

CRITICAL GROWTH STAGES FOR 2,4-D PHYTOTOXICITY TO SUGARCANE IN SOUTH AFRICA

By F.E. RICHARDSON

South African Sugar Association Experiment Station

Abstract

Field trials were used to investigate the phytotoxicity of foliar sprays of 2,4-D amine to sugarcane. Yield losses of variety NCo 376 resulted from band sprays when 3,3 kg ae/ha was sprayed onto plant or ratoon cane which had unfurled three or more leaves per shoot. The greater the foliar development of the crop at the time of spraying, the greater was the resulting crop loss. At similar stages of development plant crops were affected slightly more than ratoons. The addition of a surfactant considerably increased crop loss.

Directed sprays which minimised foliar contact caused no yield loss, even at susceptible growth stages, except when excessive doses (20 kg ae/ha) were applied. Differential varietal tolerance was recorded, NCo 376 being highly susceptible, whereas both NCo 382 and NCo 310 were tolerant. No residual effects were apparent in subsequent ratoons. Some field practices are recommended that reduce the incidence of 2,4-D injury.

Introduction

Phenoxyacetic acid herbicides such as 2,4-D are extensively used for general weed control in the South African Sugar Industry. 2,4-D is often combined with diuron and ametryne for post-emergence control measures on the watergrass species *Cyperus rotundus* and *C. esculentus*. Sugarcane plants are liable to receive sprays containing 2,4-D at any stage of growth from planting to full canopy formation. It is well established that 2,4-D can be phytotoxic to sugarcane. Hypertrophy of the node, and necrosis of the root band, together with a reduced growth rate, is commonly associated with increasing dose of the herbicide.

Nolla¹ reported that plants which were less than three months old showed more tolerance than older plants, whilst Rochecouste² considered that plant cane was highly susceptible to 2,4-D injury during the sett-root and root transition stage. In field experiments at Pongola and Mount Edgecombe, Richardson³ recorded no injury from normal pre-emergence sprays but injury did result from post-emergence sprays. The popular variety NCo 376 was relatively susceptible but significant yield losses did not occur in the experiments. Esters caused more damage than did amine formulations. Phytotoxicity from 2,4-D at low doses has also been recorded experimentally in Rhodesia (Gosnell and Strover⁴). A number of

reports and observations of post-emergence injury to NCo 376 have been received from estate agronomists and growers in South Africa.

2,4-D from overall post-emergence sprays may be absorbed into susceptible plants through the foliage or roots, but it is generally accepted that uptake is mainly through the foliage. Surfactants are commonly added to herbicide sprays to enhance the amount of foliar uptake by weeds. Robertson and Kirkwood^{5,6} report many factors that strongly influence the foliar absorption of 2,4-D. These include the cuticle structure of the plant, humidity, light, temperature, herbicide formulation, and spray pH, as well as surfactants.

Although overall sprays in sugarcane may be easier to apply than directed sprays, it is to be expected that directed sprays across the interrow will minimise herbicide uptake by the crop without reducing the efficacy of weed control. Field trials were carried out to investigate the effects of the stage of crop development, the location of herbicide placement, the addition of a surfactant and the type of cane, on the amount of 2,4-D damage occurring. This paper reports the results obtained from two trials conducted between 1968 and 1970 at Pongola, and a third trial conducted in 1969 at Mount Edgecombe.

Materials and Methods

The techniques of herbicide application and assessment of crop damage were similar in all the trials. Herbicide sprays of a commercial form of the dimethylamine salt of 2,4-D were applied either as a band spray over the cane row, or as a directed spray across the interrow. At Pongola the sprays were applied at two doses, namely 3,3 and 20 kg ae/ha, whilst at Mount Edgecombe a single 18 kg ae/ha dose was used. A non-ionic surfactant at 0,1 or 0,5% v/v concentration was included with some of the treatments.

Application was by means of a knapsack sprayer fitted with a "Spraying Systems" 8003 E teejet (for band sprays) or a TK2,5 floodjet (for directed sprays). A constant pressure valve ensured the uniform delivery of approximately 650 l/ha and 320 l/ha respectively for the two nozzles at a spraying pressure of 2 kg/cm². The experiments were kept free of weeds by regular cultivation.

Visual assessments of cane vigour were made. These included observations on retarded growth,

foliar scorch and hypertrophy of nodes. Height measurements from ground level to the uppermost visible dewlap were made at regular intervals, and provided the most accurate continuous means of assessing the degree of phytotoxicity occurring. Harvest data included cane yields, estimated recoverable sugar (ers) and stalk heights, diameters and populations. One of the experiments was continued for a succeeding crop without any additional herbicide treatments being applied, and was used to determine the extent of any residual effects

Experimental

The experiments were conducted in randomised designs with a minimum of four, but usually six replications. There were additional replications of the control plots. Experiments I and II at Pongola consisted of sprayed plots of 64 m²,

with a nett plot size of 28 m². Experiment III at Mount Edgecombe consisted of sprayed plots of 40 m² and the harvested nett plots were 15 m².

Experiment I

This was conducted on a second ratoon crop of NCo 376 to which band and directed sprays were applied at three different crop growth stages, as follows:-

- Stage I 2-3 leaves unfurled; canopy height approx. 30 cm
- Stage II 5-6 leaves unfurled; canopy height approx. 50 cm
- Stage III 7-8 leaves unfurled; canopy height approx. 80 cm.

