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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol.38, No.2, May 200

Evaluation of Hydraulic Energy Nozzles Suitable for Orchard Spraying

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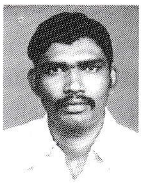

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Abstract

Manually operated sprayers are mostly used at present for orchard spraying. In a spray nozzle, is an important component which determines its performance. In manually operated sprayers, generally hydraulic energy nozzles are used. This evaluation was done to identify the suitable energy nozzle for orchard spraying. Commercially available hydraulic energy nozzles (NMD/S, BAN, Broad cone, NMM, NTM) used for orchard spraying were selected for the study. The discharge rate, droplet size and density and height of reach of all the types of nozzles were measured with a pressure range of 1.5 to 3 ksc at an interval of 0.5 ksc, 0, 30, 45 and 60 degree orientation and 50, 100 and 150 cm horizontal distances using experimental setup. The discharge rate of nozzles increased with increasing pressure. The NTM nozzle recorded a maximum discharge rate of 81.8 lit/hr at 3 ksc operating pressure followed by a broad cone nozzle (74 lit/hr). The broad cone and NTM nozzles at horizontal distances of 150 cm and 45 degree orientation gave maximum height of reach and uniform spray of droplets within 113 μm among the nozzles tested. Based on the volume distribution of droplets, a broad cone nozzle at 45 degree orientation with 100 cm horizontal distance resulted maximum height of 105 cm at which 50 % volume of spray was deposited. At this height droplet size was 150 μm.

Introduction

In India cropped area under fruits occupies 3 % of the total cultivated area and share about 14 % of total pesticide consumption. A striking feature of Indian orchards is the small size of the individual holdings. The predominance of very small orchards increases the difficulty of introducing better methods of pesticide application. The broad aim of pesticide application is to maximize control of the pest organisms with use of a minimum amount of pesticide, and to minimize the amount of loss to off-target areas. If the amount of material required for maximizing pest control can be reduced, more effective application of the pesticide to the target can be accomplished. A pesticide needs to be applied to the particular "target" area affected by insects, pest and diseases. Manually operated sprayers are mostly used at present for orchard spraying. In a spray nozzle is an important component which determines its performance. In manually operated sprayers, generally hydraulic energy nozzles are used. This evaluation was done to identify the most suitable energy nozzle for orchard spraying. Thus, it will help the farmers to reduce the waste of chemicals along with effective control of pests and diseases.

Review of Literature

Discharge Rate

Nordby and Haman (1965) stated that a solid cone nozzle gives better results of spraying than hollow cone nozzle. The coverage deteriorates with decreasing cone skin thickness.

Shukka et al. (1987) found that the average nozzle discharge varied from 0.458 lit/min to 0.820 lit/min as the pressure was increased from 2.0 to 4.0 ksc.

Droplet Size

Yeomans (1952) reported that control of forest defoliators was satisfactory with an NMD of 275 μm. Davis et al. (1956) tested sprayers with a NMD of 80, 150 and 300 μ m for the control of the spruce bud worm choristoneura fumiferana (clemens) and concluded that an NMD of 300 µm was effective in controlling the spruce bud worm choristoneura fumiferana.

Regupathy and Dhamu (1990) described the method of determination of droplet size. Droplets are collected on suitable surface on which a mark, crater or stain is left by their impact. The difference between the mark, crater or stain and the true size is the spread factor. The standard surface used to collect droplets was magnesium oxide (MgO); glass slides coated with burning magnesium ribbon. The magnesium oxide surface is less satisfactory for small droplets and those above 200 µm may shatter on impact. No spread factor is needed for grease matrix, as the droplets resume their original spherical shape on this surface. The above mentioned surfaces are difficult to use in the field. Hence glassy paper such as kromekote or photographic papers were used. The spray is colored with a water soluble (e.g. Methylene blue - 0.75 %) or oil soluble (e.g., Croceine scarlet) dye according to the spray liquid use.

Mathews et al. (1982) reported the desirability of using droplet size of 30 to 100 µm diameter to increase deposition on plant leaves. Akesson and Yates (1989) stated that droplet of 100 to 200 µm diameter are most effective for control of bush and other plant species.

