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Effect of Daminozide on 'Concord' Grapes[1]

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Abstract. **Succinic acid-2,2-dimethylhydrazide (daminozide, SADH) applied to mature 'Concord' grape vines (*Vitis labrusca* L.) at 500 and 1000 ppm at first and at 50% bloom, was observed to increase fruitfulness and yield by increasing cluster weight. During 7 years cluster weight increases were associated with 2 to 6% decreases in berry size and 14 to 22% increases in berry number. Daminozide did not affect the number of seeds per berry, but did reduce weight per berry. Thus, increases in crop yield of up to 20 to 25% were obtained by increasing cluster weight and not by increasing cluster number. Daminozide increased total acid concentration slightly but had no effect on pH. Soluble solids were reduced by daminozide when yield increases, due to daminozide, were above 2 kg/vine. The effect on soluble solids appeared to result from increased productivity rather than from direct effect of the chemical. Daminozide reduced vine size more at the 1000-ppm than the 500-ppm rate.**

Year to year variability in 'Concord' grape yield results from fluctuations in cluster weight and number. The components of cluster weight variability are flower number per cluster, percentage set, and berry size. The classical technique of bloom-time removal of the shoot tip (3) increases fruit set, but decreases vine size. Conversely, clusters on rapidly elongating shoots generally set fewer fruits. Coombe (4) showed no growth retardant effect of increasing fruit set by application of (2-chloroethyl)trimethylammonium chloride (CCC) when shoot tips had been removed. This is in agreement with unpublished data from New York on 'Concord' showing that daminozide and shoot pinching were similar in increasing cluster weight. However, Naito et al. (10) has demonstrated that spraying 'Muscat of Alexandria' with CCC before anthesis significantly enhanced fruit set when shoot pinching had no effect. Also, treating only clusters with either daminozide or CCC increased set of seeded berries without retarding shoot growth. The relationship between grape berry set and rate of shoot elongation, is the basis for the viticultural interest in growth retardants such as daminozide.

In 1964, Bukovac et al. (1) showed that daminozide in the range of 500 to 6000 ppm retarded growth of shoots of potted, non-bearing 'Concord' grapevines. Weaver (14) showed that the effect of increasing the rate of daminozide prolonged the period of inhibition of internode elongation, rather than affecting the level of inhibition near the shoot tips. Huglin and Julliard (7) also found daminozide and CCC to have a growth retardant effect on shoots. This effect essentially ceased by veraison and the beginning of wood maturation.

Whether daminozide functions in the plant by reducing the "sink strength" of metabolites to the shoot tip or has a direct effect of its own is somewhat controversial. Monselise and Luckwill (9), using $^{14}CO_2$ have shown that daminozide increased the transport of assimilates to the roots of apples and that this was detectable before a reduction in growth rate.

Application of daminozide at 750 ppm by Tukey and Fleming (11, 12) and 500-1000 ppm by McCaskill (8) reduced 'Concord' vine size, shoot length, berry size and soluble solids, but increased yield per vine by increasing the number of berries per cluster. Haeseler (6), following a 3-year study on 'Concord' grapes, concluded that annual applications of daminozide did not result in significant yield increases or reductions in annual yield fluctuations within the range of 125-1000 ppm.Tukey and Fleming (8, 9) did not apply daminozide to the same vines in 1966 as those used in 1965 and, hence, afforded data for one-year tests.

To gain repeated use and cumulative effects of daminozide over a 4 to 6 year period (1967-1973), 'Concord' vineyards in major producing areas of New York and Ohio were used. Effects of daminozide on fruit yield and maturity and vine size were determined.

Materials and Methods

Three mature 'Concord' vineyards were selected as being above average in vine size and yield. Vineyard 1 was located at Fredonia, New York[4] and Vineyards 2 and 3 at Geneva, Ohio.[4]

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[4]Vineyard 1 was owned by Mr. Florian Spoden and operated by Mr. Merle West (present owner). The continuing cooperation of Mr. West, Mr. T. D. Jordan, extension grape specialist, and the Dept. of Pomology and Viticulture of the New York Agr. Expt. Sta. is acknowledged. Mr. Donald Crowe and Mrs. Sheldon Hubbard of the Viticultural Laboratory at Fredonia, N. Y., made all measurements in vineyard 1. Vineyards 2 and 3 were owned and operated by Mr. Glen Stoltz and Mr. Anthony Debevc. The authors are indebted to these individuals for their cooperation.

