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LEAF COVERAGE PERFORMANCE OF TOBACCO SPRAY MACHINERY IN NORTH QUEENSLAND. 2. INFLUENCE OF VOLUME OF APPLICATION, NOZZLE TYPE AND NOZZLE PLACEMENT ON SPRAY DISTRIBUTION

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SUMMARY

Spray distribution patterns from a "tricrop" sprayer on tobacco plants at varying growth stages were determined using a fluorescent tracer technique. Increased leaf coverage resulted from increased volume of application but the spray nozzle placement and nozzle type appeared to limit the cover obtained as a result of increasing the volume of application. Reported deficiencies in leaf cover as a result of spraying field-grown tobacco with a tricrop spray machine can be minimized and largely overcome by the alteration of nozzle type and nozzle placement.

I. INTRODUCTION

Spray practices for tobacco insect control in north Queensland are changing from a routine spray to a recently developed method of strategic spray application (I. C. Cunningham 1971, personal communication). The effectiveness of such a spray programme is largely influenced by the ability of the spray machine to deposit the insecticide on the plant. McNee (1972) indicated the spray distribution patterns of the major types of commercial spray machines used in tobacco pest and disease control in north Queensland. This study indicated that no machine in current use could achieve the recommended level of plant cover. All machines examined gave inadequate leaf cover in the heart of the plant and on the lower leaf surface.

With the emphasis in insect control changing from routine to strategic spray application, it was expected that the deficiencies in leaf cover demonstrated earlier would assume increasing importance.

The results reported in this paper indicate the effect of spray volume, nozzle placement and nozzle type on the spray distribution from a "tricrop" sprayer.

The aim of these studies has been to clarify the influence of the above factors in the spray programme and to attempt to minimize the reported deficiencies in spray cover from this machine.

II. MATERIALS AND METHODS

Determination and assessment of spray distribution.—The procedures used to determine and assess spray distribution were similar to those reported earlier (McNee 1972), though the assessment of spray cover was restricted to the sections of the plant under investigation. The fluorescent pigment "Saturn Yellow", plus a small quantity of wetting agent, was applied through the sprayer at 8 oz/100 gal. After drying, the plants were removed to a dark room and each leaf surface was examined under ultraviolet light. The assessment of spray distribution was based on the leaf area covered by the fluorescent dye. Three categories of leaf cover were recognized:

(1) Satisfactory distribution (S): approximately 75% or over of the leaf surface showed a fluorescent deposit.

(2) Medium distribution (M); approximately 15–75% of the leaf showed a fluorescent deposit.

(3) Nil distribution (L): approximately 15% or less of the leaf surface showed a fluorescent deposit.

In recording results the number of leaf surfaces in each assessment category was expressed as a percentage of the total number of leaf surfaces examined.

Spray machine.—The tricrop sprayer used in the previous investigations and in these investigations is a self-propelled, high-clearance, rear-mounted boom spray with inter-row droppers. The machine travelled at 2 m.p.h. and was capable of spraying four rows. The number of nozzles used to spray each row depended on the size of the plants. Four nozzles per row (two dropper nozzles at ground level, and two overhead nozzles 9 in. above the crop) were used when the plants were less than 18 in. high. For the remaining spray dates two extra dropper nozzles were used per row (i.e. 6 nozzles per row) (Figure 1a). The bottom nozzles were at ground level and the two middle dropper nozzles were at a height equal to the middle of the tobacco plant. The machine applied 50–60 gal/ac when using four nozzles per row and 80–90 gal when using six nozzles per row. Spraying was conducted at 100 lb/sq in using "Rega" No. 6 nozzles. The investigations with this machine were carried out on a number of sites, each site consisting of 4-row plots 3 chains long. Six plants were selected from each row for spray distribution determination, i.e. 24 plants per spray operation.