A single dose of 3,3 or 20 kg ae/ha, together with a surfactant at 0,1% v/v concentration was applied at the relevant growth stage. The

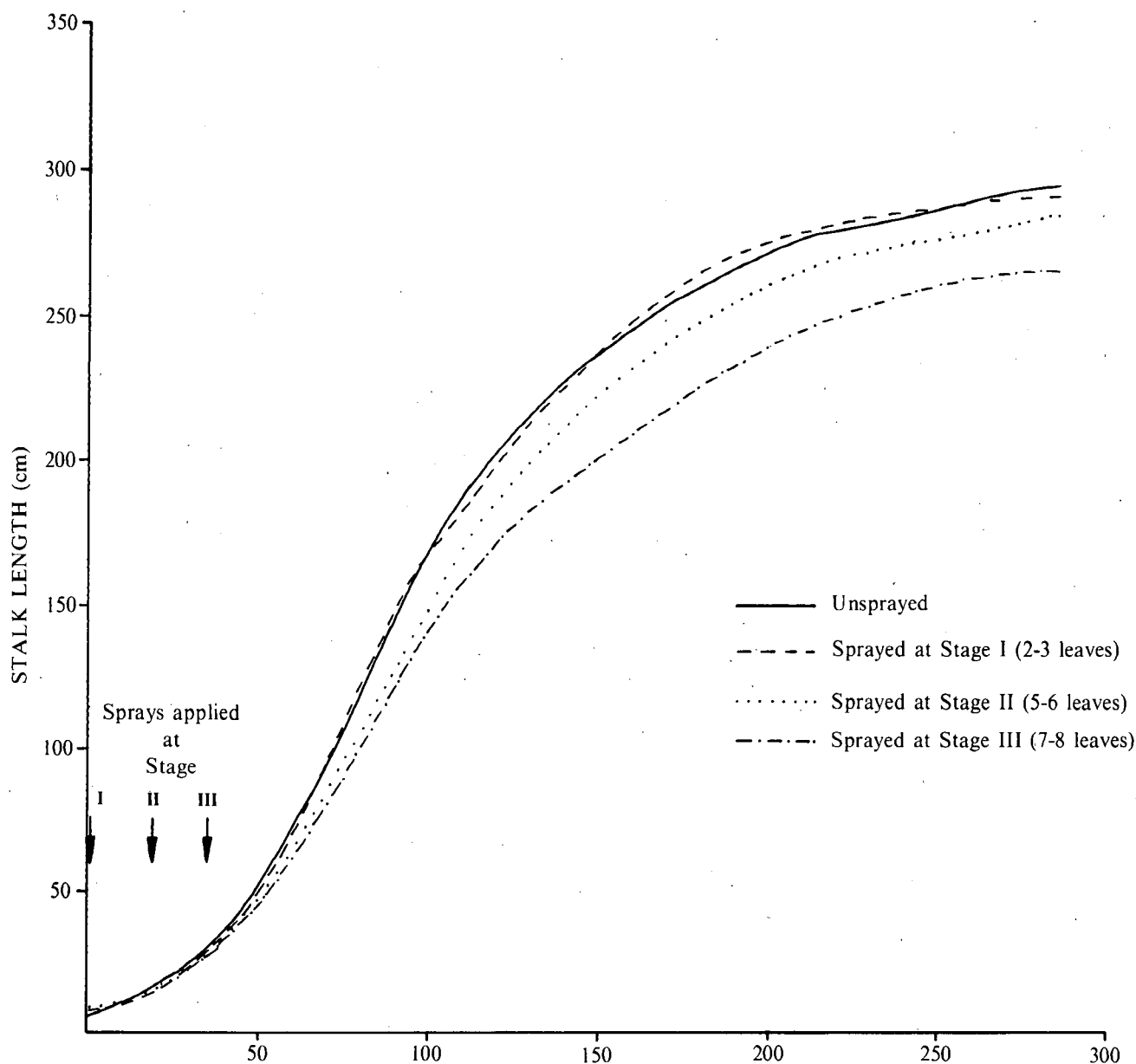


Fig. 1. The effect on growth of NCo 376 when band sprays of 2,4-D (3,3kg ae/ha) were applied over the cane row at different growth stages.

treatments were applied from mid-November and the intervals between successive stages were 19 and 15 days respectively. The 12-month old crop was harvested in November.

Results and Discussion

It was soon apparent that band applications over the cane row produced more damage than did sprays directed across the interrow, and that most damage was caused at the older growth stages. The phytotoxicity syndrome of injury included varying intensities of scorch, leaftip dieback, necrosis and the "spiky" leaf appearance usually indicative of physiological drought. A marked and immediate retardation of the growth rate occurred.

For cane receiving directed applications the phytotoxicity was generally mild, except in the case of stage I, the earliest growth stage. In this

instance the damage was more severe than it was for band applications at the same growth stage. It is considered that swath overlap, nozzle height (45 cm) in relation to the crop canopy height (30 cm) and the wide angle of the floodjet (135°) contributed to the cane foliage receiving heavy doses of herbicide.

Where phytotoxicity was severe the lowermost leaves tended to abscise and the associated nodes developed characteristic hypertrophy and callus tissue. However, even for the most severe treatments only three nodes became visibly affected, and only those stalks present at the time of spraying appeared to develop the callus tissue. The visible effects of injury slowly disappeared but height measurements, as shown in Figures 1 and 2, indicated that growth continued to be adversely affected and that crop losses could be expected.

