A COMPARISON OF THE EFFECTS OF "CYCOCEL" AND TIPPING ON FRUIT SET IN *VITIS VINIFERA* L.

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Summary

Rooted cuttings of *V. vinifera* cv. Cabernet Sauvignon were grown in nutrient culture solutions. When Cycocel [(2-chloroethyl)trimethylammonium chloride] was added to the nutrient solutions, plants retained 40% of their berries. Plants from which the shoot tip was removed at anthesis, either with or without Cycocel treatment, showed similar fruit set. Control plants retained only 20% of their berries. Percentage fruit set was inversely related to the rate of shoot elongation during the week following anthesis. The results suggest that treatment with Cycocel and tipping increase fruit set by reducing competition between the developing leaves and ovaries for available metabolites.

I. Introduction

One of the diverse effects of the growth retardant Cycocel [(2-chloroethyl)trimethylammonium chloride] (Cathey 1964) is that it increases fruit set in *Vitis vinifera* L. when applied either as a spray or directly to the bunch (Coombe 1965, 1967). It also increases the size of root meristems in *V. vinifera*, if applied to the medium in which the plants are growing (Skene and Mullins 1967). The bleeding sap of plants treated in this way was found to contain up to 20 times the cytokinin concentration of untreated plants and it was suggested that the Cycocel effect on fruit set may be directly due to increased cytokinin production (Skene 1968).

Removal of the shoot tip (tipping) at a certain stage of flowering also increases fruit set in vines (Coombe 1962). Some evidence suggests that this operation makes more metabolites available to the ovaries by reducing the demand from developing leaves. Cycocel, applied either to the roots (Skene and Mullins 1967) or as a spray (Coombe 1967), also reduces shoot growth, but its effects on shoot elongation are less clear when applied by dipping bunches into solutions (Coombe 1967). Further experiments have been carried out to explore the responses to Cycocel and tipping on fruit set and these are reported in this paper.

II. Materials and Methods

Plants were prepared from dormant cuttings of *Vitis vinifera* L. cv. Cabernet Sauvignon, which had been stored in plastic bags at 1°C. Root formation, without concomitant bud burst, was stimulated by placing the basal ends of hardwood cuttings in moist perlite maintained at 30°C. The portion of the cuttings above the perlite, consisting of four nodes, was maintained at 1°C.

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After about 6 weeks, when extensive roots had formed, the cuttings were transferred to 2·5-litre pots of aerated Hoagland's solution in a glasshouse at Adelaide. Experiments on rooted cuttings were carried out during the early summer of 1967 and 1968.

After bud burst, all emerging shoots except one were removed from each plant, and, in order to increase inflorescence retention, leaves up to the node above the basal inflorescence on each shoot were removed as they unfolded (Mullins 1966). Lateral shoots and all other inflorescences also were removed as they appeared.

In some treatments, Cycocel (50% w/v concentrate, Cyanamid DHA Pty. Ltd.) at a concentration of 200 mg/l was included in the nutrient solution at the time rooted cuttings were added; in other instances it was not added to the solutions until about 2 weeks before anthesis.

In the experiment comparing the effects of Cycocel and tipping, Cycocel was added to the solutions 18 days before anthesis; tipping, which consisted of removing the first 0·5 cm of shoot, was applied at a stage between 60 and 99% capfall (Coombe 1962).

All abscised flowers and berries were collected through paper funnels below each inflorescence, and were eventually counted. When no further berries abscised (2–3 weeks after anthesis), fruit set was regarded as complete, plants were harvested, and the measurements indicated in Section III were recorded. In the Cycocel–tipping experiment, shoot growth was measured each week.

Experiments were laid out in the glasshouse as randomized blocks, with 14 plants per treatment in the first experiment and 10 plants per treatment in the second.

III. Results

The first experiment compared the effect of Cycocel in the nutrient culture solution throughout the entire experiment with that of Cycocel added to the solutions 2 weeks before anthesis. There was no significant difference between the effects of either treatment on shoot and root growth (Table 1). Both treatments reduced shoot growth compared with the controls, and although Cycocel had no detectable effect on weight of the roots, it increased their diameter and reduced their length in the manner previously described (Skene and Mullins 1967).

