Summary: The use of narrow-angle cone nozzles to spray cocoa pods and other slender biological targets

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Abstract

The performance of atypical disc-swirl plate hydraulic cone nozzle configurations was investigated in order to maximise fungicide dose transfer to cocoa pods (for control of diseases such as black and frosty pod rots). There is a need to improve the efficiency and work rate of the fungicide application process: where farmers frequently use variable cone nozzles at present. Droplet size spectra and cone angles for standard tips and combinations of discs (D1 - D3) and commonly marketed swirl plates (13, 32, 25 and 45) were compared at a low-range of pressures (100-300 kPa). Narrower cones and finer droplet spectra are achieved with smaller orifice plates, but these are subject to a greater risk of blockage (especially with particulate formulations). Wider disc (>D2) combinations should minimise the risk of blockage, but flow rates are high and (except with the No. 45 swirl plate) are usually accompanied with wide-cone sprays. While broadly similar, the outputs produced by discs and swirl plates from different manufacturers may vary. The need for international coding standards with disc and swirl plate nozzles is discussed.

Descriptive information on nozzle outputs should be helpful for a number of applications where efficient spray deposition is required on smaller biological targets, such as narrow branches and individual fruit. In an indicative field study, fluorescein tracer residues on cocoa pods were assessed in two trials and spray recovery was estimated in terms of deposit ($ml.m^{-2}$ of cocoa pod surface) per unit emitted ($ml.s^{-1}$ – equivalent to approximately 1 m of branch). In each trial two alternative nozzles were compared with a “standard” configuration (D2-45 at 300kPa), that gave a 40° cone of spray and had been used in other field trials. Of particular interest were nozzles that produced a very narrow angle and low flow rates: they were the DC31-25 and D1.5-25 (both at 200 kPa) that produce spray angles of approximately 25° and 35° respectively. In both trials, these nozzles achieved substantially better (approximately x 3) deposits on pods per volume emitted than the D2-45.

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

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Introduction

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, pod diseases such as *Phytophthora megakaryia* (black pod in W.Africa) and *Crinipellis (Moniliophthora) roreri* (frosty pod rot in Latin America) have the capacity to reduce yields by up to 80%. Current research into improved cocoa disease control includes work on better application methods in order to: (a) provide practical and economic techniques to reduce the use of chemical fungicides and (b) to improve the effectiveness of experimental microbial and chemical control agents.

Application of large volumes of carrier water is inefficient in terms of dose transfer, and makes spraying tedious and labour intensive. In commercial operations, the cost of labour can be reduced substantially by reducing volume application rate, and thus increasing work rate (effectively by reducing the number of tank-loads per hectare). Most pesticide application to cocoa takes place using low-cost, manual, (hydraulic) knapsack sprayers. If necessary, treatment of tall trees can be achieved by the use of extended booms fitted to manual sprayers, but their pumps must be adequate to achieve sufficient pressure (>200 kPa) at the nozzle. Many locally-available sprayers are fitted with variable cone nozzles that produce an infinitely variable range of droplet sizes and flow rates, and are arguably a contributory factor to reported poor or variable fungicide efficacy.

Cone nozzles are most appropriate for applying insecticides and fungicides to complex surfaces such as dicotyledonous foliage. High pressures can be used to create small droplet sprays, sometimes reaching 1-2 MPa (150-300 p.s.i.), but manual equipment is more typically operated at 100 - 300 kPa (15-45 p.s.i.). Low flow rate nozzle tips with narrow orifice sizes are prone to blockage, especially with tank mixtures containing particulate suspensions.

The angles of cone nozzle spray (normally >70°) are visibly too wide for most target cocoa pods, so much fungicide is wasted. This paper provides a survey of the spray output from a number of potentially useful, lower-range cone nozzles. I have focused on disc and swirl plate nozzle combinations since these appear to be the most widely and easily available means of achieving narrow cone sprays in cocoa producing countries visited. The objective was to identify nozzle combinations that achieve <40° (ideally <30°) with relatively fine droplet size spectra.