[5]Registered trade name of the product of Uniroyal Chemical, Division of Uniroyal, Inc., Naugatuck, Conn., it contains 85% daminozide.

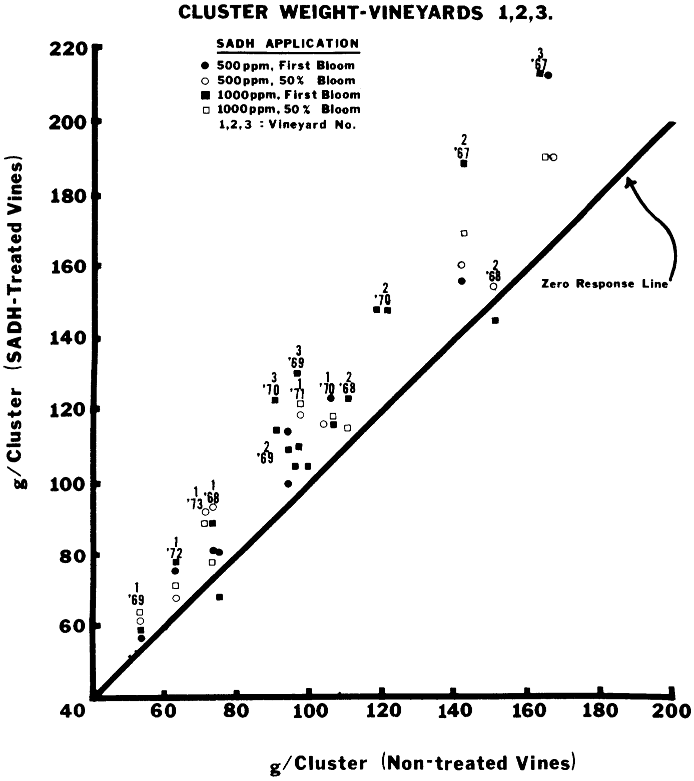

Fig. 1. Mean weight of 'Concord' grape clusters from vines treated with 0, 500 and 1000 ppm daminozide (SADH) at first and 50% bloom in vineyards 1, 2, and 3. 1967-1973.

All were well established, own-rooted, Umbrella-Kniffin trained vines planted 2.7 m between rows and 2.4 m between vines.

The experimental design for daminozide treatments was basically the same in all 3 vineyards and consisted of 3 to 5 replications of 5 treatments: 3 rates of daminozide (0-500-1000 ppm) at each of 2 timings (first bloom and 50% bloom). Each plot had 6 sprayed vines with data obtained from the central 4 vines. Vines in all treatments were balance pruned to a 30 + 2 scale to determine the degree to which daminozide may have affected vine size (30 + 2 = 30 nodes for the first 5 hectograms (hg) of cane prunings plus 2 nodes for each additional hg of cane prunings).

In vineyard 1, vines were treated the same in each of 6 years, 1968-1973. In vineyards 2 and 3, two of the 5 treatments were maintained from 1967-1970; in the other 3 daminozide treatments either concn or time of application was modified as shown in Table 1 footnote. Daminozide was applied with a commercial vineyard sprayer calibrated to deliver 1,871 liters/ha. A hooded boom was used in vineyards 2 and 3, otherwise, spray application conditions were the same. We applied 500 ppm daminozide in 1,871 liters/ha of spray, equivalent to 0.94 kg daminozide or 1.1 kg of Alar 85[5] per ha; 1,000 ppm is equivalent to 1.87 kg daminozide or 2.2 kg Alar 85[5] per ha.

Data were obtained on an individual vine basis each year for cluster number, yield, weight of cane prunings, node number retained, cluster and berry size, seed number (vineyard 1 only) and soluble solids. Total acid, soluble solids and petiole nutrient measurements were made in vineyards 2 and 3. To determine effect of cluster size in vineyards 2 and 3, 10 basal clusters were randomly selected from each treatment vine; in vineyard 1, the total number of clusters per vine was used.