Table 1

Treatment effects on shoot and root growth (experiment 1)

Treatment	No. of Nodes per Plant	Shoot Length (cm)	Shoot Dry Wt. (g)	Root Fresh Wt. (g)	Root Dry Wt. (g)
Control	26·5	113·6	9·28	24·4	1·34
Cycocel throughout experiment	22·0	53·1	4·84	29·2	1·29
Cycocel 2 weeks before flowering	23·6	58·6	6·07	27·4	1·30
L.S.D. ($P = 0 \cdot 05$)	1·8	9·5	1·37	n.s.	n.s.

Both Cycocel treatments promoted fruit set (Table 2, Fig. 1), the percentage of berries retained being increased from 20 to 39–41%. Treatment with Cycocel also increased bunch weight and mean berry weight in this instance (Table 2), although the results do not indicate what effects the treatments might have had on final yields. They are included to show that at this stage increased set under the influence of

Cycocel is not due to a larger number of abnormally small berries. This conclusion is supported by Figure 2(*a*), showing the percentage of berries in various size classes for each treatment.

TABLE 2

TREATMENT EFFECTS ON FRUIT SET AND FRUIT GROWTH (EXPERIMENT 1)

Treatment	No. of Flowers per Inflor-escence	Percentage Set	Percentage Set (angular trans-formation)	Total Berry Dry Wt. per Plant (g)	Mean Berry Dry Wt. (mg)	Mean Seed No. per Berry
Control	629	20	26·29	0·39	3·2	1·62
Cycocel throughout experiment	638	39	38·25	1·01	4·4	1·61
Cycocel 2 weeks before flowering	692	41	39·60	1·23	4·8	1·62
L.S.D. ($P = 0 \cdot 05$)			5·74	0·25	1·1	n.s.

In the second experiment, the effects of Cycocel and tipping on vegetative growth and fruit set were investigated. Control plants were compared with tipped plants, untipped plants treated with Cycocel, and tipped plants treated with Cycocel.

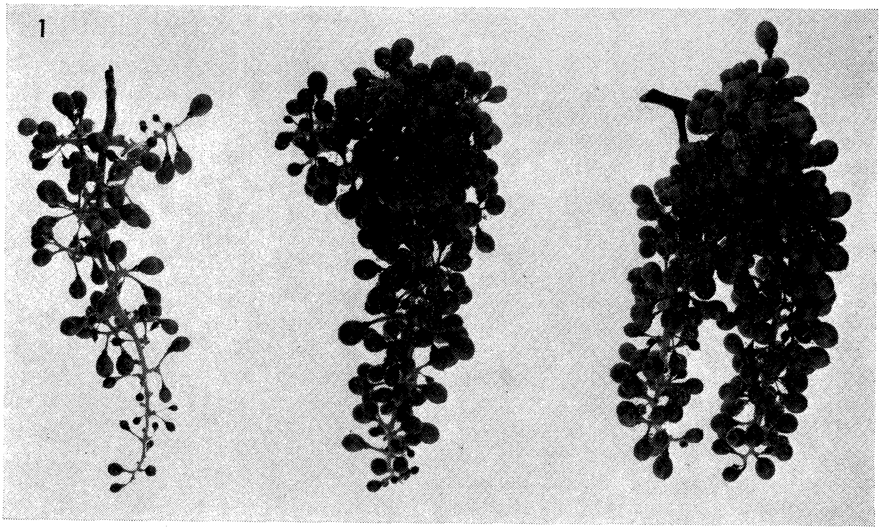

Fig. 1.—Effect of Cycocel on fruit set in *V. vinifera*, cv. Cabernet Sauvignon. Left, control; centre, Cycocel throughout experiment; right, Cycocel applied 2 weeks before anthesis.

There was no difference between the effects of tipping and Cycocel on shoot elongation during the experimental period, both markedly reducing growth below that of the controls (Fig. 3). Tipping plus Cycocel treatment caused a further depression in growth.

Final data on shoot and root growth are summarized in Table 3. Leaf number, shoot length, stem dry weight, and leaf dry weight were all decreased by tipping and by Cycocel. Tipping plus Cycocel treatment caused further reductions which, however, were not additive. None of the individual treatments appeared to affect root weight, but overall, tipping significantly reduced both root fresh and dry weight.