Materials and Methods

Tests were carried out on various cone nozzles obtained from Spraying Systems Co. (Wheaton IL, USA), Hypro Lurmark Ltd. (Longstanton, Cambridge, UK) and a single standard nozzle fitted to Aspee sprayers (ASPEE Pvt. Ltd., Malad, Mumbai, India). All spray output measurements were with tap water with 0.1% Agral, (a standard surfactant used for spray nozzle evaluation, *e.g.* Arnold, 1983), which was placed in a tank and propelled to the nozzle with a pressure-regulated air line. Nozzle pressures were 100 to 300 kPa (1-3 bars) at 50 kPa intervals, and checked with a meter (Bundenberg: accurate to 10 kPa) connected with a 'T-piece' adjacent to the nozzle body. Just before measuring droplet spectra, the cone angle was estimated using a large (150 mm radius) protractor, with a back-light to aid observation of the spray.

Droplet spectra were measured with a Malvern 2600 PSA (Malvern Instruments Ltd., Spring Lane South, Malvern, Worcestershire, UK), fitted with an 800 mm lens. Each reading comprised of 1000 scans (equivalent to sub samples). Measurements were repeated at least once on a separate occasion to check for consistency and are presented here as means. The experimental design was similar to that used by Arnold (1983), with the cone nozzle directed horizontally and positioned approximately 200 mm in front of the beam. A 150 mm flexible pipe, connected to a centrifugal fan and situated at the rear of the apparatus, withdrew spray away from the sampling area (in order to minimise operator exposure to spray and prevent small droplets re-circulating in the beam). Numbers were exported electronically into a data-base in the form of cumulative volume distributions over 32 size classes.

Results

The droplet size spectra and cone angles of a number of standard cone tips is given in Figure 2. 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. The very small orifice TX1 and TY1 (Spraying Systems) nozzles produce relatively narrow, and similar, cone angles at the pressures tested, but atomisation is visibly unstable in the ranges. Concerned about nozzle blockage, Matthews (1974) recommended the use of the TY3 or larger. However, the cone angles of both this and the TY4 widened to near the specified 65° at pressures of >200 kPa. The Aspee 60-250 similarly widens to its specified 60° at relatively low pressures, and although possibly more suitable than other common cone nozzles, it is still too wide for optimal deposition on narrow targets such as pods. Should nozzle blockage not be a problem, the HCX2 at 200 kPa produces a relatively fine droplet spectrum in 35° of spray. The cone angles of the larger HCX3 and HCX4 are too wide for this purpose though.

Combinations of lower-range discs (DC31/D1.5, D2 and D3) and standard swirl plates, from Hypro-Lurmark and Spraying systems, are illustrated in Figures 3, 4 and 5 respectively. The small aperture disc combinations (Figure 3) appear to give suitably narrow angles of spray at a range of pressures: especially with the no. 25 swirl plate. In order to produce <40° sprays, D2 discs must be used with the high flow rate, no. 45 swirl plate (Figure 4), but the VMD and relative spans are appreciably higher than with smaller disc sizes. D3 – type discs (Figure 5) show a similar pattern, but spray angles are even larger, and thus unsuitable for small targets.

Field studies also took place on spray recovery with cocoa pods.

Figures 2, 3, 4 and 5.

Summaries of droplet size spectra and cone angles for plate-disc combination, from two manufacturers, over the 100-300 kPa range.

NB: the bars represent the relative span of the spray droplet size spectra (bounded by the 10% and 90% volume fractions) and are <u>not</u> error bars.