Results

Effect of daminozide on cluster weight. Application of daminozide increased cluster weight each year of treatment and at both rates, 500 ppm and 1000 ppm in both states (Fig. 1). In vineyard 1, the application of daminozide at 50% bloom tended to produce larger clusters. The concentration applied was of less importance. In vineyards 2 and 3, the greatest cluster size increase was more frequently obtained by the 1000 ppm rate.

Differences in cluster weight between New York and Ohio vineyards were due to the method by which cluster size was determined rather than to a real difference. Total cluster number was counted in vineyard 1 in New York while randomly selected basal clusters were counted in Ohio vineyards. In both states the direction of response to daminozide was similar (Fig. 1).

In each of the 7 years of the experiment, daminozide-induced increases in cluster weight were associated with 2 to 6% decreases in berry size (Fig. 2, Table 3C) and 14 to 22% increases in berry number (Table 3A). The net result was an increase in cluster weight (Fig. 1). Daminozide did not affect number of seeds per berry (Table 3B); but did reduce weight of 1-, 2-, 3-seeded berries. Berry weight reduction, about 4%, was similar to that obtained at harvest (Fig. 2, Table 3C)..

Daminozide effect on fruitfulness and yield. Crop yield per vine is the product of the number of nodes retained after pruning time and fruitfulness (weight of fruit per retained node). Increasing either cluster number or cluster weight can increase fruitfulness and yield. Fruitfulness was increased in this study by either rate of daminozide and, to a lesser extent, by the time of application (Table 1). This increased fruitfulness, the major basis for increased yields, varied from year to year, but averaged 20-25% (Table 2).

In 1968 the 500 ppm daminozide application rate was omitted in vineyard 2 at both first and 50% bloom (Tables 1, 2, and 4; see footnotes). Fruitfulness and yield when daminozide was omitted were no different from control treatments. Reapplication in 1969 of either 500 or 1000 ppm daminozide resulted in increased fruitfulness and yield in vineyard 3, but not in vineyard 2.

In 1970, increases in fruitfulness and yield in vineyard 2 was primarily the result of a 1000 ppm daminozide application.

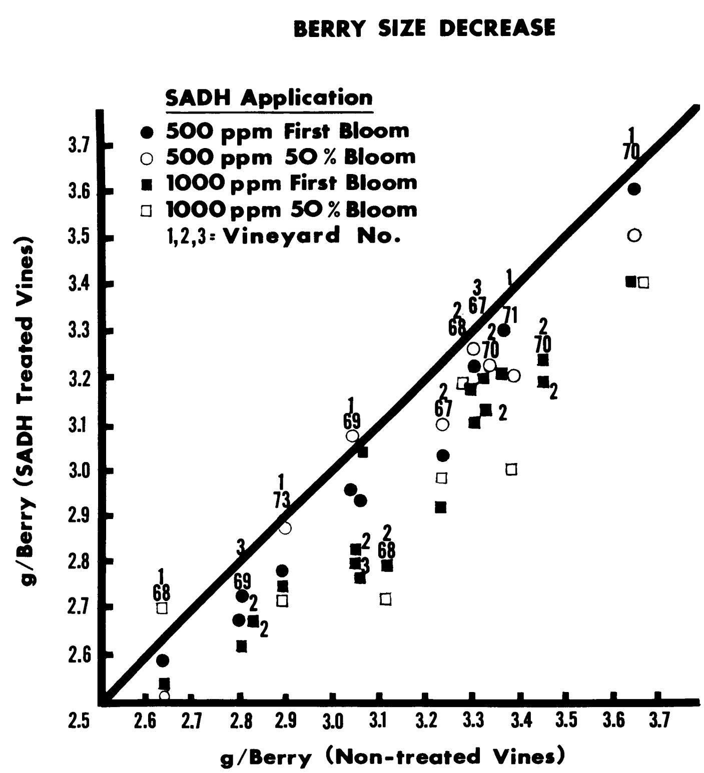

Fig. 2. The influence of season and 0, 500 and 1000 ppm daminozide (SADH) applied at first and 50% bloom on 'Concord' berry size in vineyards 1, 2, and 3.

