RECENT RESEARCH ON CROP SPRAYING IN VICTORIA

J.H. COMBELLACK

Keith Turnbull Research Institute
Frankston, Victoria, 3199.

Summary. The research in Australia over the past three years has been aimed at reducing the dose rate of herbicides by 12.5 to 25% and the volume rates to 25-30 L ha^{-1}. To achieve these aims this review shows that boom stability and durability have improved, and herbicide transfer systems and better nozzles have been introduced. For example, extensive nozzle testing has shown that the injected moulded nylon or acetal plastic nozzles are an improvement over the machined brass and stainless steel nozzles. Also, nozzle wear assessments have demonstrated that a wettable powder increased the flow rate of nozzles in the order brass >stainless> nylon > acetal plastic > sintered alumina = hardened stainless steel. However, neither the suspension concentrate nor emulsifiable concentrate tested increased flow rates with any nozzle by over 5.5% after 40 hr of use. The effects of changes in boom height and pressure on distribution are demonstrated. The performance characteristics of the most common sprayer, a ground wheel driven metered sprayer, have been assessed and operating parameters for optimum performance are given.

The work on droplet capture in crops is reviewed. This shows that there are variations in capture between varieties of the one crop, between weeds and the crop and between herbicides. It is suggested that these are due to variations in droplet trajectory and to changes in droplet spectra. Further trends in research are also considered.

INTRODUCTION

Important areas of research need into herbicide application were: (i) to define optimum spraying parameters; (ii) to assess droplet spectra for commonly used nozzles; (iii) to improve the construction of the boom sprayer and, (iv) to ensure that the spray operator was made aware of the best available ways of using their equipment (Combellack, 1981). To meet these needs the following aims were drawn up for research work in Victoria. In the short-term, these were to: (a) reduce the dose rate by 12.5 to 25% and (b) to reduce the volume rate to 25 to 30 L ha^{-1}. The long-term aims were to re-design the sprayer to: (a) enable reductions of 33-50% in herbicide dose rates and (b) to reduce the volume rate to 1-10 L ha^{-1}. In both cases, reduction in both operator and environmental hazard were sought. If these aims could be met there would be significant reductions in herbicide and application costs.

(1) Initial Assessment of Farmers' Boom sprayers. Tests on growers' booms were made using a sheet of inclined corrugated fibreglass. The spray was collected in the 75mm channels and drained into 250ml collection cups. The nozzles and filters were cleaned before assessment, the boom was operated at the correct height and the pressure set at that recommended by the manufacturer. These tests showed that the maximum variation in collection was + 132 to - 96% of the mean whilst the majority ranged between ± 40-60%. The C.V. (Coefficient of Variation) of the booms varied from 11 to 46%. Careful inspection of the sprayers also revealed a number of ob-

vious defects which would lead to inefficient application. In view of these tests the following changes to the spraying operation were suggested: -

(1) More functional chassis for the spraying machines should be encouraged, in particular pivoting axles to increase durability and stability.

(2) Better tanks with improved drainage, site gauges, and more accessible openings to ensure safer filling.

(3) Improved booms, particularly with respect to structure, durability, height adjustment and improved stability in both the vertical and horizontal directions.

(4) Nozzles with accurate flow rate, even distribution and droplet spectra maximized in the 100 to 300 micron range.

(5) Monitors on some spraying units to measure flow rate, in-line pressure and ground speed.

(6) The development of efficient marking systems.

(7) The fitting of electric solenoid valves on the boom and the development of effective and efficient herbicide transfer system to increase safety of the operation.

How far have we progressed toward obtaining the appropriate information and implementing these aims?

(2) Boom sprayer changes 1981-84.
(a) Safety to the operator.

This has been improved in a number of ways. A most important change has been the introduction of concentrate herbicide transfer systems, usually based on a Venturi system. Though these systems have a few shortcomings such as their inability to accurately measure the volume transferred and their difficulty in transferring suspension concentrates their further development is to be encouraged.

Most spray manufacturers now offer electric solenoids valves on boom sprayers which obviate the need to have 'live' spray lines leading into enclosed tractor cabs. Such devices should not still be an 'optional' extra but a standard fitting.