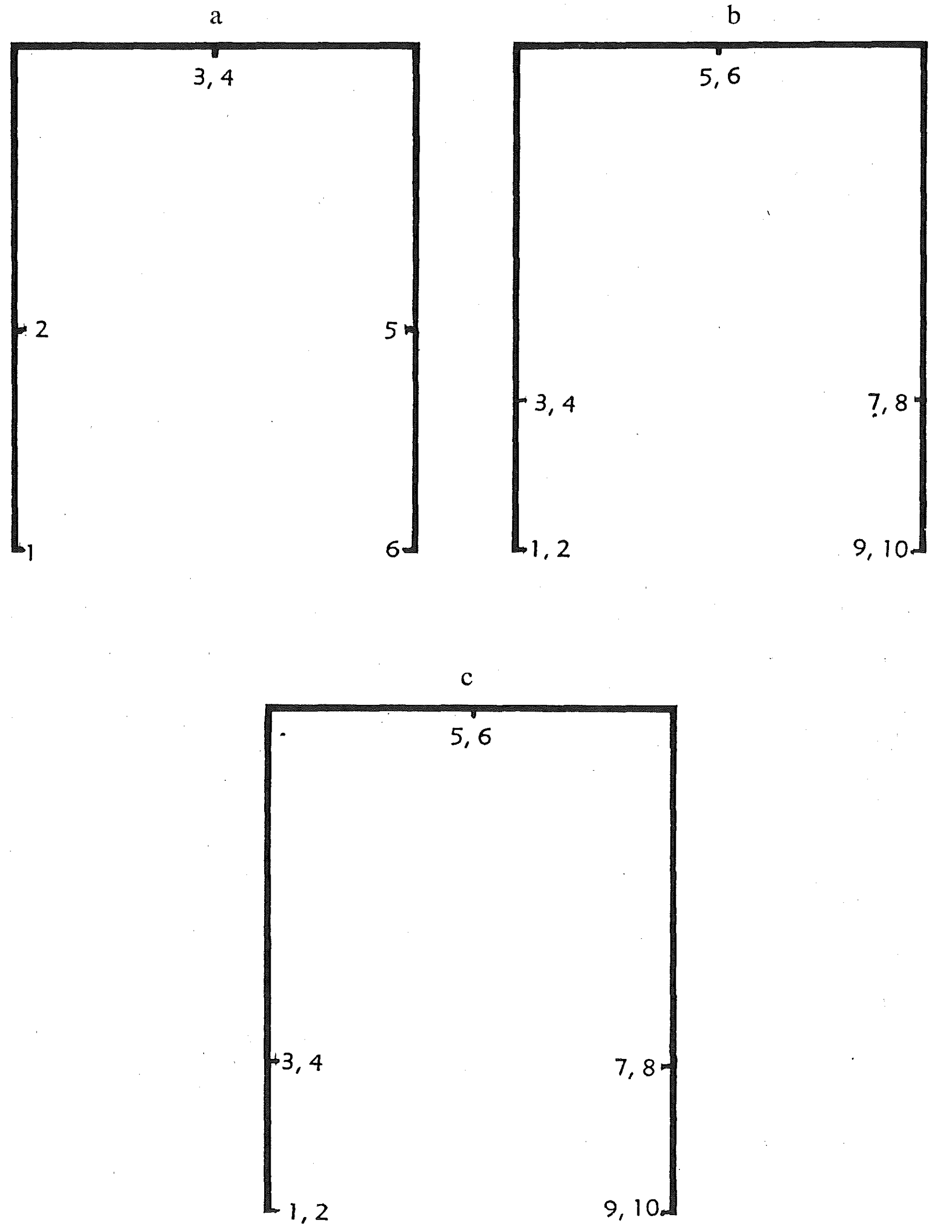

Fig. 1.—(a) Normal tricrop nozzle arrangement indicating the position of the 6 nozzles spraying each row. Volume per acre 90 gal. Pressure 100 lb/sq in. (b) Alternative tricrop nozzle arrangement indicating the position of the 10 nozzles spraying each row. Volume per acre 25 gal. Pressure 100 lb/sq in. (c) Alternative tricrop nozzle arrangement indicating the position of the 10 nozzles spraying each row. Volume per acre 45 gal. Pressure 100 lb/sq in.

Procedure.—The investigations conducted from 1967 to 1970 followed three lines of approach:

(i) Volume of application. Variations in the volume of spray applied were obtained by varying the nozzle size. Spray distribution determinations involved the following: (a) prior to flowering (4 nozzles per row): 2 growth stages (plants 12 in. and plants 18 in.) x 3 rates of application (30, 60, 90 gal/ac), and (b) following flowering (6 nozzles per row): 2 growth stages (plants flowering, and plants ½ harvested) x 3 rates of application (50, 95, and 140 gal/ac).