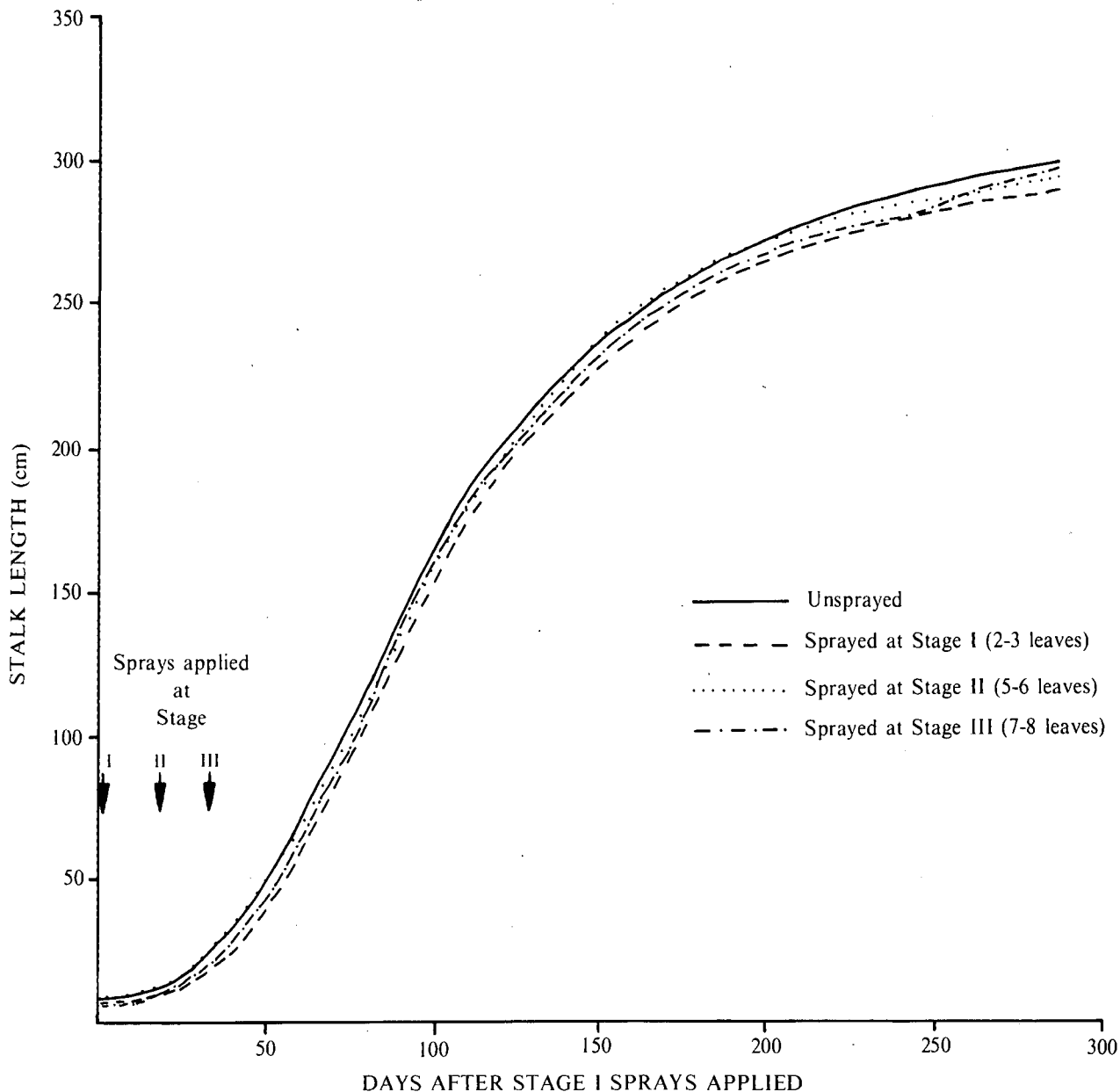


Fig. 2. The effect on growth of NCo 376 when directed sprays of 2,4-D (3,3kg ae/ha) were applied across the interrow of cane at different growth stages.

Figure 3. Stalk length at harvest :

The effect of 2,4-D (3,3 kg ae/ha) + 0,1% surfactant sprayed as a band over the cane row at different growth stages