Ramesh Babu et al. (1990) found that the droplet size in pressurized sprayers was observed to be 150 to 190 µm. In all the sprayers 30 to 50 cm height of application was observed to give good performance of deposition efficiency.

Materials and Methods

Selection of Nozzles

The following commercially available hydraulic energy nozzles used for orchard spraying were selected for the study. The specifications of the nozzle are given in **Table 1**.

Determination of Discharge Rate

The discharge rate of the nozzle was tested for pressure range of 1.5 to 3 ksc at an interval of 0.5 ksc. The discharge liquid was collected for a period of 1 minute in a measuring jar of 1 lit capacity. The total volume of water was measured and discharge rate was calculated.

Determination of Droplet Size

The most widely used parameters to represent droplet size are the volume median diameter (VMD) and the number mean diameter (NMD) measured in micro meters (µm). Droplets are collected on photographic paper. The spray is coloured with water soluble methylene blue of 0.75 % concentration. The droplets size was measured with a microscope equipped with an ocular recticle after allowing a minimum period of 24 hrs

Table 1 Specification of the selected nozzles

Commercial code	Type	Orifice diameter, mm
NMD/S	Solid cone	1
BAN	Solid cone	0.5
Broad cone	Hollow cone	2
NMM	Solid cone	0.5
NTM	Solid cone	2

The following parameters were measured using experimental setup.
a. Discharge rate, b. Droplet size and density, c. Height of reach

Table 2 Discharge rate of nozzles

Nozzle	Discharge rate, lit/hr			
	1.5 ksc	2 ksc	2.5 ksc	3 ksc
NMD/S	24.7	26.6	28.8	30.8
BAN	22.4	24.2	25.9	28.0
Broad cone	54.2	61.8	68.6	74.2
NMM	19.8	22.2	24.5	27.0
NTM	68.0	72.2	74.0	81.8

Fig. 1 Effect of dischage rate on pressure

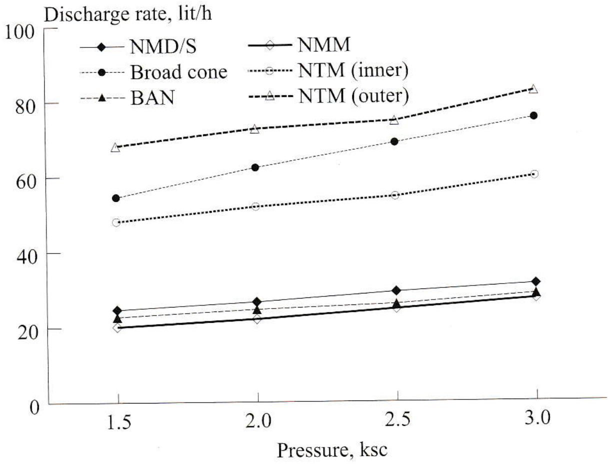
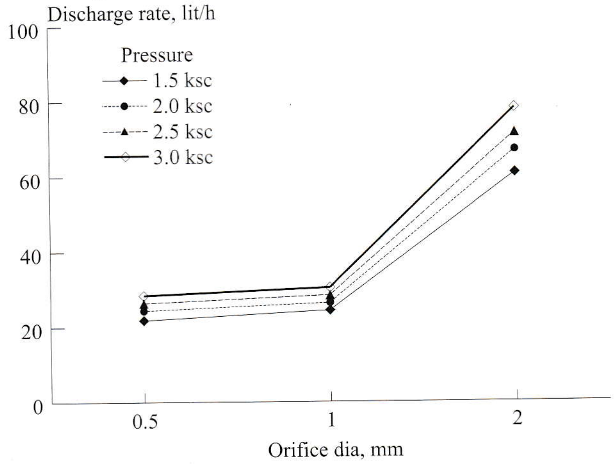


Fig. 2 Effect of dischage rate on orfice diameter



for complete spreading of droplets on the sampling surfaces.

The droplets were collected at a vertical interval of 25 cm and a horizontal interval of 25 cm distances. By using this arrangement the height of reach was also measured. The distance between the nozzle and photographic paper was selected to be 50, 100 and 150 cm. The nozzle orientation was kept at 0, 30, 45 and 60 degrees. The nozzle was fixed at 50 cm above the ground level.