Table 1. Average weight of fruit per retained node from vines treated with 0, 500 and 1000 ppm daminozide at first bloom and 50% (1967-1973).

Treatment: Time	Daminozide (ppm)	Fruit (g)/retained node: 1969	1970	1971	1972	1973	Avg
		Vineyard 1					
	0	122a[w]	238a	281a	158ab	146a	189
1st bloom	500	164b	244ab	328b	175bc	217a	226
1st bloom	1000	160b	258ab	328b	181c	197a	225
50% bloom	500	165b	266ab	365c	153a	183a	227
50% bloom	1000	166b	296b	379c	177c	202a	244
		1967	1968	1969	1970		
		Vineyard 2					
	0	196a[w]	150a	186a	191a		181
1st bloom	500	218a	131a[z]	195ab	231ab[x]		–
1st bloom	1000	254b	209b	281c	281c		256
50% bloom	500	209a	158a[z]	200ab[y]	268c[xy]		–
50% bloom	1000	268b	204b	236bc[y]	285c[y]		–

[z]Vines not treated in 1968.

[y]1000 ppm daminozide applied at 1st bloom instead of 50% bloom.

[x]100 ppm GA applied at shatter.

[w]Mean separation within columns within vineyards by Duncan's multiple range test, 5% level.

Application of 100 ppm gibberellic acid at shatter, following the application of 1000 ppm daminozide at first bloom, did not consistently increase yield or fruitfulness over the 1000 ppm daminozide at first bloom.

Daminozide effect on soluble solids and acid content. There was some tendency for daminozide to reduce soluble solids concentration of the fruit (Table 4). When increases in yields due to daminozide were less than 2 kg/vine, the frequency of a soluble solids decrease was less than if yield increases were above 2 kg/vine (Fig. 3, Table 2). Thus, the daminozide effect on soluble solids concn appeared to result from increased productivity rather than a direct effect of the chemical on soluble solids.

Table 2. Average weight of fruit from vines treated with 0, 500 or 1000 ppm daminozide at first bloom or 50% bloom, 1967-1973.

Treatment: Time	Daminozide (ppm)	Yield (kg/vine: 1969	1970	1971	1972	1973	Avg
		Vineyard 1					
	0	6.0a[w]	11.7a	15.0a	7.4ab	6.5a	9.3
1st bloom	500	7.8b	12.7a	18.4b	8.5b	8.4a	11.2
1st bloom	1000	7.3ab	13.1a	17.3ab	8.0ab	7.7a	10.7
50% bloom	500	7.5ab	13.0a	19.5b	7.0a	8.0a	11.0
50% bloom	1000	6.4ab	12.7a	19.1b	7.2ab	8.1a	10.7
		1967	1968	1969	1970		
		Vineyard 2					
	0	8.0a[w]	6.8a	8.7a	9.8a		8.3
1st bloom	500	10.4b	5.9a[z]	9.8a	10.9ab[x]		–
1st bloom	1000	11.6b	8.4c	11.5b	12.2ab		10.9
50% bloom	500	10.0b	7.0ab[z]	10.2ab[y]	12.7b[yx]		–
50% bloom	1000	11.3b	8.1bc	9.5a[y]	13.2b[y]		–

[z]Vines not treated in 1968.

[y]1000 ppm daminozide applied at 1st bloom instead of 50% bloom.

[x]100 ppm GA applied at shatter.

[w]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 3. The effect of bloom-time, whole vine sprays of daminozide on 'Concord' berry characteristics. Vineyard 1.