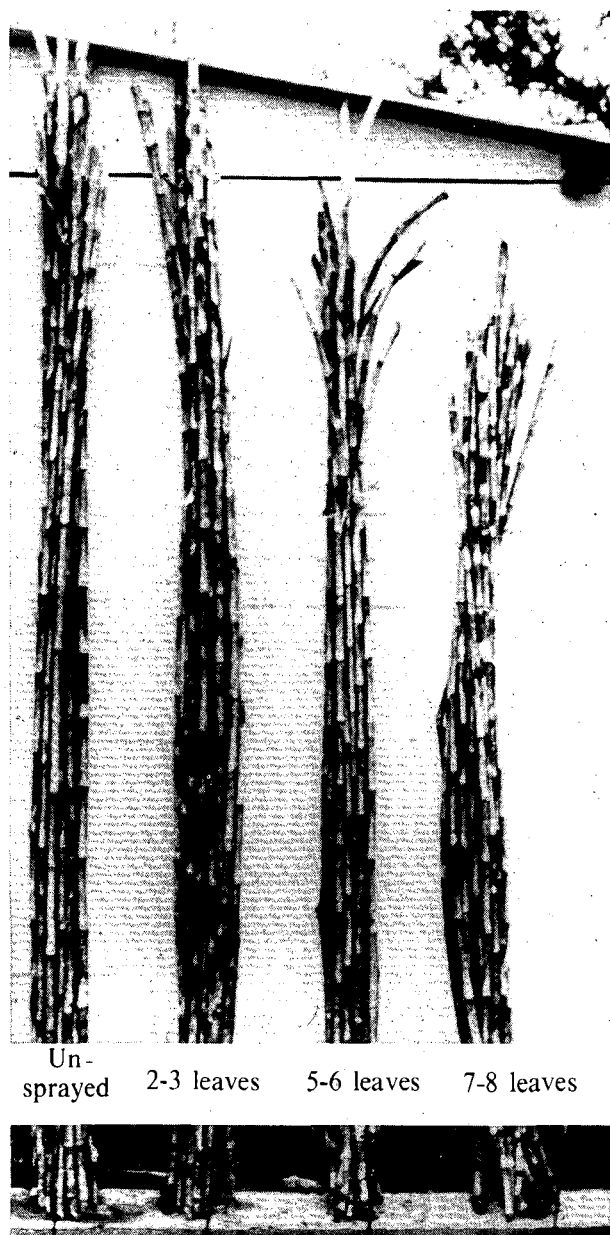
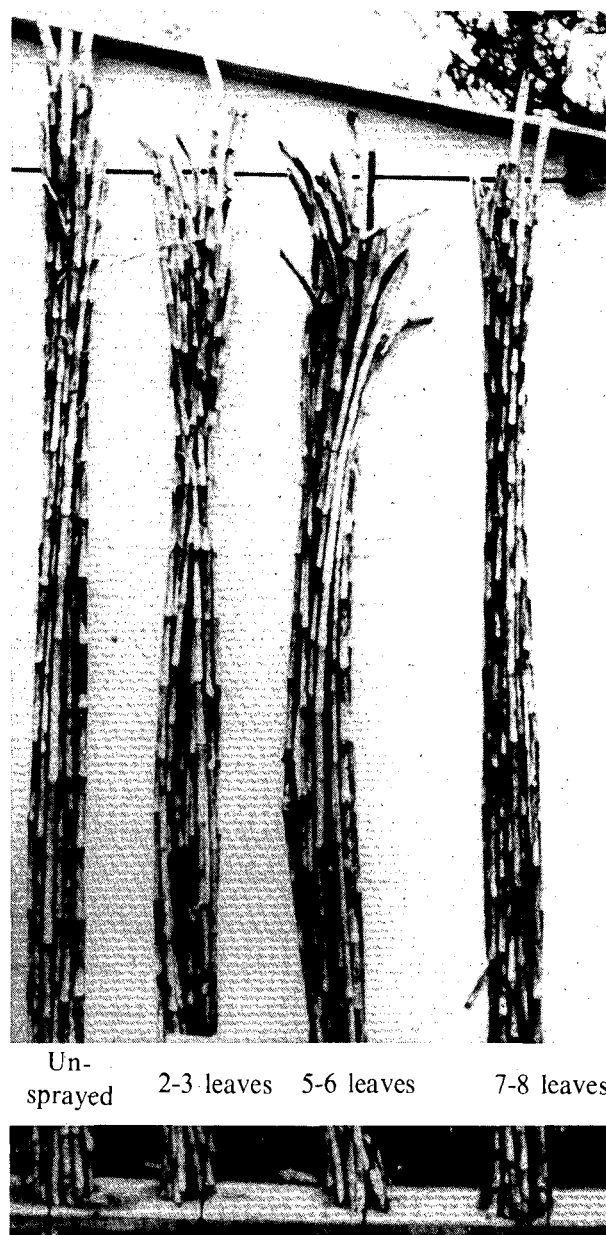


Figure 4. Stalk length at harvest :

The effect of 2,4-D (3,3 kg ae/ha) + 0,1% surfactant with sprays directed across the interrow of cane at different growth stages.



The harvest data are presented in Table I. It can be seen that there were statistically significant effects for the stages at which sprays were applied, and for the area to which the sprays were applied. For low doses (3,3 kg ae/ha) at growth stage I, band spraying over the row caused no yield loss, whereas the same spray at stage III caused a yield reduction of 22 t.c./ha.

It is interesting that an excessive dose (20 kg ae/ha) did not cause very much more yield loss than that sustained from a low dose. Effective translocation of 2,4-D from the foliage depends upon the maintenance of live phloem cells, and it

is probable that the high dose did not cause greater damage because it destroyed the conducting tissue too rapidly. It is well known that repeated small doses of herbicides are usually more toxic than single large ones. The high dose was included in the experiment to ensure that some yield differences would be obtained. The results tend to support those obtained for the low dose applications, with increasing loss resulting from sprays applied at succeeding stages of foliar development.

Sprays directed across the interrow had an opposite effect. Stage III sprays caused no yield

TABLE I
Experiment I : Yield of cane (NCo 376) after spraying at different growth stages