Results and Discussion

Discharge Rate

The discharge rate of 5 types of nozzles with different operating pressures are presented in **Table 2**.

Effect of Pressure on Discharge Rate

The discharge rate for all types of nozzles was directly proportional to pressure. Irrespective of pressure charge the NTM nozzle recorded maximum discharge rate of 68 to 81.8 lit/h followed by broad cone nozzle (54 to 74 lit/h). The discharge rate of the nozzles gradually increased with increase in pressure (**Fig. 1**).

Inter relationship between orifice diameter and discharge rate

The discharge rate was measured for nozzles in different orifice diameter viz. 0.5, 1.0, and 2.0 mm. **Fig. 2** illustrates the relationship between the discharge rate and orifice diameter of the nozzles. The results indicate that generally the discharge rate increased with the increasing orifice diameter for all the operating pressure. The variation in discharge rate was minimum for the orifice diameters of 0.5 and 1.0 mm where as the variation was maximum when the orifice diameter increased from 1 to 2 mm.

Droplet Distribution

Droplet distribution was measured with the number mean diameter (NMD) and volume mean diameter (VMD) for the test nozzles.

Number Median Diameter

The number mean diameter (NMD) was calculated for all nozzles with 0, 30, 45 and 60 degree orientation and 50, 100 and 150 cm horizontal distances. The average NMD and coefficient of variance for each nozzle orientation was summarized in **Tables 3** to **6**. From the **Table 3** it was observed that the NMD/S nozzle with a horizontal distance of 150 cm and 30 degree nozzle orientation gave more uniform droplets distribution with a CV of 0.1 with average NMD of 126.23 µm. The broad cone nozzle gave best performance at 150 cm horizontal

Table 3 NMD for NMD/S nozzle

Distance, cm	Angle, deg.	NMD, µm								Average NMD, µm	CV
		-50	-25	0	25	50	75	100	125		
50	0	77.92	157.02	122.34	186.58	-	-	-	-	139.99	0.34
	30	-	-	129.34	125.57	156.89	159.56	-	-	147.34	0.12
	45	-	-	177.84	156.35	206.33	132.52	-	-	168.26	0.18
	60	-	152.29	164.81	200.89	125.71	188.56	325.44	-	192.94	0.36
100	0	86.42	142.29	124.26	162.32	-	-	-	-	100.75	0.56
	30	-	-	157.02	268.53	270.74	313.64	205.38	-	243.06	0.25
	45	-	120.03	191.26	238.26	219.08	230.01	-	-	199.72	0.24
	60	-	149.73	146.60	86.64	92.31	-	-	-	118.82	0.28
150	0	-	241.74	615.42	-	-	-	-	-	428.58	0.61
	30	-	109.82	134.77	122.77	121.35	143.04	-	-	126.23	0.10
	45	-	-	94.08	152.37	92.62	85.92	59.73	-	96.84	0.35

Table 4 NMD for Broad cone nozzle

Distance, cm	Angle, deg.	NMD, µm								Average NMD, µm	CV
		-50	-25	0	25	50	75	100	125		
50	0	123.48	176.29	111.32	114.48	-	-	-	-	131.39	0.23
	30	-	-	183.58	143.44	146.21	271.71	-	-	186.23	0.32
	45	-	170.22	114.42	158.29	118.88	64.15	-	-	125.19	0.23
	60	-	127.32	141.03	171.89	203.71	182.78	134.46	101.37	151.68	0.23
100	0	204.51	224.09	117.50	297.09	258.79	-	-	-	220.30	0.30
	30	-	206.98	255.63	271.26	97.91	78.73	-	-	183.30	0.49
	45	-	103.58	141.74	199.24	161.01	107.51	115.08	159.86	141.16	0.24
	60	-	189.22	143.42	121.35	188.27	97.92	67.71	-	134.64	0.36
150	0	141.24	103.63	69.85	397.26	-	-	-	-	177.79	0.83
	30	-	168.81	88.17	262.46	122.61	120.46	-	-	52.50	0.44
	45	-	105.92	130.35	100.31	106.55	100.22	128.26	87.97	108.51	0.14

distance and 45 degree orientation with NMD of 105 µm and CV value of 0.14. In this combination height of reach was also maximum. For the NMM nozzle the best performance was obtained with a horizontal distance of 100 cm and 0 degree orientation with the average NMD of 124.83 µm and CV of 0.18, but the height of reach was minimum.

