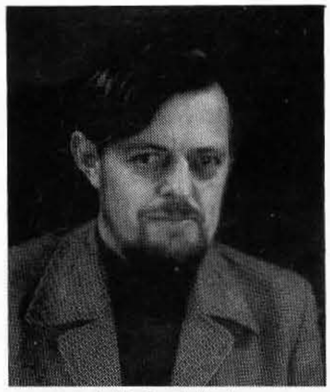
Laboratory tests on some nozzles used to apply herbicides by boom sprayers in Australia

J. H. Combellack and Leah Andrew
Keith Turnbull Research Institute, Frankston, Victoria 3199



J. H. Combellack

L. Andrew

Summary

The performance of over 400 single orifice flat fan nozzles commonly used to apply herbicide to broad acre crops at 30-100 L ha^{-1} was assessed. Flow rates, spray sheet angles and spray distribution patterns were measured for nozzles constructed of brass, stainless steel, sintered alumina, nylon and acetal plastic at 200 kPa using water as the liquid. The flow rates were generally very consistent between nozzles of the same type but often varied from that stated by the manufacturer. The spray distribution pattern was very variable (especially in stainless steel nozzles) and reflected poor quality control. The coefficient of variation of distribution in pattern was greater than 20% in over 50% of the nozzles tested. The reasons for the results are discussed.

Introduction

The most commonly used device to meter, disintegrate and distribute a herbicide spray is the nozzle (atomizer, nozzle tip or jet). Its functions make it one of the most important parts of the spraying machine and yet it is invariably the most neglected. The most versatile, and thus most widely used, nozzles for herbicide application have been hydraulic pressure nozzles which utilize pressure energy to force liquid through a small orifice to create a thin sheet of liquid. This becomes unstable and subsequently disintegrates into variously sized droplets by perforated sheet, wavy sheet or rim disintegration (Dombrowski and Fraser, 1954; Clarke and Dombrowski, 1972). Various hydraulic pressure nozzle designs are available including the anvil (flood or impact), single orifice fan (flat fan), single orifice even spray fan (even flat spray), cone (hollow or solid) and solid stream. By far the most commonly used nozzle for broad acre boom spray herbicide applications in Australia is the single orifice flat fan (Combellack, 1981).

As single orifice flat fan nozzles are so widely used, knowledge about spray distribution pattern, flow rate and droplet spectrum is required to select the most appropriate nozzle. Whilst information on flow rate and spray angle are given in the nozzle manufacturer's literature, data is not readily available for spray distribution pattern and droplet spectrum. Spray distribution data has been reported for a range of nozzles by Nystrom (1981), Porskamp (1980), Combellack *et al.* (1982) and Faber *et al.* (1979), but most of the nozzles tested by authors other than Combellack *et al.* (1982) had flow rates greater than 1.0 L min^{-1} at 300 kPa which is higher than those generally required or used in Australia. Indeed, for broad acre herbicide applications the volume used is generally 50-100 L ha^{-1} in eastern Australia, which is achieved by using nozzles giving flow rates of 0.5-1.0 L min^{-1} at 200-300 kPa. In Western Australia the volumes used are generally 30-50 L ha^{-1} using nozzles which give 0.25-0.5 L min^{-1} at 200 – 300 kPa.

This paper presents results of tests conducted on a wide range of single orifice flat fan nozzles commonly used to apply herbicides by boom sprayers in Australia.

Methods

Angle to boom

A test was carried out to determine the effect of varying the angle of the nozzle orifice to the line of the spray boom. For this test four Spraying Systems 80015 nozzles were operated at a height of 460 mm and a pressure of 200 kPa at the nozzle and at orifice angles varying from 0° to 25° to the spray boom. The results of this test were used to determine a standard nozzle orifice to spray boom angle for all other tests.

Nozzle assessments

Ten to twenty of each of the most commonly used single orifice flat fan nozzles for herbicide application at 30-100 L ha^{-1} were purchased from their manufacturers, Albuz Desmarquest, Delavan Corporation, Govan Drewburn Pty Ltd, Hardi Pumps and Sprayers, Jetstream, Lurmark Ltd, Rega Pty Ltd and Spraying Systems Australia Pty Ltd. The nozzles were fitted with 80 mesh filters and operated at 200 kPa whilst the following tests were carried out on each using water as the spray liquid.

Flow rate

The flow of water from individual nozzles was measured over a 60 second period (±0.5 sec) into a graduated cylinder. The accuracy of flow rate between nozzles and the variation compared with that stated in the manufacturer's catalogue was then assessed.