Placement	Treatment		Yield			Stalk counts	Stalk lengths
	Dose (kg ae/ha)	Growth Stage (leaves)	t.c./ha	ers	t.ers/ha	10 ⁻³ /ha	cm
Band Spray (Row)	3,3	I (2-3)	165	11,3	19,2	159	257
		II (5-6)	152	10,6	16,1	153	251
		III (7-8)	142	11,8	16,8	149	247
	20,0	I (2-3)	147	11,7	16,7	141	247
		II (5-6)	149	11,0	16,2	161	241
		III (7-8)	132	11,3	14,9	157	216
Directed spray (Interrow)	3,3	I (2-3)	151	11,5	17,4	146	252
		II (5-6)	155	11,9	18,5	146	255
		III (7-8)	165	11,9	19,4	153	257
	20,0	I (2-3)	147	11,6	17,1	145	244
		II (5-6)	149	12,0	17,8	147	253
		III (7-8)	145	12,0	17,4	136	248
Unsprayed (double replications)			164	12,0	19,7	151	259
S.E.			±4,37	±0,30	±0,68		
L.S.D. (0,05)			12	0,8	1,9		
L.S.D. (0,01)			16	1,1	2,6		
C.V. %			7,0	6,4	9,5		

loss and stage I sprays caused the most loss. The swath of stage III sprays was well below the crop canopy, and any spray overlap at the base of the plants only contacted the stalks and the dried leaf sheaths. When stage I sprays were applied however, the leaf blades were within the spray

swath and were thoroughly sprayed with herbicide. In accordance with general commercial field practice, no attempt was made to shield or lift the leaves out of the way. Spray pattern overlap resulted in greater quantities of 2,4-D being applied to the foliage than to the interrow soil surface.

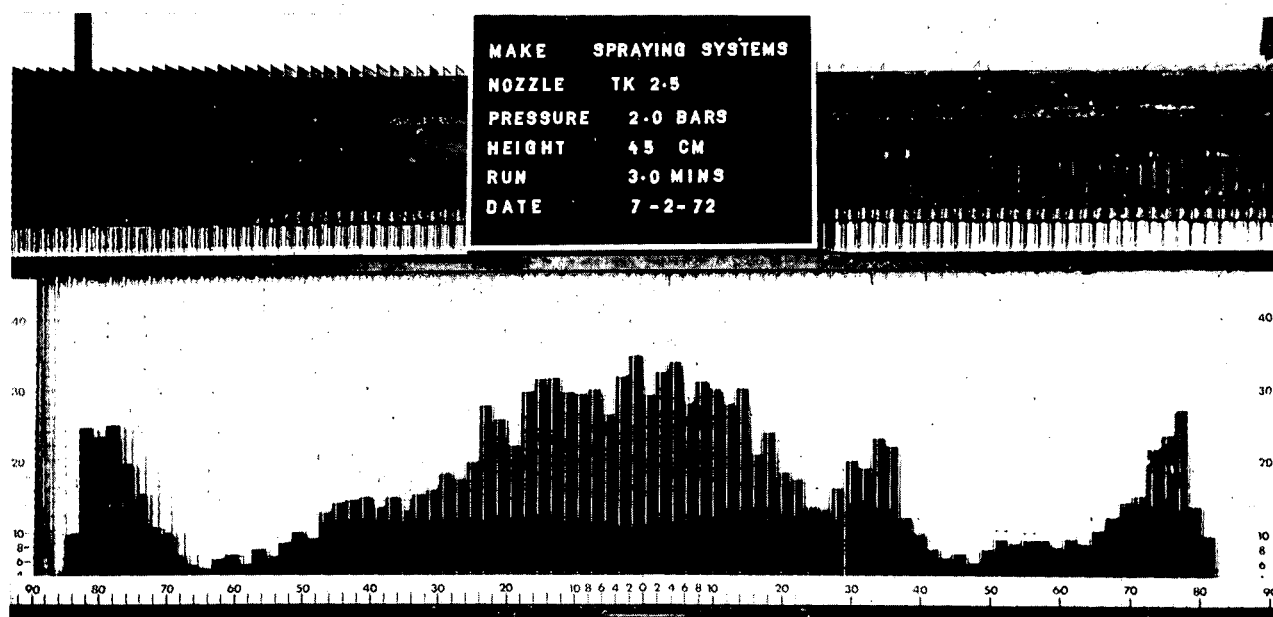


Figure 5. The spray distribution of a T.K. 2,5 floodjet nozzle (scale in cm).

An additional factor influencing the dose was that a floodjet was used to apply the sprays across the interrow. Floodjets suffer from the disadvantage of delivering a greater concentration of liquid at the extremities of the fan-shaped pattern, than in the centre of the pattern. (Fryer and Evans⁷, Kasasian⁸). Figure 5 shows the spray distribution from a TK 2,5 floodjet at heights and pressures similar to those used in the experiment.

Harvest results show that, for any post-emergence spraying of 2,4-D, even at low rates, every effort should be made to reduce the amount of spray which contacts the cane leaves. At the very young growth stages the cane appears to be fairly tolerant, but careful attention to the method of spray application is required. At late growth stages directed sprays seem to be essential.

The experiment was continued into the succeeding ratoon without further herbicide treatments being applied. No visual signs of phytotoxicity were observed in the cane and there were no yield differences between plots receiving any of the previous treatments. It seems clear that, despite large yield differences in the crop which received the herbicide application, residual

effects did not persist to affect the subsequent crop.

Experiment II

The experiment was designed to compare the effects of 2,4-D sprays on a plant and a second ratoon crop at the same stages of growth. The harvesting of the previous ratoon was timed so that when the herbicide treatments were required, the regrowth of the ratoon would be approximately at the same canopy height, and stage of foliar development, as an adjacent plant crop. The population of the ratoon crop was about four times that of the plant crop, but the respective growth stages when the herbicide treatments were applied in January, were very similar.

	Plant	Ratoon
Mean number of leaves unfurled/shoot	6,9	6,5
Mean canopy height (cm)	50	60

Single doses of 3,3 and 20 kg ae/ha, with and without a surfactant at 0,5% v/v concentration, were applied as band and directed sprays over the crop row and interrow respectively.