In the case of NTM nozzle, the best performance was obtained at the horizontal distance of 150 cm and 45 degree orientation with a CV of 0.14 and 118 µm NMD value with maximum height of reach. It was concluded that the broad cone and NTM nozzle at a horizontal distance of 150 cm from the target and 45 degree orientation of the nozzle resulted in maximum height of spray with the droplet size of 113 + 5 µm with CV of 0.14. These nozzles are suitable for orchard spraying among the nozzles tested.

Volume Distribution of Droplets

The volume of spray was calculated by multiplying the number of droplets with the volume median diameter (VMD). From this data the height at which 50 % volume of spray deposited was calculated. Graphs were drawn between the calculated height of 50 % volume spray deposited and the horizontal distance between the nozzles and target (**Figs. 3** to **6**).

The maximum height of spray was obtained when orientation of the nozzle was at 45 and 60 degrees. The height of spray gradually increased from 0 degree orientation of the nozzle to 45 degree for all nozzles. Spray above that the height of reach was not appreciable. Hence the spray nozzles should be oriented at 45 degree for orchard spraying to obtain maximum spray volume and height.

The NMD values of 50 percentile volume height was calculated and presented in table.8. It was observed that for the broad cone and NTM nozzle the NMD value at 50 percentile volume height for 45 degree nozzle orientation was almost equal. For NMD/S and NMM nozzles it was not uniform in any orientation. Among the nozzles tested the broad cone nozzle at 45 degree orientation with 100 cm horizontal distance resulted maximum height of 105 cm at which 50 % volume of spray deposited. At this height droplet size was 150 µm.

Conclusions

- The discharge rate of nozzles increased with increasing pressure. The NTM nozzle recorded maximum discharge rate of 81.8 lit/hr at 3 ksc operating pressure followed by the broad cone nozzle (74 lit/hr).
- The broad cone and NTM

Table 5 NMD for NMM nozzle

Distance, cm	Angle, deg.	NMD, µm								Average NMD, µm	CV
		-50	-25	0	25	50	75	100	125		
50	0	104.49	131.50	156.89	196.72	-	-	-	-	147.42	0.26
	30	-	150.23	162.81	169.17	122.38	261.33	-	-	173.20	0.38
	45	-	184.26	68.43	186.97	151.22	120.20	83.48	-	132.92	0.31
	60	-	93.20	111.04	139.75	145.96	100.54	179.37	-	128.31	0.25
100	0	145.88	93.97	122.38	137.12	-	-	-	-	124.83	0.18
	30	-	184.26	87.51	205.16	226.07	71.53	446.68	-	209.39	0.72
	45	-	206.35	97.37	167.38	168.52	270.79	156.20	-	177.76	0.32
	60	-	102.42	124.06	87.53	72.93	-	-	-	96.73	0.22
150	0	109.20	148.82	80.21	-	-	-	-	-	96.07	0.62
	30	-	225.78	112.26	114.82	156.26	-	-	-	152.28	0.34

Table 6 NMD for NTM nozzle

Distance, cm	Angle, deg.	NMD, µm								Average NMD, µm	CV
		-50	-25	0	25	50	75	100	125		
50	0	120.32	168.02	184.28	183.77	-	-	-	-	164.14	0.18
	30	-	-	90.42	128.46	186.38	346.72	-	-	187.84	0.59
	45	-	125.05	130.62	172.53	198.59	108.10	293.78	-	171.39	0.40
	60	-	-	106.47	101.99	168.85	200.52	134.48	118.86	138.52	0.28
100	0	192.08	147.32	274.11	349.70	-	-	-	-	240.80	0.37
	30	396.89	160.02	248.12	174.26	262.45	-	-	-	268.34	0.44
	45	-	108.12	173.72	230.01	180.57	210.48	135.01	77.53	159.35	0.34
	60	-	129.09	153.93	190.92	86.65	181.92	245.95	174.06	167.50	0.29
150	0	176.73	119.32	80.13	-	-	-	-	-	125.35	0.38
	30	144.25	125.10	113.25	111.17	73.46	64.11	-	-	117.55	0.36
	45	-	78.39	119.98	148.01	122.65	117.39	97.89	122.11	118.01	0.14
	60	-	-	97.91	126.46	84.12	61.42	54.22	83.61	90.45	0.21