(b) Boom construction. Some manufacturers have gone to considerable lengths to improve the design of the boom. In particular they have reduced vertical instability by including springs and/or hydraulic dampers on the sub frame. These modifications have been reasonably effective in reducing roll and most have tended to increase boom durability. Whilst horizontal stability (yaw) is still not adequately addressed by many manufacturers reasonably effective attempts have been made using tensioned wires or struts. Boom stability has been increased by the use of pivoting or walking beam axles which also tend to make the units more durable. The recent introduction of an off set pivoting axle is seen as a further advance as this reduces soil compaction. However, stability and durability is still of concern on booms over 17m in width.

The introduction of quick fit plastic nozzle holders, and triple jets, whilst improving spray alignment has led to a slight increase in down time due to breakages. These can be caused by guide wires, impaction on the soil or even by animals rubbing when the sprayer is not in use. Some form of protective guard should be added to the boom.

Boom height adjustment is critical. From Figure 1 it can be seen that if one requires a C.V. of 15% then maximum variability about a 50cm height setting is only 8.6cm for the 80^{o} and 27.4cm for the 110^{o} nozzles. However, on many sprayers it is still very difficult to easily adjust boom height. The recent introduction of hydraulics and simple, but effective screw devices are an improvement. It is recommended that wide angled (110^{o}) nozzles be used on booms which are difficult to adjust.

(c) Filtration. Filtering systems both on the suction and delivery side of the pump have greatly improved over recent years. Such systems have dramatically reduced nozzle blockages when low volumes <50 L ha^{-1} are used. Care must be paid to the suction/filling side of the operation on sprayers which do not have the advanced systems.

(d) Metered sprayer performance. The most commonly used sprayer for crop spraying in Australia is a ground driven metered sprayer. The effect of ground speed changes on the droplet spectra and the lateral distribution of spray of these units has been investigated (Wills and Combellack, 1984). Their results show that variation in nozzle pressure with ground speed is a major factor affecting the performance of the nozzles. With the nozzles tested they found that at spraying speeds below 13km hr^{-1} the C.V. of the static spray distribution increased sharply. Also if it was found that when other nozzles from another manufacturer were fitted into the boom the C.V. could be reduced from over 20% to less than 10%. The volume of small droplets increased by approximately 60% when the pressure was increased from 200 to 350 kPa; this represents a speed change of 6 to 7.9 km hr^{-1}. These authors concluded that all such units should have a pressure gauge and that the operating pressure range be restricted to between 200 and 350 kPa.

(d) Nozzle performance. The nozzle performs the three important functions of metering, atomising and distributing the spray. It is therefore the most critical part of the spray unit, and thus selection of the most appropriate nozzle is essential. Over the past three years in excess of 1,000 nozzles have been tested at KTRI to find those most suitable to apply herbicides at 30-50 L ha^{-1}. In these tests flow rate, distribution, spray sheet angle, optimum operating height, optimum spray sheet angle to the boom, optimum pressure and the effect of herbicides on nozzle wear have been assessed.

Initial results (Combellack, Richardson and Andrew, 1984; Combellack and Andrew, in press) showed that flow rates between nozzles were generally consistent but were often different to that stated by the manufacturer. Distribution, as measured on a patternator, was very variable and reflected poor quality control; stainless steel nozzles were particularly variable. Of the nozzles tested almost 50% gave a CV of over 20%.

Later, injected moulded nylon, acetal plastic and sintered alumina nozzles became available. Tests on these nozzles showed that both the nylon and acetal plastic nozzles generally gave very even distribution (C.V.s <12%), however, the sintered alumina nozzles were generally more variable (C.V. 15-20%). With the injection moulded nozzles evenness of distribution is related to the accuracy of design of the moulding equipment. Thus in certain instances nozzles were found to have high CVs (15-20%) due to such factors as occlusions in corners, remnants left in orifice openings and in the case of sintered alumina "graininess" around the orifice. Generally speaking nylon and acetal plastic types of nozzles are extraordinarily accurate when the mould has been refined and CVs less than 10% are common with both acetal plastics and nylon.