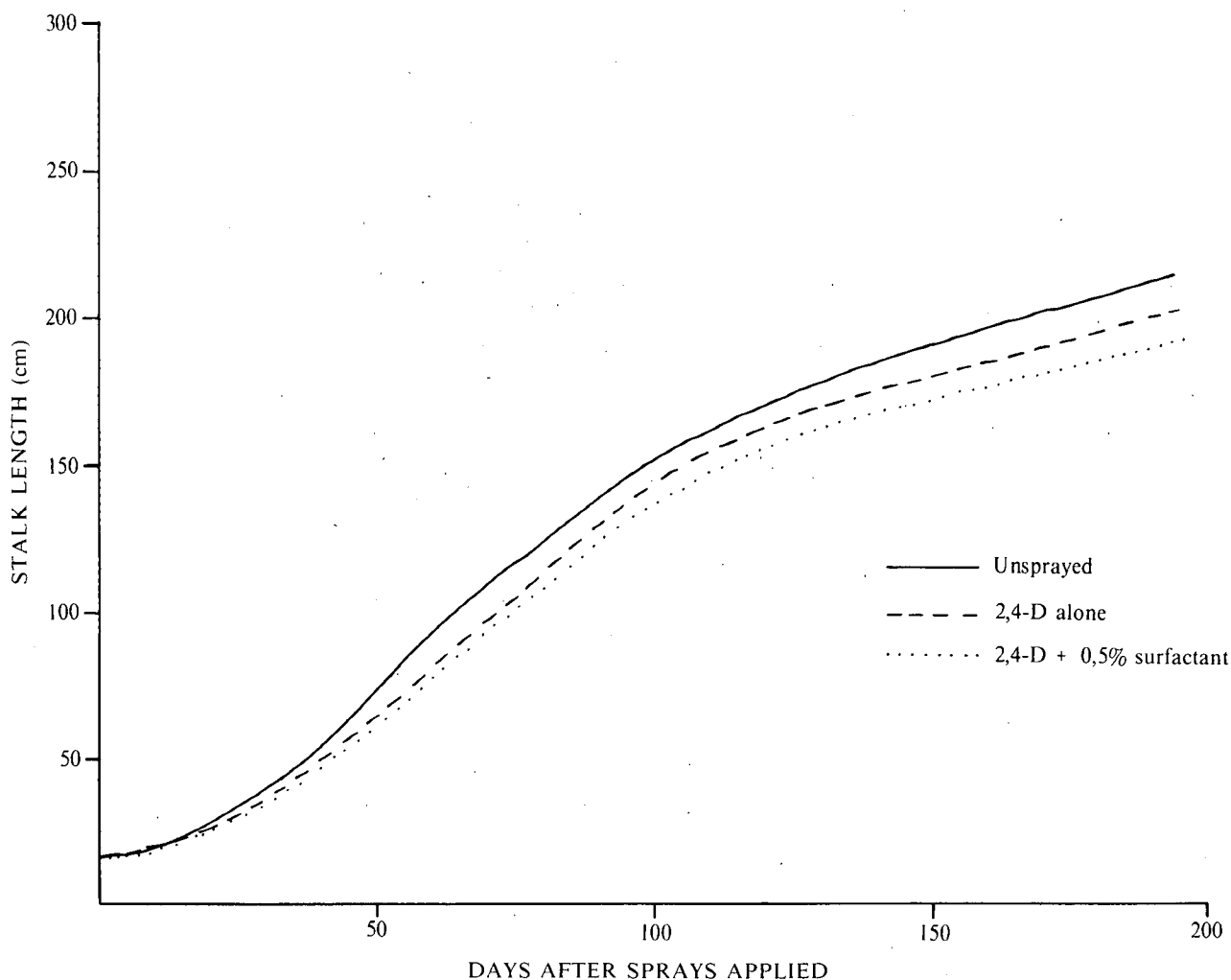


Fig. 6. The growth of plant cane after receiving band sprays of 2,4-D (3,3kg ae/ha) with and without added surfactant (0,5% v/v).