(ii) Spray distribution: heart of plant. A marked deficiency in leaf cover occurs in this section of the plant with the tricrop sprayer (McNee 1972). The investigations reported here aimed at concentrating the spray volume from the overhead nozzles at this plant position. Two aspects were examined:

(a) Placement of "overhead" nozzles. Three nozzle placements (6, 12 and 18 in. above the crop) x 2 times of application (plants 12 in. and plants 18 in. high) x 2 nozzle spray pressures (50 and 100 lb/sq in) were used. The volume applied through the overhead nozzles was maintained at 20–30 gal/ac.

(b) Effect of nozzle type. The hollow cone type nozzle normally used on the tricrop was compared with the flat fan and solid cone type nozzles. Spraying was conducted prior to flowering (plants 18 in. high) at 100 lb/sq in pressure. The volumes applied varied with the nozzle type and size and are shown in Table 4.

(iii) Spray distribution: under-surface of leaf. The major deficiency with all tobacco spray machines examined previously (McNee 1972) was their inability to deposit spray on the under-surface of the lower leaves. The dropper nozzles are largely responsible for depositing spray on these leaf surfaces. The influence of nozzle placement and nozzle number on the spray distribution to these leaf surfaces was studied from two aspects:

(a) Dropper placement. The studies were conducted prior to the plant flowering (plants 8 in. and plants 12 in. high). Comparisons were made between the normal spraying procedure, where the dropper nozzles were 24 in. from the plant line, and an adjusted position where the dropper nozzles were 12 in. from the plant line.

(b) Nozzle placement and nozzle number. After the plants commenced flowering the normal tricrop nozzle arrangement (Figure 1a) was compared with alternative arrangements (Figures 1b and 1c), where the number of nozzles per row was increased (from 6 to 10 nozzles per row) and their placement altered. Two points were considered in deciding the alternative nozzle placement—first, if nozzle placement was limiting coverage on the under-surface of the leaf, the volume applied would not be critical and could be reduced; and second, in actual practice two-thirds of the volume applied is directed at the upper half of the plant, i.e. the section of the plant with the least leaf area.

III. RESULTS

(a) Volume of Application

The spray distribution patterns resulting from varying the volume of spray applied are shown in Table 1 for the two spray dates prior to flowering. Similar results are indicated in Table 2 for the two growth stages following flowering.

TABLE 1

INFLUENCE OF VOLUME OF APPLICATION ON SPRAY COVERAGE PRIOR TO FLOWERING

Spray coverage expressed as percentage of leaf surfaces falling into each of the spray cover ratings $S > 75\%$, $M = 15\text{–}75\%$, $L < 15\%$.

Leaf Position	Leaf Surface	Volume Applied, using 4 Nozzles per Row								
		30 gal/ac			60 gal/ac			90 gal/ac		
		S	M	L	S	M	L	S	M	L
(1) Plants 12 in. high										
Top 4 (heart of plant)	Upper	41	12	47	62	13	25	51	17	32
	Lower	46	17	37	46	25	29	54	21	25
Middle	Upper	100	..	..	100	..	..	100	..	..
	Lower	..	12	88	4	..	96	25	17	58
Lower 3	Upper	100	..	..	95	5	..	80	7	13
	Lower	..	..	100	..	..	100	24	8	69
(2) Plants 18 in. high										
Top 4 (heart of plant)	Upper	8	13	79	..	4	96	8	26	66
	Lower	4	8	88	17	4	79	17	37	46
Middle	Upper	90	6	4	98	2	..	97	3	..
	Lower	6	51	43	30	54	16	56	37	7
Lower 3	Upper	100	..	..	94	6	..	94	6	..
	Lower	11	6	83	6	28	66	33	51	26

TABLE 2

INFLUENCE OF VOLUME OF APPLICATION OF SPRAY COVERAGE FOLLOWING FLOWERING

Spray coverage expressed as percentage of leaf surfaces falling into each of the spray cover ratings $S > 75\%$, $M = 15\text{–}75\%$, $L < 15\%$.