Optimum operating height has been determined by operating the nozzles at 300 kPa and raising the boom until the lowest C.V. is found. (Tables 1 and 2). Such tests demonstrate the importance of a stable boom (Fig. 1). Having determined the optimum height, the effect of operating pressure is determined. It can be seen from the two typical nozzles (Fig. 2) that the C.V. rises quickly when the pressure drops below 200 kPa. These results underline the importance of maintaining a stable boom height and a pressure over 200 kPa.

Table 1. Effect of height and pressure on distribution across boom of single orifice flat fan nozzles - Hardi 4110-10 (Acetal plastic) at 50cm spacing.

kPa	C.V. at 45cm ht	Ht (cm)	C.V. at 300 kPa
100	27.9	30	19.8
200	9.0	40	8.9
300	8.5	45	8.5
400	8.9	50	8.9
500	9.2	60	10.8
		70	11.6

Table 2. Effect of height and pressure on distribution across boom of single orifice flat fan nozzles - Spraying Systems 11001 (Brass) at 50cm spacing.

kPa	C.V. at 40cm ht	Ht (cm)	C.V. at 300 kPa
100	12.6	30	10.5
200	7.1	40	5.7
300	5.7	50	8.2
400	6.5	60	13.3
500	6.8	70	12.4

Droplet spectra analysis of the nozzles has been measured using a Malvern droplet spectra analyser with the laser passing through the long axis of the spray cloud (Combellack and Matthews, 1981). The data from these measurements is being used to calculate the volume of droplets which are drift prone (<100 μm), the optimum droplet size (100-300 μm) and those that are too large (>300 μm). This data is used in a comparative assessment of the nozzles.

A project of nozzle wear has been undertaken. The results (Table 3) showed large increases in flow rate with various materials when a wettable powder was used compared with small increases when a suspension concentrate and an emulsifiable concentrate were used. These results show that most materials used to construct the nozzles are adequate for up to 40 hours' use if wettable powders are not to be used. There was a variable effect on spray distribution with certain brass nozzles, which had an initial C.V. $>$20%, as it was decreased initially to 12-15% and then increased. With other brass nozzles the C.V. continuously increased when the flow rate increased by over 20%. With most other nozzles tested the C.V. remained relatively constant over the 40 hr test period.

Table 3. Percentage increase in flow rate of single orifice flat fan nozzles at 300 kPa after 40 hours.

Nozzle	Material	Wettable powder	Suspension concentrate	Emulsifiable concentrate
Albuz Brown	Sintered alumina	0.8	2.7	-3.2
Delevan LF15	Nylon	14.7	0.7	-0.9
Hardi 4110-10	Acetal plastic	11.4	0.5	-1.5
Lurmark F110-01	Acetal plastic	10.5	5.0	1.9
Spraying Systems 110-01	Brass	65.4	5.5	4.5
Spraying Systems 110-01	Hardened stainless steel	2.5	1.9	0.6
Spraying Systems 110-01	Stainless steel	16.0	1.9	1.9
L.S.D. (P=0.05)		3.0	N.S.	3.0

Wettable powder - 'Gesaprim 80' 4.5 kg in 50 L
Suspension concentrate - 'Gesaprim 50' 7.2 L in 50 L
Emulsifiable concentrate - 'Ulvapron' 2 L in 50 L.

Summarising, injected moulded acetal plastic or nylon nozzles are recommended where quick fit nozzle holders or plastic/nylon bodies are used and where wettable powders will not be used. If wettable powders and metal nozzle body holders are to be used then hardened stainless steel nozzles are recommended. In both cases the use of 110^{o} nozzles is recommended except where drift hazards exist in which case low pressures (200 kPa) and 80^{o} nozzles are recommended.