Treatment: Time	Daminozide (ppm)	1969	1970	1971	1972	1973	Avg
		A: Berry number/cluster[z]					
	0	17.1a[z]	29.0a	29.5b	24.2a	24.5a	24.9
1st bloom	500	20.1b	29.4a	30.2b	28.6b	30.1b	27.7
1st bloom	1000	20.2b	33.4b	32.3b	31.3c	32.5b	29.9
50% bloom	500	20.2b	32.5b	37.1a	27.8b	31.7b	29.9
50% bloom	1000	21.8b	34.3b	40.2a	29.6bc	32.8b	31.7
		B: Mean seeds/berry					
	0	1.48a[z]	2.16a	2.14a	1.74a	1.60a	1.82
1st bloom	500	1.55a	2.23a	2.29a	1.74a	1.60a	1.88
1st bloom	1000	1.41a	2.15a	2.09a	1.68a	1.56a	1.78
50% bloom	500	1.45a	2.29a	2.15a	1.79a	1.63a	1.86
50% bloom	1000	1.48a	2.11a	2.17a	1.74a	1.63a	1.82
		C: Grams/berry at harvest					
	0	3.07a[z]	3.63a	3.36a	2.59a	2.90a	3.11
1st bloom	500	2.95a	3.58a	3.34a	2.55a	2.74a	3.03
1st bloom	1000	3.07a	3.44a	3.22a	2.44a	2.71a	2.98
50% bloom	500	3.09a	3.54a	3.16a	2.44a	2.87a	3.02
50% bloom	1000	2.95a	3.44a	2.98a	2.43a	2.69a	2.90

[z](Note: 1 berry no/cl = 2/cl ÷ g/berry).

[y]Mean separation within columns within groups by Duncan's multiple range test, 5% level.

There was a tendency in vineyard 2 for both the 500 and 1000 ppm rate to increase total acid content during 1967 and 1970.

Daminozide and vine size. In both vineyards daminozide applied at 1000 ppm or 500 ppm decreased vine size, as measured by pruning weight (Table 5). However, vine size reduction was greater at the 1000 ppm rate than the 500 ppm rate. In vineyard 2, 1968, when the 500 ppm daminozide treatments were omitted at first and at 50% bloom, pruning weights increased 25% over the previous season. Reapplication in 1969 again reduced vine size.

Some additional changes were observed in the characteristics

Table 4. Average soluble solids content of vines treated with 0, 500 or 1000 ppm daminozide at first bloom or 50% bloom, 1967-1973.

Treatment: Time	Daminozide (ppm)	Soluble solids (%): 1969	1970	1971	1972	1973	Avg
		Vineyard 1					
	0	16.5a[w]	15.1a	16.1b	16.3a	16.6a	16.1
1st bloom	500	17.0a	15.3a	16.0ab	16.2a	17.1a	16.3
1st bloom	1000	16.8a	14.6a	16.0ab	16.2a	17.0a	16.1
50% bloom	500	16.8a	14.9a	16.1b	16.1a	16.8a	16.1
50% bloom	1000	16.5a	15.2a	15.3a	16.2a	16.8a	16.0
		1967	1968	1969	1970		
		Vineyard 2					
	0	14.4b[w]	14.2a	14.8a	14.7b		14.5
1st bloom	500	13.4ab	14.7a[z]	14.9a	14.5ab[x]		14.4
1st bloom	1000	13.2a	14.5a	14.4a	14.3a		14.2
50% bloom	500	13.1a	14.3a[z]	14.2a[y]	14.7b[yx]		14.1
50% bloom	1000	13.6ab	14.4a	14.2a[y]	14.4ab[y]		14.2

[z]Vines not treated in 1968.

[y]1000 ppm daminozide applied at 1st bloom instead of 50% bloom.

[x]100 ppm GA applied at shatter.

[w]Mean separation within columns by Duncan's multiple range test, 5% level.