Leaf Position	Leaf Surface	Volume Applied, using 6 Nozzles per Row								
		50 gal/ac			95 gal/ac			145 gal/ac		
		S	M	L	S	M	L	S	M	L
(1) Plant flowering										
Top 4	Upper	100	..	..	96	4	..	100	..	..
	Lower	88	12	..	75	25	..	96	4	..
Middle	Upper	100	..	..	100	..	..	99	1	..
	Lower	53	30	17	36	48	16	84	16	..
Lower 4	Upper	99	1	..	100	..	..	100	..	..
	Lower	4	38	58	8	20	72	8	40	53
(2) Plant half harvested										
Top 5	Upper	97	3	..	100	..	..	97	3	..
	Lower	14	46	40	23	63	14	50	30	20
Remainder	Upper	100	..	..	100	..	..	97	3	..
	Lower	..	6	94	17	17	66	8	28	64

The results for all growth stages examined indicate that irrespective of volume applied there was no deficiency in leaf cover on the upper leaf surface except in those leaves forming the heart of the plant. Increased volume of application slightly improved spray deposition in the heart of the plant, but irrespective of the volume applied between 60 and 90% of these leaf surfaces showed negligible spray deposit (Table 1).

Prior to flowering a deficiency in leaf cover occurred on the under-surface of leaves forming the middle and lower sections of the plant. This deficiency decreased with increasing volume of spray applied (Table 1). At neither of the two growth stages was the improvement in leaf cover with increased volumes of spray application sufficient to overcome this deficiency.

Following flowering (Table 2) the spray distribution on the under-surface of the lower four leaves was not affected by the volume of spray applied. In the other plant positions increasing the volume of spray resulted in increased spray deposition, and at the highest volume of application (145 gal/ac) the deficiency in leaf cover was overcome.

At the final spray date, when half the leaves on the plant had been harvested (Table 2), a slight improvement in leaf cover resulted from increased spray volumes, but more than 60% of the under-surface of the leaves showed no spray deposit.

(b) Spray Distribution: Heart of Plant

(a) Overhead nozzle placement (Table 3). For the plants 12 in. high increased spray deposition on leaves forming the heart of the plant resulted from decreasing the height of the overhead nozzles above the crop. However, this improvement in spray deposition did not occur at the later growth stage (plants 18 in. high). Variations in spraying pressure (50 and 100 lb/sq in) did not affect the results obtained.

TABLE 3

INFLUENCE OF OVERHEAD NOZZLE PLACEMENT ON SPRAY COVERAGE OF LEAVES FORMING THE HEART OF THE PLANT (TOP 4 LEAVES)

Spray coverage expressed as percentage of leaf surfaces falling into each of the spray cover ratings $S > 75\%$, $M = 15\text{–}75\%$, $L < 15\%$.

Nozzle Height above Plants (in.)	Spraying Pressure					
	50 p.s.i.			100 p.s.i.		
	S	M	L	S	M	L
(1) Plants 12 in. high						
6	65	10	25	65	10	25
12	48	14	38	50	10	40
18	38	14	48	48	4	48
Mean	50	13	37	54	8	38
(2) Plants 18 in. high						
6	32	11	56	37	13	50
12	25	11	63	28	10	61
Mean	29	11	60	32	12	56

(b) Nozzle type (Table 4). The results indicate an improvement in spray deposition in the heart of the plant as a result of using the flat fan and solid cone type nozzle. Increasing the volume applied through these two types of nozzles also resulted in increased spray deposition.

TABLE 4

INFLUENCE OF NOZZLE TYPE ON SPRAY COVERAGE OF LEAVES FORMING THE HEART OF THE PLANT (TOP 4 LEAVES)

Spray coverage expressed as percentage of leaf surfaces falling into each of the spray cover ratings S > 75%, M = 15–75%, L < 15%.

Nozzle Size (Orifice)	Nozzle Type											
	Hollow Cone				Solid Cone				Flat Fan			
	Vol. (gal/ac)	S	M	L	Vol. (gal/ac)	S	M	L	Vol. (gal/ac)	S	M	L
Tricrop standard ..	30	48	24	28								
·039 in.					24	58	17	23	28	60	14	26
·046 in.					32	73	16	10	36	83	8	8

(c) Spray Distribution: Under-surface of Leaf

(a) Dropper placement (Table 5). At the two growth stages examined, increased leaf cover was obtained when the dropper nozzles were placed closer to the plant line. Following the growth stage at which plants were 12 in. high, the advantage gained by moving the dropper nozzles closer to the plant line was lost as the droppers in the adjusted position caused physical damage to the actively growing crop.