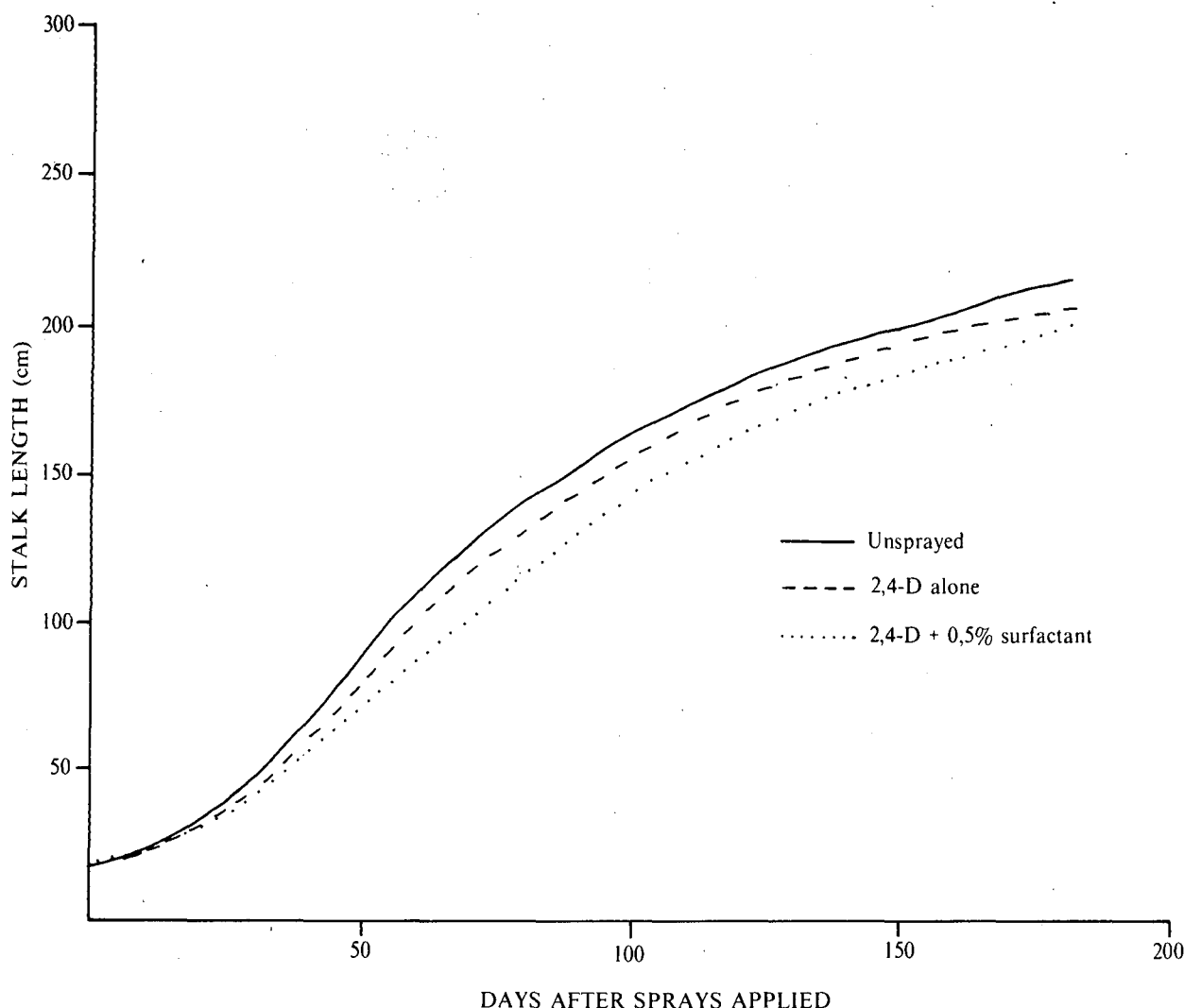


Fig. 7. The growth of ratoon cane after receiving band sprays of 2,4-D (3,3kg ae/ha) with and without added surfactant (0,5% v/v)

Results and Discussion

The visual phytotoxicity symptoms were similar to those previously reported. However the plant crop was affected to a far greater extent than was the ratoon. Increased injury due to the addition of the surfactant was especially noticeable on the plant crop, the treatment causing severe leaf scorch, necrosis, and subsequent leaf dieback. The ratoon crop was also severely scorched. As may be seen in Figures 6 and 7, the addition of the surfactant to band sprays caused a marked decrease in mean stalk length, and this effect was not reduced as the crop developed. As in the first experiment, interrow sprays generally caused less damage than did treatments which were applied over the cane row.

The crop yields are presented in Table II. The most important conclusion to be drawn from the results is that the addition of the surfactant resulted in a significant yield reduction which amounted to 8 + 3 t. cane/ha when the herbicide was sprayed in a band over the cane row.

Although treatments were applied at the 6 to 7 leaf stage in this trial, band sprays of 3,3 kg ae/ha without surfactant caused yield losses which were small and not statistically significant. At the excessive rate of 20 kg ae/ha band sprays tended to cause more yield loss than did directed sprays. Yield data gave no conclusive evidence that plant cane was affected more than ratoon cane, although greater visual damage was observed in the plant crop. The general impression was that plant cane tended to be more susceptible than ratoon cane to a band treatment which included surfactant.

Experiment III

The experiment was used to compare the differential tolerance of first ratoon crops of the varieties NCo 376, NCo 382 and NCo 310 to band sprays applied at different stages of growth. A single post-emergence treatment of 2,4-D at 18 kg ae/ha was applied over the crop row when 7-8 leaves (stage III), and 9-10 leaves (stage IV) had unfurled. Canopy heights varied slightly between

TABLE II

Experiment II : Yield of plant and ratoon cane (NCo 376) after spraying with 2,4-D and a surfactant

Crop	Treatment		Yield		
	Dose (kg ae/ha)	Placement/Surfactant	t.c./ha	ers	t.ers/ha
Plant	Unsprayed	—	133	10,1	13,4
	3,3	Band	129	9,4	12,1
		Band & surfactant	117	9,5	11,2
		Directed	122	9,7	11,8
	20,0	Band	122	8,8	10,8
		Band & surfactant	119	9,0	10,8
Directed		132	9,5	12,7	
Ratoon	Unsprayed	—	138	10,0	13,8
	3,3	Band	135	10,3	13,9
		Band & surfactant	130	9,9	12,9
		Directed	132	9,8	13,0
	20,0	Band	124	10,2	12,6
		Band & Surfactant	116	9,9	11,4
Directed		127	10,1	12,8	
S.E.		±4,6	±0,4	±0,7	
L.S.D. (0,05)		13	1,2	2,0	
L.S.D. (0,01)		17	1,5	2,7	
C.V. %		7,2	8,3	9,4	

varieties but were approximately 65 and 85 cm for the respective stages. The first treatment was applied in November 1968 during cold weather and in poor growing conditions, with the second treatment being applied some two weeks later during hot and humid conditions. The crop, which was not irrigated, was harvested at 13 months of age.