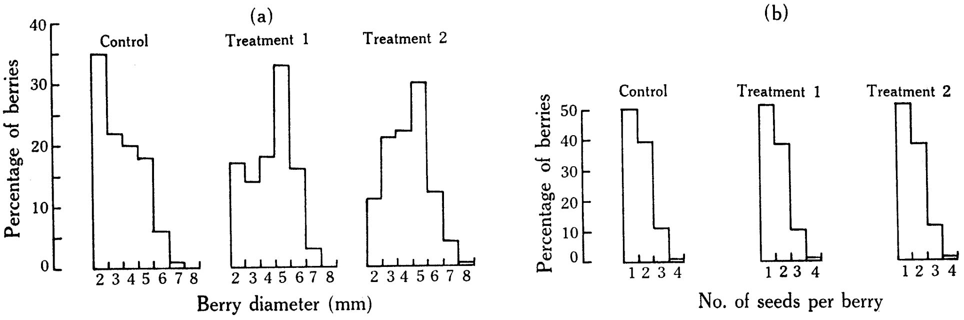

Fig. 2.—Effects of treatment on proportion of berries (*a*) in various size classes and (*b*) with one, two, three, or four seeds. Treatment 1, Cycocel throughout experiment; treatment 2, Cycocel 2 weeks before anthesis.

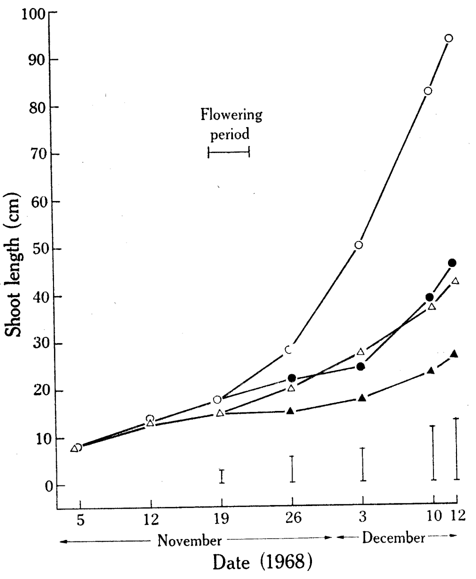

Fig. 3.—Effect of Cycocel and tipping on shoot elongation. Vertical bars indicate least significant differences ($P = 0 \cdot 05$).
○ Control.
● Tipped.
△ Cycocel treatment.
▲ Tipped + Cycocel treatment.

All treatments increased the total number of berries retained per plant to the same extent (Table 4). Furthermore, the adjusted means for percentage fruit set (Table 4) show that tipped, untipped Cycocel-treated, and tipped Cycocel-treated plants all differed significantly from control plants, but did not differ significantly from each other. That is, the net effect of tipping and treatment with Cycocel on fruit set is the same.

Table 3

TREATMENT EFFECTS ON SHOOT AND ROOT GROWTH (EXPERIMENT 2)

Treatment	Leaf No. per Plant	Shoot Length (cm)	Stem Dry Wt. (g)	Leaf Dry Wt. (g)	Root Fresh Wt. (g)	Root Dry Wt. (g)
Control	21·8	94·2	3·65	5·69	29·6	1·76
Tipped	14·2	45·7	1·36	3·19	23·8	1·36
Cycocel	17·6	42·0	0·89	3·04	33·4	1·49
Tipped + Cycocel	11·5	25·9	0·51	1·82	24·8	1·15
L.S.D. ($P = 0 \cdot 05$)	2·1	12·9	0·83	1·21	n.s.	n.s.

Mean berry weights were not affected significantly by any of the treatments (Table 4).

Table 4

TREATMENT EFFECTS ON FRUIT SET AND FRUIT GROWTH (EXPERIMENT 2)

Treatment	No. of Berries Retained per Plant	Percentage Set*	Total Berry Dry Wt. per Plant (g)	Mean Berry Dry Wt. (mg)
Control	144	27·22	1·65	11·8
Tipped	227	36·53	2·88	13·1
Cycocel	220	34·18	2·62	12·3
Tipped + Cycocel	240	37·17	2·22	9·1
L.S.D. ($P = 0 \cdot 05$)	48	4·57	0·71	3·0

* Angular transformation; means adjusted for flower number.