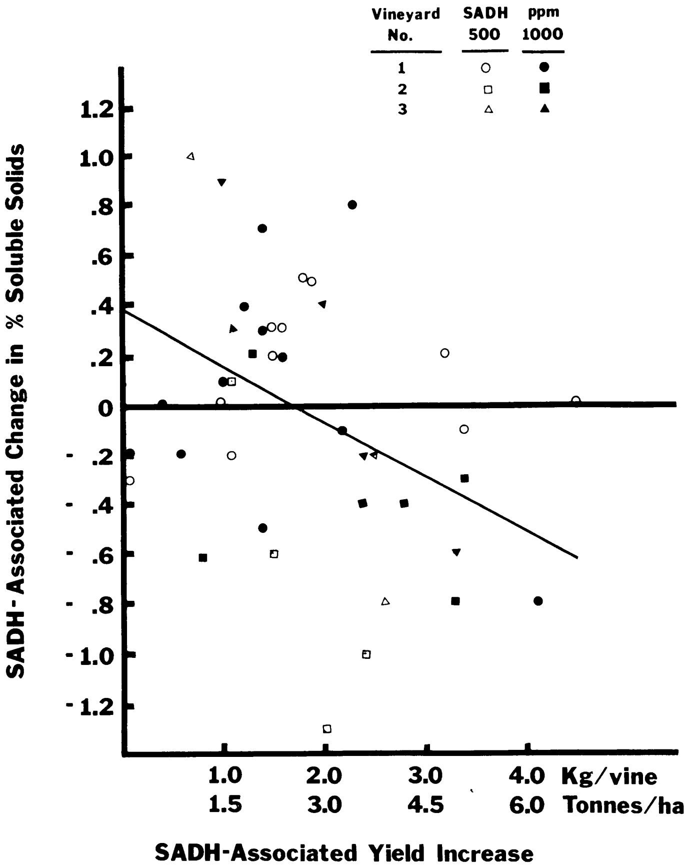

Fig. 3. Relationship between yield increase due to daminozide (SADH) application and soluble solids content, vineyards 1, 2 and 3. 1967-1973.

of vineyard 2 which are attributed to balanced pruning (Table 5). Initially, the control vines averaged 1.07 kg/vine. When balanced pruned during the next 3 years, they increased in size (1.09, 1.25 and 1.39 kg/vine). Daminozide-treated vines receiving 1000 ppm at first bloom were reduced in size (1, 19, 0.86, 0.97 and 1.09 kg/vine). Vines treated with 1000 ppm at 50% bloom were also reduced in size.

In vineyard 1, daminozide at the 1000 ppm rate reduced vine size slightly more than the 500 ppm rate and both the 500 and 1000 rate more than the control (Fig. 4). In 1969-70, the daminozide-treated vines increased in size as much or more than control vines. The huge crop of 1971 caused a general reduction in vine size. The largest vine size differences were in 1968, the initial year of vine size measurements. The daminozide treatments had no statistically significant effect on vine size when a covariance adjustment on initial (1968) vine size was applied (Table 5).

Discussion

The application of daminozide (Tables 1 and 2) rather consistently increased the fruitfulness and yield of 'Concord' grapes. This yield increase was primarily due to larger grape clusters. Average berry size was reduced by daminozide application (Fig. 2, Table 3C), therefore, cluster weight increase resulted from increased berry number per cluster (Table 3). Results, in general, were in agreement with previous investigators (2, 8, 10, 11, 12). It is important to note that in a year of large clusters (1967, 1970 and 1971, Fig. 1), daminozide-treated vines set more berries than they did in a year of small clusters. For example, in 1969, a small cluster year, berry number per cluster (Table 3) was 17.1 for the control with increases of 3.1 and 3.5 berries per cluster for 500 and 1000 ppm, respectively. In 1971, a large cluster year, the comparable data were 29.3, 4.0

Table 5. Average pruning weight (kg/vine) for vines treated with 0, 500 and 1000 ppm daminozide at first bloom and 50% bloom. 1967-1973.

Treatment: Time	Treatment: Daminozide (ppm)	Pruning wt (kg/vine): 1968	1969	1970	1971	1972	Avg
		Vineyard 1					
	0	1.61a[w]	1.56b	1.77a	1.25b	1.15a	1.47
1st bloom	500	1.64a	1.76b	2.04a	1.31b	1.06a	1.56
1st bloom	1000	1.37a	1.46ab	1.64a	1.11ab	0.88a	1.29
50% bloom	500	1.26a	1.45ab	1.79a	1.16ab	1.11a	1.36
50% bloom	1000	0.96a	1.15a	1.48a	0.94a	0.92a	1.09
		1966	1967	1968	1969		
		Vineyard 2					
	0	1.07a[w]	1.09ab	1.25b	1.39c		1.20
1st bloom	500	1.20ab	1.08ab[z]	1.39b	1.23bc[x]		1.23
1st bloom	1000	1.19ab	0.86a	0.97a	1.09ab		1.02
50% bloom	500	1.30b	1.13b[z]	1.40b[y]	1.29bc[yx]		1.28
50% bloom	1000	1.00a	0.95ab	0.78a[y]	0.95a[y]		0.92

[z]Vines not treated in 1968.