Results and Discussion

NCo 376 was by far the most severely affected variety, and only slight scorch symptoms occurred on NCo 382 and NCo 310. As in Experiment I the sprays applied at the later growth stage caused more damage than did the early sprays.

The yield results are presented in Table III. These show that NCo 382 and NCo 310 suffered negligible yield losses from the treatments, whereas NCo 376 was affected so severely by sprays applied at stage IV that yields were reduced by 20%. These differences in varietal tolerance to 2,4-D confirm work previously reported (Richardson³).

It is surprising that no yield loss resulted when NCo 376 was sprayed at a relatively susceptible stage of crop development (7-8 leaves, 65 cm high). The visual effects of this spray were very mild and it is believed that the cold weather conditions that prevailed during and after spraying, and the consequently less active growth of the crop, contributed to this apparent tolerance. There was very little scorching of the cane leaves, whereas severe foliar damage was caused by sprays applied at the later growth stage.

The crop sprayed at stage III could take full advantage of the ensuing good growing conditions that prevailed in summer, whereas cane sprayed at stage IV had a much reduced photosynthetic area available during this peak growing period.

TABLE III

Experiment III : Yield of cane varieties after spraying at different growth stages (18 kg ae 2,4-D/ha)

Variety	Treatment		Yield		
	Growth stage (leaves)	t.c./ha	ers	t.ers/ha	
NCo 376	Unsprayed	108	11,6	12,7	
	Stage III (7-8)	105	12,2	12,9	
	Stage IV (9-10)	86	11,1	9,6	
NCo 382	Unsprayed	89	10,6	9,4	
	Stage III (7-8)	92	10,2	9,4	
	Stage IV (9-10)	86	10,3	8,8	
NCo 310	Unsprayed	90	14,1	12,6	
	Stage III (7-8)	97	13,9	13,4	
	Stage IV (9-10)	87	14,5	12,6	
S.E.		± 3,14	±0,23	±0,43	
L.S.D. (0,05)		9	0,7	1,2	
L.S.D. (0,01)		12	0,9	1,6	
C.V.%		8,2	4,8	9,4	

Conclusions

There is a possibility that crop losses will be incurred when post-emergence sprays containing 2,4-D are applied in commercial fields of NCo

376. Plant crops have proved to be more susceptible than ratoon crops. The degree of phytotoxicity that may occur can be influenced by a great many factors, including those of the prevailing climate and the state of the crop itself. The recovery that follows will also depend to a large extent on the climate. If a favourable growing period follows the spray application and if the foliar damage is not excessive, the crop will recover rapidly and yield losses will be minimised. Past results (Richardson³) indicate that yield losses do not necessarily occur even following excessive doses of 2,4-D, and it must be noted that 2,4-D damage does not often occur in commercial practice despite the widespread use of this herbicide within the industry.

The experiments have shown that certain field precautions may be taken by growers in order to reduce both the risk of damage occurring and the amount of damage that may occur. Extra care is required when spraying variety NCo 376. Every effort, both in field application and in machine design, must be made to reduce the amount of herbicide falling onto cane leaves. Measures towards achieving this objective include the lifting of cane leaves out of the spray swath, the more efficient use of directed sprays, and the avoidance of all band or overall sprays once the crop reaches a canopy height of 40-50 cm. When the crop is this high, only directed sprays across the interrow should be used.

Although surfactants improve weed control they also increase phytotoxicity to the crop. With sprays containing 2,4-D, the use of surfactants during hot humid weather is rarely necessary, and is dangerous to the crop. If, due to accident or poor application, excessive doses are applied and severe phytotoxicity results, there should be no

residual effects, and the loss should not be carried into the succeeding crop.

Recent observations in other experiments indicate that the phytotoxic effects of repeated low-dose applications of 2,4-D may be more damaging to cane than single large doses. Nevertheless the present recommended field precautions to reduce the incidence and the degree of cane damage should still apply.

Acknowledgement

Thanks are extended to Mr. M.G. Murdoch for the statistical analyses of the results

REFERENCES

1. Nolla, J.A.B., 1950. Injury to sugarcane from 2,4-D. Proc. int. Soc. Sug. Cane Tech. 7 : 178-189.
2. Rochecouste, E., 1967. Weed control in sugarcane. Mauritius Sugar Industry Research Institute, Reduit, Mauritius p. 12-13.
3. Richardson, F.E., 1969. Injury to sugarcane by 2,4-D formulations. Proc. S. Afr. Sug. Technol. Ass. 43 : 122-129.
4. Gosnell, J.M., and Strover, P.M., 1971. Private communication.
5. Robertson, Margaret M., and Kirkwood, R.C., 1969. The mode of action of foliage-applied translocated herbicides with particular reference to the phenoxy-acid compounds. I : The mechanism and factors influencing herbicide absorption. Weed Research 9 : (3) 224-240.
6. Robertson, Margaret M., and Kirkwood, R.C., 1970. The mode of action of foliage-applied translocated herbicides with particular reference to the phenoxy-acid compounds. II : The mechanism and factors influencing translocation, metabolism and biochemical inhibition. Weed Research 10 : (2) 94-120.
7. Fryer, J.D. and Evans, S.A., 1968. Weed Control Handbook. Volume I. Principles. 5th Ed. Blackwell Scientific Publications. Oxford p. 113.
8. Kasasian, L., 1971. Weed control in the tropics. Leonard Hill. London. p. 31-33.

The surfactant used contained the dodecylether of polyethylene glycol.