(f) Droplet capture. Tests have been carried out to ascertain the amount of spray captured by weeds and crops and to determine what factors are most influential in this process. A technique using fluorosciene has been developed (Richardson, in press). This enables the amount of spray captured on plants rather than artificial surfaces to be measured. Using this technique it has been possible to show that in the field spray collection on crops and across the swath varies from -41 to +80% of the mean (Richardson, personal communication, 1984). Further tests in both the laboratory and field have shown that spray collection ($\mu g\ cm^{-2}$) on wheat is three to ten times less than on ryegrass and two to four times less than on radish (Combellack and Richardson, in press). Other tests have shown that there can be a 100% variation in capture between cultivars of wheat and whilst there was some variation between barley cultivars these were not significant (Combellack and Richardson, in press). Further tests have shown that increasing the small droplet component (<100 µm) of the spray from 8.1% to 28.3% increases spray capture by up to 238% for wheat, 92% for Wimmera ryegrass and 81% for radish (Richardson, personal communication, 1984). When examining the effect of herbicide formulation and spray concentration, Dempsey, Combellack and Richardson (in press) found that 2,4-D ester increased the variability of spray distribution, measured on a patternator, more than 2,4-D amine. Also they noted that the small droplet component (<100 μm) increased as the concentration of both amine and ester increased. Furthermore their results showed that changes to 2,4-D concentration or its form did not consistently alter collection on either radish or ryegrass. However, on wheat collection was increased by a factor of three to four with increasing concentration of the ester whilst with the amine it varied from three to five-fold. These results indicate that reducing spray volumes to 10 L ha^{-1} with 2,4-D may predispose the crop to increased damage. Tests have also been conducted to ascertain the effect of spray sheet direction at varying angles (45 to 90^{o} to the vertical in each direction) on uniformity of distribution and on capture. The results show that whilst capture is increased by on average 30 to 112% it is at the expense of increased variability (Combellack and Richardson, in press).

In summary over the past three years there have been a number of improvements in boom sprayer design, particularly in relation to boom stability and durability. These improvements together with the improved performance characteristics of injected moulded nozzles should ensure more reliable weed control at lower volumes.

(g) Quo Vadis boom spray research. To enable the long-term objectives of the initial aims to be achieved work has been initiated on utilizing boom canopies to induce either turbulence or a stable air zone into which the spray can be emitted. This line of research is being persued following field observations that up to 300% more spray was collected when air turbulence was accidentally created. These investigations are in a preliminary stage. The value of other application research activities in other countries, for example CDA in Europe (Taylor and Merritt, 1974; Bailey et al., 1978), electrostatics in USA (Law, 1980) and Europe (Morton, 1984) boom design (Nation, 1980) were all considered before the move into the effects of turbulent air transfer on spray capture was made. It will be interesting to see if this is the best direction.

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LITERATURE CITED

Bailey, R.J., Kitchen, R., Smartt, A. and Roebuck, J. (1978). Proceedings 1978 British Crop Protection Council Conference - Weeds 2, 695-700.

Combellack, J.H. (1981). Proceedings 6th Australian Weeds Conference, 2, 153-166.

Combellack, J.H. and Matthews, G.A. (1981). Aerosol Science, 12, 529-540.

Combellack, J.H., Richardson, R.G. and Andrews, L. (1982). Efficient Boom Spraying: Special Technical Bulletin, Frankston, Victoria, Australia. Keith Turnbull Research Institute.

Combellack, J.H. and Andrew, L. (1984). Australian Weeds - in press.

Combellack, J.H. and Richardson, R.G. (1985). Proceedings British Crop Protection Council. Application and Biology, Reading, U.K. - in press.

Dempsey, C., Combellack, J.H. and Richardson, R.G. (1985). Proceedings British Crop Protection Council. Application and Biology, Reading U.K. - in press.

Law, S.E. (1980). British Crop Protection Council Monograph No. 24, pp. 145-158, Croydon, B.C.P.C.

Morton, N. (1982). Crop Protection 1, 1, 27-54.

Nation, H.J. (1980). British Crop Protection Council Monograph No. 24, pp. 145-158, Croydon, B.C.P.C.

Richardson, R.G. (1984). Australian Weeds - in press.

Taylor, W.A., Merritt, C.R. (1974). Weed Research 14, 245-250.

Wills, B. and Combellack, J.H. (1984). Institution of Engineers, Australia. Conference on Agricultural Engineering, p. 132-136.