Spray sheet angle

The spray sheet angle was assessed when they were operating at the recommended height by measuring the width of the base of the spray pattern on a channel patternator with 30 mm divisions. The nozzle angle was subsequently calculated from this data. Since the spray sheet angle also varies with pressure it was calculated for 275 kPa based on the data of Akesson and Yates (1979).

Spray distribution pattern

A wide range of nozzles with spray sheet angles varying from 65° to 110° and made of nylon, brass, stainless steel, sintered alumina or acetal plastic by a variety of companies were tested. Four nozzles were selected from each batch and set up at 500 mm intervals along the boom. The operating height used was that recommended by the manufacturer and generally related to a one and a half overlap spray distribution pattern (i.e. the area covered on the ground by one nozzle is 1.5 times the distance between any two nozzles). The spray from each nozzle was collected in pre-weighed test tubes from a 30 mm channel patternator and the test tubes weighed on a Sartorius balance which was directly interfaced to a computer. The statistic coefficient of variation was calculated as it is generally used to measure the spray distribution pattern from nozzles.

Results

Angle to the boom

The coefficient of variation (CV) of deposition of spray along the spray boom was least when the angle of the spray sheet is between 10° and 17.5° to the boom (Figure 1). In view of these results all further tests were conducted with the spray sheet offset 10° to the boom. Operators should be encouraged to adopt this practice.

Flow rate

Nozzle flow rates were fairly consistent between nozzles for all but the acetal plastic nozzles, as can be seen from column II of Table 1 and Table 5, but later tests (unpublished data) have shown the latter nozzles to be equally consistent. Overall, around 90% of all the other nozzles tested gave a flow rate of within ±5% of the mean. Thus if one accepts the recommendation that farmers should discard nozzles which give a flow rate of more than ±5% of the average for the nozzles on the boom (Combellack *et al.* 1982; Friesen, 1982) then on average one in every 10 nozzles would need to be discarded before use. If the more commonly used figure of ±10% is accepted (Anon, 1976; Anderson *et al.*, 1974) then less than one in every hundred would need to be discarded before use. The rate of discard should not exceed one in 20 and a variation of ±5% is considered to be the minimum standard required. The figures in column 1 of Table 1 show that only around 60% of the nozzles tested gave a flow rate within ±5% of that stated by the manufacturer at the pressure tested, with one in five nozzles giving a flow of over ±10%. These figures clearly indicate that farmers should not rely on the manufacturer's literature as a basis for calibration, but merely use it as a guide to obtain an estimate of expected volume rate.

Spray sheet angle

The spray sheet angle for a flat fan single orifice nozzle is a function of pressure, the orifice shape and liquid density. The spray angle for most