Figure 2: Various cone nozzles showing droplet size spectra (left hand scale) and cone angle (right hand scale)

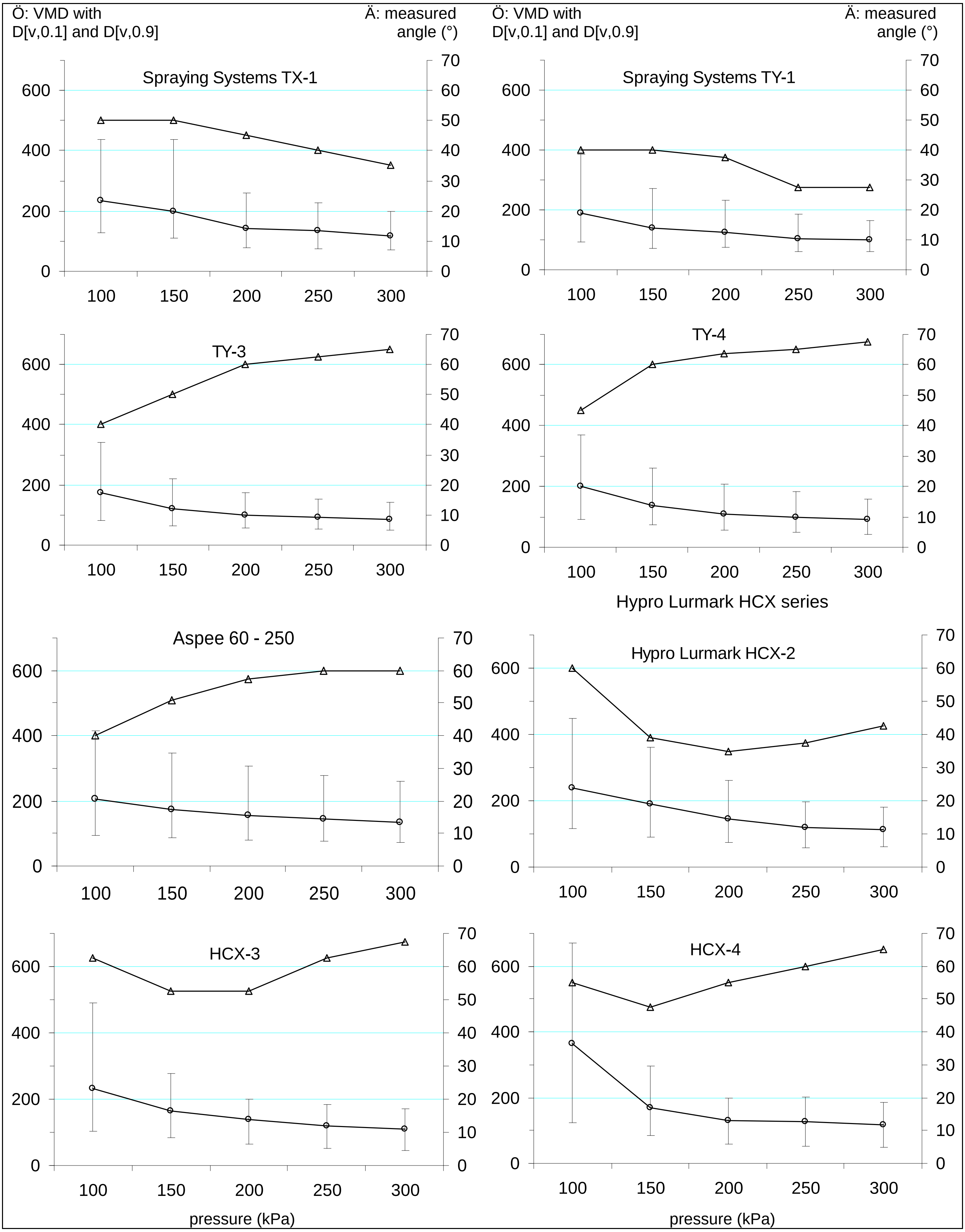