TABLE 5

INFLUENCE OF DROPPER PLACEMENT PRIOR TO FLOWERING ON THE SPRAY COVER OF LEAVES BELOW THE HEART OF THE PLANT

Spray coverage expressed as percentage of leaf surfaces falling into each of the spray cover ratings S > 75%, M = 15–75%, L < 15%.

Leaf Position	Leaf Surface	Spray Dropper Position					
		Normal Spraying (Dropper 24 in. plant line)			Adjusted Dropper (Dropper 12 in. plant line)		
		S	M	L	S	M	L
(1) Plant 8 in. high							
Leaves below heart	Upper	100	..	..	100	..	..
	Lower	31	42	27	82	15	3
(2) Plant 12 in. high							
Leaves below heart	Upper	88	12	..	96	2	2
	Lower	56	22	22	85	2	12

(b) Nozzle placement and nozzle number (Table 6). The results indicate the importance of nozzle placement and number in obtaining spray deposition on the under-surface of the leaf. Leaf coverage was improved in all but the lowest three leaves by increasing the nozzle number, but improvement in spray distribution resulted when the volume applied through 10 nozzles per row was increased from 25–30 gal/ac to 45–50 gal/ac.

TABLE 6

INFLUENCE OF NOZZLE PLACEMENT AND NOZZLE NUMBER FOLLOWING FLOWERING ON SPRAY COVER ON LEAVES OCCURRING BELOW THE HEART

Spray coverage expressed as percentage of leaf surfaces falling into each of the spray cover ratings S > 75%, M = 15–75%, L < 15%.

Leaf Position	Leaf Surface	Normal Spraying 6 nozzles/row 90 gal/ac			10 nozzles/row 25 gal/ac			10 nozzles/row 45 gal/ac		
		S	M	L	S	M	L	S	M	L
Middle	Upper	100	. .	. .	100	. .	. .	100	. .	. .
	Lower	53	22	25	67	22	11	83	10	7
Lower 3 . .	Upper	100	. .	. .	100	. .	. .	100	. .	. .
	Lower	12	28	60	21	25	54	58	8	34

IV. DISCUSSION

Paddick (1965) indicated that the area of foliage to be covered and also the degree of atomization of the spray applied largely govern the volume of spray required to obtain maximum leaf cover. In the present investigations, other than after the commencement of harvest, increasing the volume of spray resulted in increased leaf cover on the under leaf surface, and at a rate of 145 gal/ac at flowering maximum leaf cover was obtained. The increased volume of application was not sufficient to overcome the deficiency in leaf cover that occurs with the tricrop machine. Subsequent investigations reported in this paper indicate that both in the heart of the plant and on the under-surface of the leaf the effectiveness of increased volumes of spray was limited by the placement of the spray nozzles. The results obtained from consideration of spraying factors other than the volume of spray applied indicate methods that exist for obtaining a marked improvement in spray distribution and which have the added practical advantage of a considerable reduction in the volume of spray required.

To overcome the deficiency in leaf cover in the heart of the plant it is necessary to concentrate the volume of spray directed at these leaf surfaces. The advantage gained from placing the overhead nozzles closer to the plant is limited, as the spray angle largely governs the effectiveness of the spray operation. At the higher positions (12 and 18 in.) the spray angle is sufficiently wide to allow for variation in steering and row spacing, but at this height the decrease in concentration of spray directed to these leaves results in reduced leaf cover. In terms of the increased leaf cover obtained, the use of the flat fan nozzle to spray this section of the plant would appear warranted. The spray angle with this type of nozzle at a practical working height above the crop would allow for variation in steering and row spacing while maintaining maximum leaf cover on these leaf surfaces.

The major point of practical importance concerning the deposition of spray on the under leaf surface arising from investigations relates to both the increased number and the placement of the dropper nozzles. The adoption of the increased number of dropper nozzles, from 6 to 10, as a commercial practice is warranted. The resulting increased leaf cover will increase the efficiency of the applied pesticide. The reduced volume of spray which can be applied effectively with the greater number of nozzles will reduce the spraying time required to cover a given area. The latter point assumes importance when the spraying operation has not been completed by mid morning, as increased spray deposition is obtained by early morning spraying when the plants are upright and turgid (McNee, unpublished data). At the earlier growth stage prior to flowering, the adjustment of the dropper nozzles closer to the plant line as a practical proposition would depend on the flexibility and adjustment possible in the design of the spray machine.

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