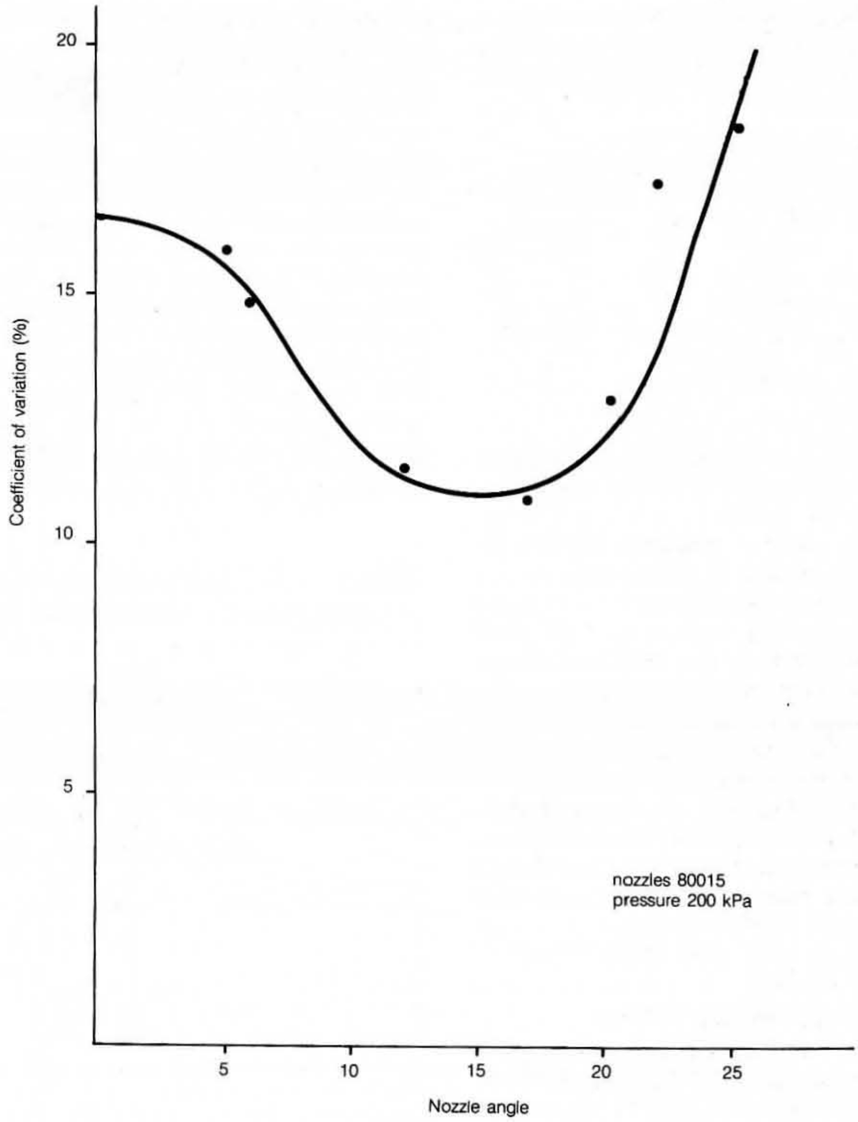


Figure 1 Pressure nozzles: effect of varying angle to the boom

Table 1 Comparison of actual flow rates with those stated by manufacturers for single orifice flat fan nozzles made of different materials

Manufacturer	Nozzle material	Percentage of nozzles tested					
		< ±5%		±5%–10%		± >10%	
		I	II	I	II	I	II
1	SA	26	88	42	12	14	0
2	N						
	B	77	88	30	12	3	0
	SS						
3	B	0	93	0	7	100	0
4	B	0	98	0	2	100	0
5	AP	55	50	35	45	10	5
6	B	40	90	43	10	17	0
7	B	60	97	40	3	0	0
8	B SS	72	93	28	7	0	0
Mean percentage		57	89	23	11	20	<1

I = variation compared with that stated in manufacturer's catalogue.
II = variation compared with the mean for those nozzles tested.

The figures represent a summary of all nozzle materials tested: N - nylon, B - brass, SS - stainless steel, SA - sintered alumina, AP - acetal plastic.

Table 2 Comparison of the actual spray sheet angles with those stated by the manufacturer for single orifice flat fan nozzles

	Spray sheet angle			
Nominal	**Mean**	**Lowest**	**Highest**	**Calc.***
65°	58.7°	51°	65°	59°
73°	72.3°	61°	83°	68°
80°	80.1°	59°	90°	76°
110°	103.6°	85°	119°	105°

* Based on data after Akesson and Yates 1979.

nozzles is based on the use of water at a pressure of 275 kPa and thus represents the nominal spray angle. Though mean measured angles at 200 kPa (as shown in Table 2) did not differ greatly from those calculated at 275 kPa based on a formula by Akesson and Yates (1979), both the 65° and 110° nozzles differed sufficiently to affect spray distribution. The difference for the 65° and 110° nozzles represents a boom height difference of 8 cm and 3.5 cm respectively, thus an approximately 12%–14% increase in boom height is necessary to achieve one and a half overlap coverage. There is considerable variation between nozzles for any given nominal spray sheet angle.

Spray distribution pattern

Table 3 shows that considerable variation occurred in the accuracy of nozzles and over 50% of the nozzles gave a CV of over 20%; none gave a CV of <10%. Stainless steel nozzles were less accurate, particularly when compared to nylon or acetal plastic, as over 44% of the stainless steel nozzles gave a CV over 30%, the highest being over 50%, whilst 29% of the brass gave over 30% with the highest being over 40%. The variation in manufacturing quality control of brass nozzles was considerable. In almost all cases where distribution was poor (over 20% CV) the nozzles were found to have burrs around the orifice, whilst in the stainless steel nozzles the 'V' cut across the orifice was frequently machined to a variable depth or angle.