Figure 3: Small aperture disc – swirl plate combinations

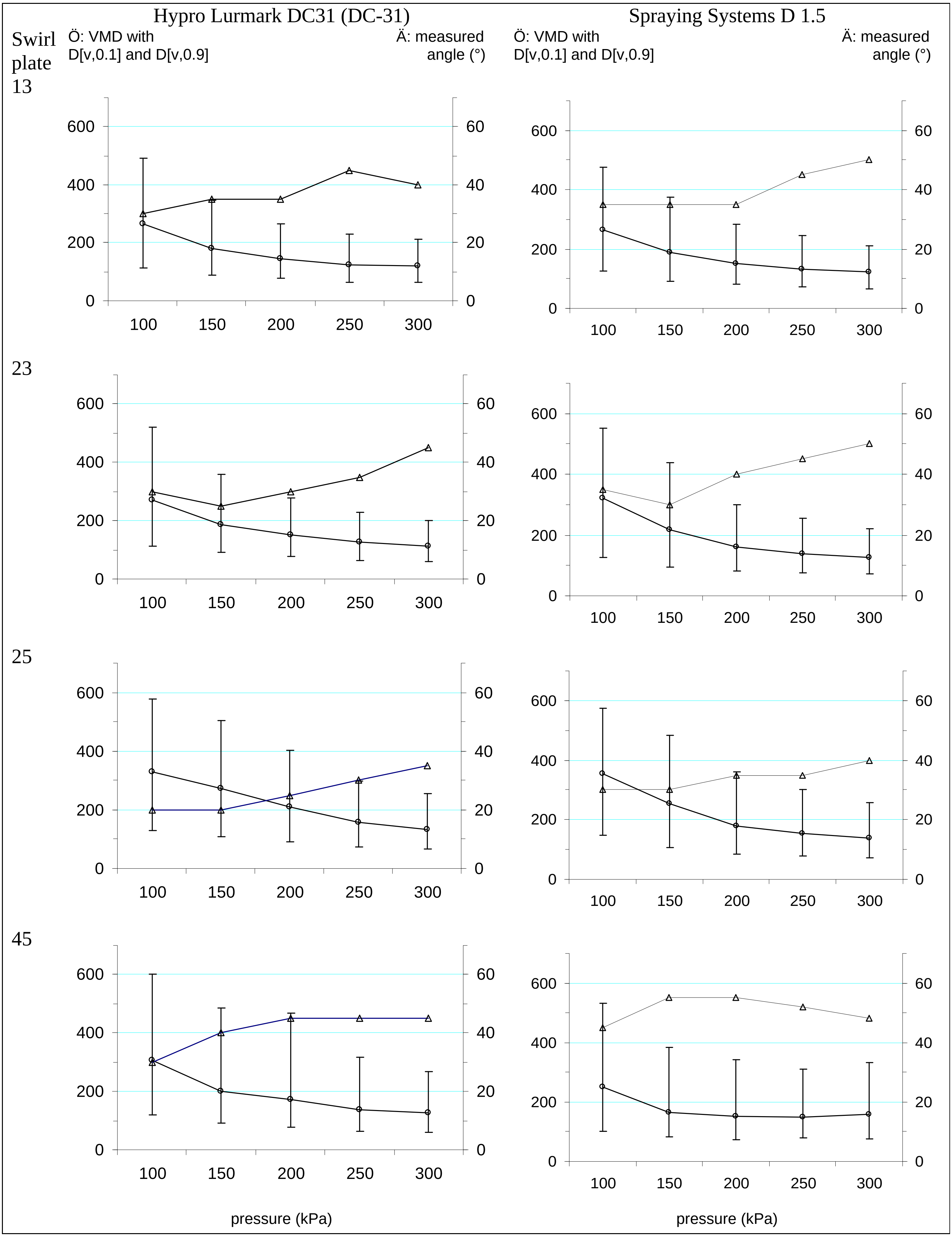
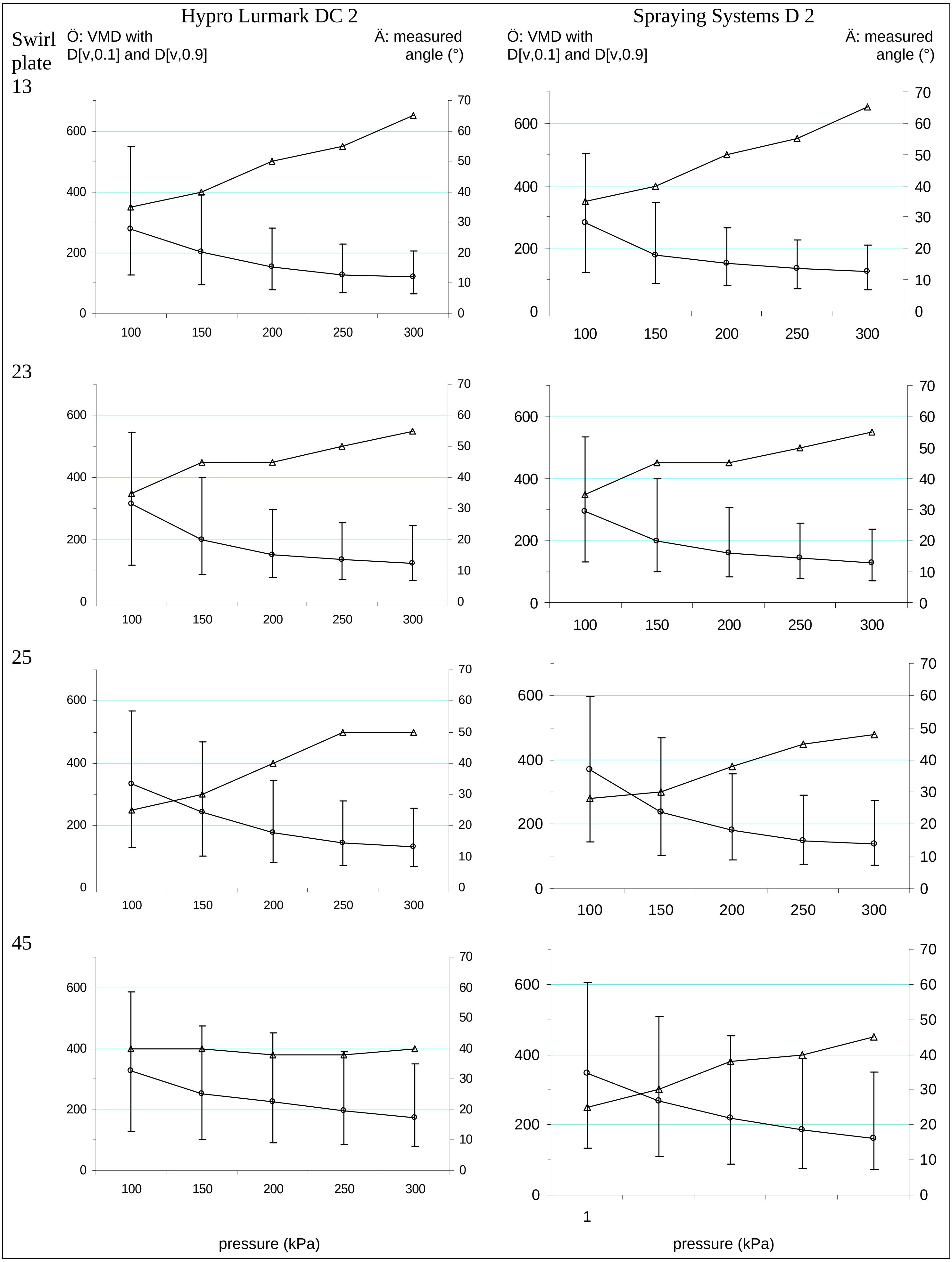


Figure 4: D2 type disc – swirl plate combinations



Hypro Lurmark DC 2
Spraying Systems D 2
Swirl plate
13
23
25
45
Ö: VMD with D[v,0.1] and D[v,0.9]
Ä: measured angle (°)
pressure (kPa)

Figure 5: D3 type disc – swirl plate combinations