and easily available means of achieving narrow cone sprays in cocoa producing countries. The objective was to identify nozzle combinations that achieve <40° (ideally <30°) spray angle with a relatively fine droplet size spectra that would avoid "run off".

Example analyses are shown Fig. 1, where data have been presented as diagrams that consist of a line with bars (left hand scale) that represent the Volume Median Diameter (VMD) or $D_{[v,0.5]}$ with the 10% and 90 percentiles ($D_{[v,0.1]}$ and $D_{[v,0.9]}$) of the droplet size spectra (*i.e.* representing the relative span). The lines marked with triangles (right hand scale) represent the measured angle of cone. These and other nozzle analyses can be down-loaded from www.dropdata.net – in order to make the information as widely available as possible.

Fig. 1 shows that with standard hollow cone tips such as the Hypro HCX-6, increasing the pressure above 150kPa, to achieve a reasonable fungicide/insecticide spray spectrum, results in an increase of cone angle to >60°. Narrow (<45°) spray angles can be achieved by using a number of disc and swirl plate combinations, and generally, reducing disc hole size or increasing swirl plate rating reduces the angle (for a given pressure). Cone angles can often be reduced by lowering the pressure, but there is a "pay off" with an accompanying increase in droplet size. For a given nozzle combination, the VMD always decreases at higher pressures, but narrower discs such as the Spraying Systems (or Hypro equivalent) D1 and D1.5 (as illustrated) combined with a #25 swirl plate, produce <40° sprays over a range of pressures.



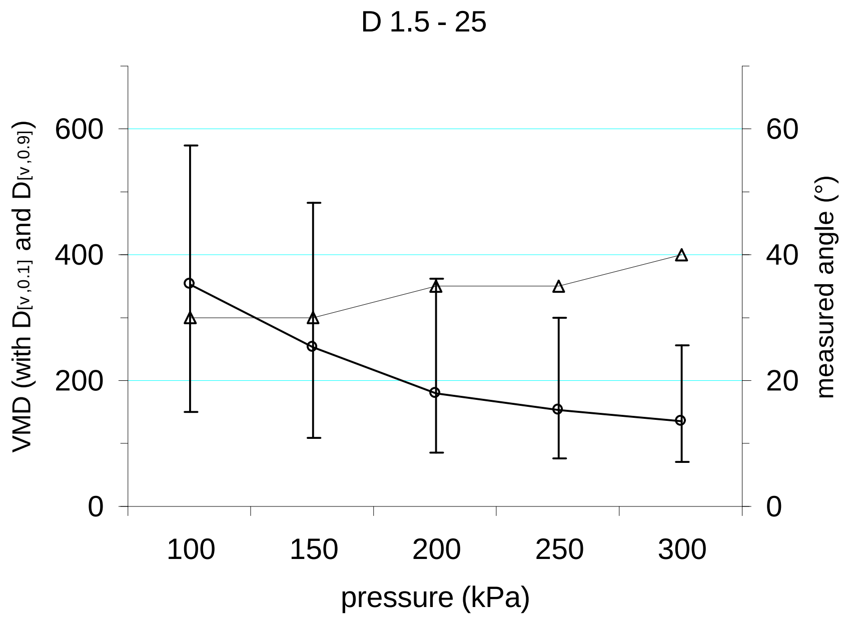


Fig. 1. Droplet size spectra (left hand scale) and cone angle (right hand scale) for two cone nozzles

Field evaluation

In a series of field trials for control of *M. roreri*, a directional spray was simulated in a reproducible way with a D2-45 fitted to a 300 kPa pressure regulating valve to give a VAR of 200 $L.ha^{-1}$ at a flow rate of 0.76 $L.min^{-1}$ (Hidalgo *et al.*, 2003) and a 40° cone of spray. Even though this hydraulic nozzle combination had not been optimised, it achieved better cocoa pod disease control than a motorised mistblower fitted with a rotary atomiser. It appeared that a greater proportion of the spray cone had hit the biological target (flowers, pods, *etc.*) with less wastage of fungicide (copper hydroxide in water). Bateman (2004) assessed deposit ($ml.m^{-2}$ of cocoa pod surface) per unit emitted ($ml.s^{-1}$ – equivalent to spraying approximately 1 m of branch), in field studies, where fluorescein tracer residues were measured on cocoa pods. The combinations DC31-25 and D1.5-25 (both at 200 kPa), that produce spray angles of approximately 25° and 35° respectively at low (< 0.5 $L.min^{-1}$) flow rates, achieved substantially better (approximately x 3) deposits on pods per volume emitted than the D2-45 'standard'.

For the purposes of field trials, improved reproducibility can be achieved by using hydraulic pressure control valves together with nozzle combinations. Pressure management valves are available rated at 100, 150, 200 and 300 kPa, but they may be perceived as too expensive for regular use by small-holders. Some side-lever knapsack (SLK) sprayers (such as the 'Cooper Peggler CP15') are fitted with an internal valve as standard, that avoids over-pressurisation (in this case, preventing excessive widening of the cone angle). Agbeniyi *et al*. (2005) compared application of fungicide using CP15 sprayers: set to 300 kPa and fitted with DC3-45 cone nozzles, with Nigerian farmer practice: application using 'trombone' sprayers. Black pod disease is normally treated with locally manufactured copper oxychloride (Bordeaux mixture: made from copper sulphate and lime), and there was considerable concern about nozzle blockage, so a relatively high flow rate was selected (0.91 $L.min^{-1}$).

The work took place in 20 small-holder farmers fields in three field locations as part of a farmer-field research (FFR) validation exercise involving the Tonikoko Farmers' Union (TFU), the Cocoa Research Institute Nigeria (CRIN), and the Sustainable Tree Crops Programme (STCP). Table 1 shows that that black pod incidence was reduced consistently, with increases in yield, with the improved application technique.

Table 1. FFR validation of improved spraying techniques in Nigeria (values are averages: given for plots of 50 trees each).

Location	Sprayer	Black pods (no.)	Yield (kg)
Bamikeno	Trombone	68	53
	SLK	42	67
Wasimi	Trombone	48	128
	SLK	17	168
Idanre	Trombone	30	44
	SLK	12	71

Conclusions

Training of cocoa farmers in spraying techniques will be essential in order to achieve better application, lower pesticide usage and improved and pest control. Extensive field testing is still underway to show whether better insect and disease management can be achieved with narrow angles of spray and reduced flow rates. Nozzle output data, available from the 'DropData' web site, should assist researchers to "fast-track promising candidates" before carrying out expensive and time consuming field trials on cocoa and similar crops. Improving the efficiency of spray application could be especially useful for applying some of the newer, less toxic, but perhaps relatively expensive chemical and biological pesticides, by keeping their field dosage to a minimum.

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