IV. Discussion

Few of the flowers initially present in a grape inflorescence develop into mature fruits. In Cabernet Sauvignon, the seeded cultivar under study, about 20% of the flowers set in untreated plants (Tables 2 and 4). Tipping (Coombe 1962) and applications of gibberellins (Coombe 1965), cytokinins (Weaver, van Overbeek, and Pool 1965), or growth retardants (Coombe 1965, 1967) all increase the proportion of flowers which develop into berries. In the experiments reported here, both tipping and treatment with Cycocel increased set in Cabernet Sauvignon (Tables 2 and 4), the net effect of both treatments being the same.

The mean number of seeds per berry (Table 2) and the distribution of berries with various numbers of seeds [Fig. 2(*b*)] were not affected by Cycocel. This is in general agreement with the findings of Coombe (1967), and indicates that Cycocel does not affect fertilization. Nor does Cycocel predominantly affect seedless berries, as is the case for gibberellic acid (Coombe 1965).

The results of the second experiment provide a direct comparison between the effects of Cycocel and tipping on vegetative growth and fruit set. Both tipping and Cycocel treatment resulted in the same increase in percentage set, and the effect of applying Cycocel to tipped plants was not significantly different from the effect of either treatment alone (Table 4). All treatments reduced vegetative growth (Table 3; Fig. 3); the reductions induced by Cycocel and by tipping were similar, and although the tipping plus Cycocel treatment caused further reductions, the effects of the interaction between tipping and Cycocel were highly significant.

Many of the effects of growth retardants, such as reduction of stem growth, can be related to an inhibition of gibberellin biosynthesis (Kende, Ninnemann, and Lang 1963; Ninnemann *et al.* 1964; Baldev, Lang, and Agatep 1965; Zeevaart 1966), although other observations (Halevy, Dilley, and Wittwer 1966; Beevers and Guernsey 1967; Brook, West, and Anthony 1967) suggest that growth retardants may exert their primary effect on nucleic acid metabolism. Indeed, the wide variety of effects of Cycocel on *Vitis* led Coombe (1967) to propose a "far reaching alteration in cell metabolism". The increased levels of cytokinin in xylem exudate of grape roots treated with Cycocel (Skene 1968) could be a result of such alterations in cell metabolism, and it was suggested that they might be implicated in the stimulation of set by Cycocel (Skene, *loc. cit.*).

However, the reported effects of Cycocel, tipping, and combinations of the two treatments on both set and vegetative growth suggest an additional explanation for the stimulation of set by Cycocel. For instance, one of the factors likely to limit ovary development during the setting stage of grapes is the supply of metabolites to the inflorescence (Coombe 1962), and Coombe has suggested that tipping increases set by reducing competition between the developing leaves and ovaries for these available metabolites. Whilst an increased cytokinin level induced by Cycocel (Skene 1968) may also affect the distribution of metabolites (Seth and Wareing 1967; Shindy and Weaver 1967; Kriedemann 1968), inhibition of shoot growth itself (Tables 1 and 3) could be expected to affect distribution in favour of developing berries.

If shoots are in fact competing with berries for available metabolites, the most critical period for shoot growth to influence berry retention would be the period immediately after anthesis, when set occurs. In the second experiment, this period was the week between November 26 and December 3 (Fig. 3). In fact, there is a highly significant relationship ($r = -0\cdot9998$, $P = 0\cdot001$) between shoot growth rate (X, cm/week) during this week and the transformed means for percentage set (Y), the regression equation being of the form

$$Y = 38\cdot1 - 0\cdot496X.$$

With Cycocel applied to grapes as a bunch dip, set is increased without obviously affecting shoot growth (Coombe 1967), although detailed measurements of shoot growth during the setting period are lacking. Without this information it is not possible to comment on the influence of bunch dips on short-term competition between shoots and berries. However, the results of the experiments reported indicate that root applications of Cycocel, like tipping, seem to increase fruit set by reducing shoot growth. This suggests a reduction in competition between the developing leaves and ovaries for available nutrients, although the significance of other effects of Cycocel, such as those on cytokinin production, is not eliminated.

V. Acknowledgments

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