Discussion

The results of tests on more than 400 nozzles clearly indicate that manufacturing quality control of the nozzles was poor for at least five out of eight manufacturers, resulting in variation in both flow rate and spray distribution pattern. Users should closely inspect orifices when purchasing or fitting new nozzles and should return any nozzle which has obvious manufacturing flaws such as burrs or non-uniform 'V' cuts across the orifice. Users should measure the flow rates of all new nozzles and retain the data obtained, which should be referred to when assessing nozzle wear rather than the data presented in the manufacturer's catalogue. The most commonly used index of spray evenness is the coefficient of variation (Nordby, 1978; Nystrom, 1981). Nordby (1978) suggested the following descriptions for nozzle CVs: <10% particularly good, 10%–12% very good, 12%–16% satisfactory, 18%–20% usable, >20% unusable. On this basis over 50% of the nozzles reported on here would be described as unusable, whilst only 40% would be described as satisfactory or better. Only 22% of the stainless steel nozzles would be described as satisfactory.

The high coefficients of variation obtained in these tests could be due to manufacturing problems related to the production of smaller nozzles (those with a flow rate of <1.0 L min^{-1} at 300 kPa) as Nystrom (1981) and Faber *et al.* (1979) tested larger nozzles.

As a result of these tests further research has been initiated to determine a way of reducing the variability of spray distribution pattern.

Table 3 Spray distribution pattern accuracy of single orifice flat fan nozzles at the manufacturer's recommended height and 500 mm spacing

Manufacturer	Nozzle material	Percentage of nozzles tested <10%	10%–20%	>20%
		Coefficient of variation (%)		
1	SA N	0	67	33
2	B SS	0	29	71
3	B	0	67	33
4	AP	0	100	0
5	B	0	67	33
6	B	0	67	33
7	B	0	0	100
8	B SS	0	83	17
Mean		0	45.5	54.5

Figures represent a summary of all nozzle materials tested: N - nylon, B - brass, SS - stainless steel, SA - sintered alumina and AP - acetal plastic.

Table 4 Distribution accuracy of single orifice flat fan nozzles made from different materials

Material	Percentage nozzles tested <10%	10%–20%	>20%
	Coefficient of variation (%)		
Brass	0	53	47
Stainless steel	0	33	67
Nylon/acetal plastic	0	63	37
Sintered alumina	33	67	0

Table 5 Flow rate

Material	Percentage nozzles tested with variation < +5%	+5%–10%	+ >10%
Brass	94	6	0
Stainless steel	88	12	0
Nylon/acetal plastic	76	23	1
Sintered alumina	88	12	0

References

Akesson, N. B. and Yates, W. E. (1979). *Pesticide application equipment and techniques.* FAO Agricultural Services Bulletin 38. Publications Division, Food and Agricultural Organisation of the United Nations, Rome, Italy.

Anderson, D. T., Clark, D. E. and Sexsmith, J. J. (1974). *Field sprayers.* Publication 1482. Department of Agriculture, Ottawa. Canada.

Anon (1976). *Fundamentals of Machine Operation, Crop Chemicals.* John Deere & Company, Moline, Illinois, U.S.A.

Clarke, C. J. and Dombrowski, N. (1972). On the formation of drops from the rims of fan spray sheets. *Aerosol Science* **3**: 173–83.

Combellack, J. H. (1981). History and trends in the design of ground boom sprayers for Australian conditions. *Proceedings of the Sixth Australian Weeds Conference, Gold Coast,* 1981, **1**:87–91.

Combellack, J. H., Richardson, R. G. and Andrew, L. (1982). *Efficient boom spraying.* Special Technical Bulletin. Keith Turnbull Research Institute, Frankston, Victoria.

Dombrowski, N. and Fraser, R. P. (1954). A photographic investigation into the disintegration of liquid sheets. *Philosophical Transactions of the Royal Society, London, Series A* **247**(924): 101–30.

Faber, H., Goffre, P. and Mussillami, S. (1979). Influence sur la repartition au sol de l'usure de buses a fente pour faibles volumes/hectares. *Columa,* Volume 1. pp. 37–44.

Friesen, O. (1982). *Field Sprayers.* Agdex 744–1. Manitoba Agriculture, Manitoba, Canada.

Nordby, A. (1978). *Dyseposisjon pa spredebommer-dysenoyde arebeidstyrykkvaeskedordeling.* N.J.F. Seminar: Akersproyter og akersproyting, As, NLH, Norway.

Nystrom, P. (1981). Double-outlet and conventional flat spray nozzles. *Proceedings 22nd Swedish Weed Control Conference.* pp. 106–16.

Porskamp, H. A. J. (1980). *De vloeistofverdeling van land bouwspuiten.* Publication 133. Institut voor Mechanisatie Arveid en Gebouwen, Wageningen, Netherlands.