nozzles at horizontal distances of 150 cm and 45 degree orientation gives maximum height of reach and uniform spray of droplets within 113 µm among the nozzles tested.

- Based on the volume distribution of droplets, the broad cone nozzle at 45 degree orientation with 100 cm horizontal distance resulted maximum height of 105 cm at which 50 % volume of spray deposited. At this height droplet size was 150 µm.

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Fig. 3 Effect of distance on 50 percentile volume height NMD/S nozzle

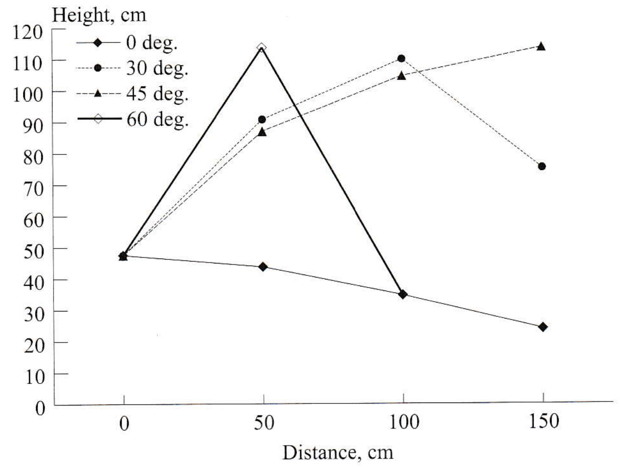

Fig. 4 Effect of distance on 50 percentile volume height broad cone nozzle

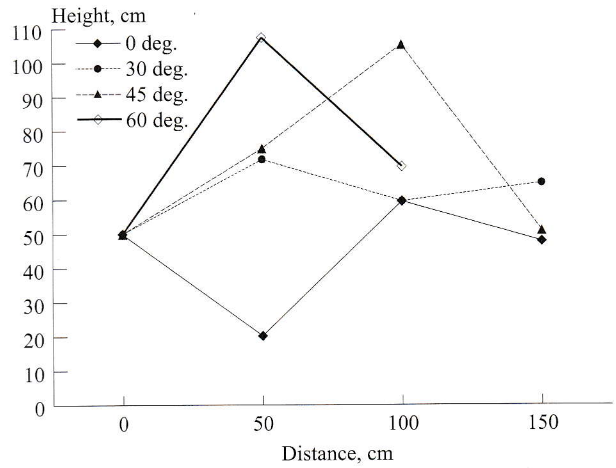

Fig. 5 Effect of distance on 50 percentile volume height NMM nozzle

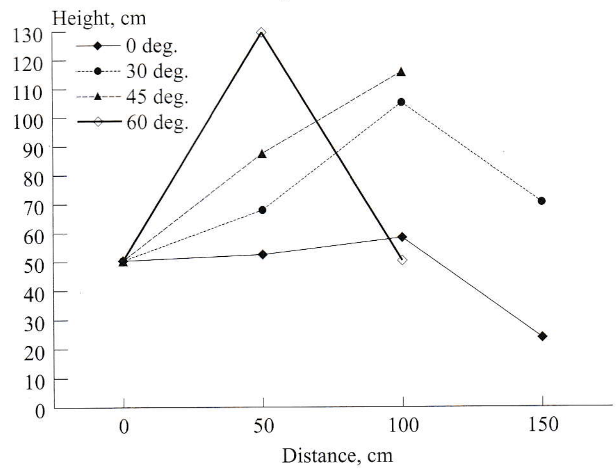

Fig. 6 Effect of distance on 50 percentile volume height NTM nozzle