FIGURE 1. COEFFICIENT OF VARIATION vs. NOZZLE HEIGHT

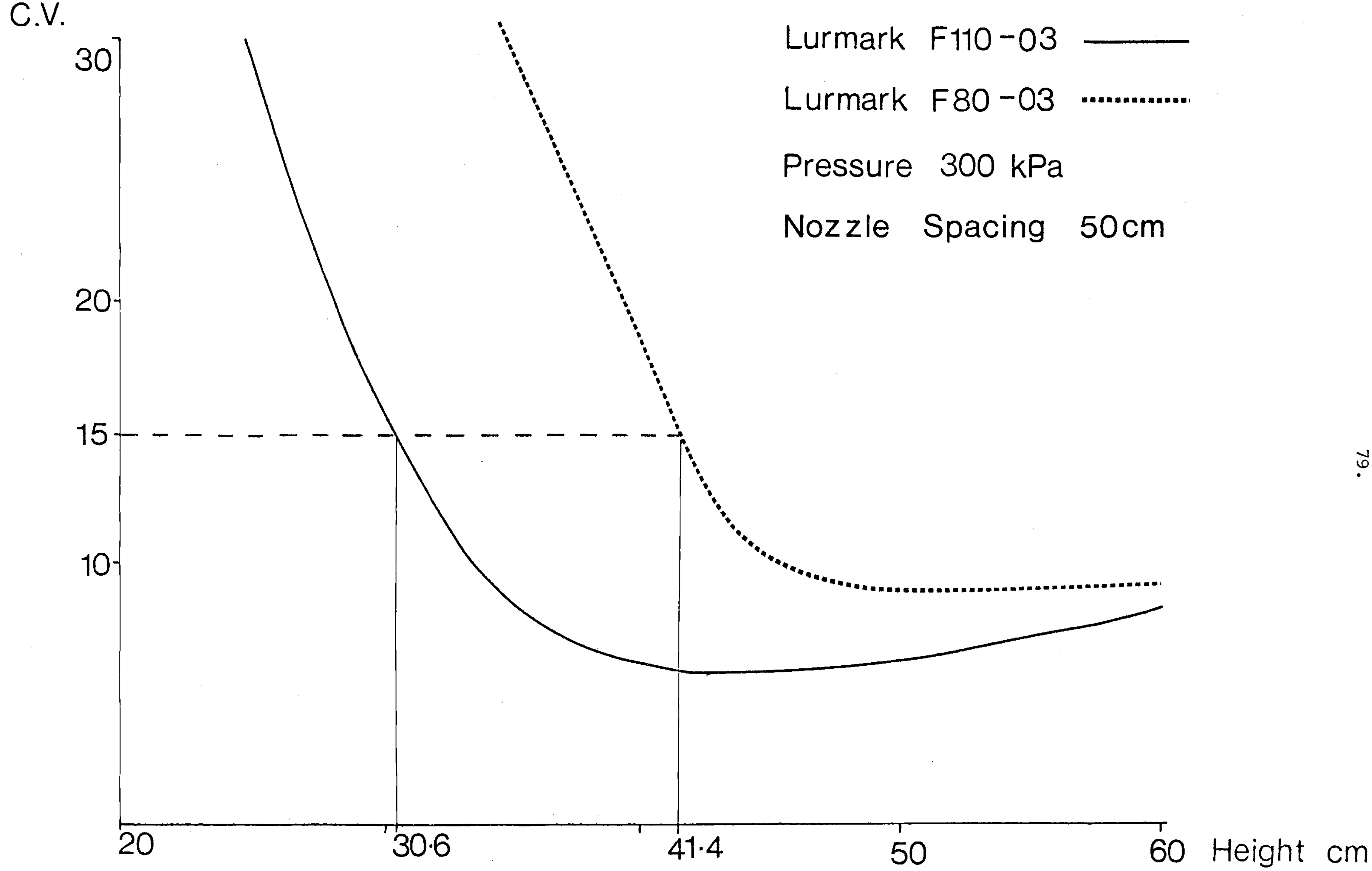

FIGURE 2. COEFFICIENT OF VARIATION vs. PRESSURE