[y]1000 ppm applied at 1st bloom instead of 50% bloom.

[x]100 ppm GA applied at shatter.

[w]Mean separation within columns by Duncan's multiple range test, 5% level.

and 6.9 berries per cluster. The increase of 3.5 berries per cluster in 1969 was desirable, but inadequate. In 1971 the increase of 6.9 berries was nearly excessive because it resulted in a cluster weight and compactness which increased the hazard of berry cracking. In large cluster years, which cannot be predicted accurately because berry size and set is the product of climatic conditions plus several other factors, it is possible that 500 ppm daminozide would be preferred over the higher concn, especially when applications are made annually.

Since the effect of daminozide was to increase the weight of each cluster by setting a few more berries, high yields and even excessive production could occur during years when vines have a high cluster number. In such years lower soluble solids may result in delayed maturity and poorer quality (Fig. 3, Table 4). During this study daminozide statistically reduced soluble

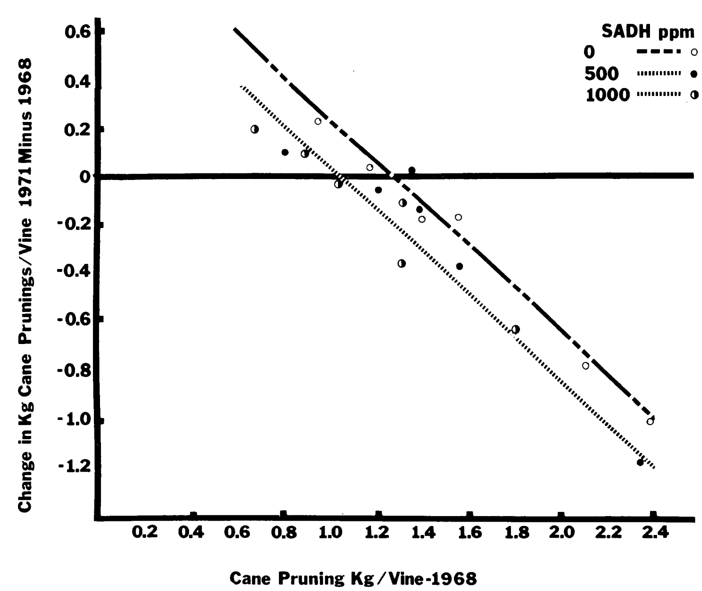

Fig. 4. Vineyard 1 – effect of 0, 500 and 1000 ppm daminozide (SADH) on change in mean balanced pruning weight (30 + 2) of 'Concord' grape vines over a 4-year period, 1968-1971.

solids 2 years in vineyard 2, and 1 year in vineyard 1. A soluble solids depression of 0.4% or more was slightly greater in fruits from vines treated with 1000 ppm than those treated with 500 ppm daminozide. Daminozide had a slight tendency to increase total titratable acid. pH and petiole nutrient content were also measured but found not to be influenced by daminozide application. This is in agreement with results from other experiments on 'Concord' as well as, other cultivars (2, 5).

The overall effect of daminozide application to the foliage and flower clusters was to produce a very significant yield increase with only minor side effects. These were: the near certainty of a vine size reduction (Table 5), a soluble solids decrease if the increased yield was more than 2 kg/vine (Fig. 3), and the hazard of excessive cluster compactness. The choice of adequate size vines and the use of the low rate of daminozide (0.94 kg/ha) reduced these hazards to minor proportions. A desirable characteristic of daminozide was its non-critical timing effects. Both first bloom and 50% bloom applications, as well as, the 500 and 1000 ppm concn produced significant yield responses (Tables 1, 2).

For 'Concord' vines spaced 2.4 m apart in the row an optimum vine size is about 1.5 kg of cane prunings per vine. Because none of the vines in these plots were balanced-pruned prior to the first year of daminozide applications, it was not surprising to find that such a procedure would change the pruning severity of most vines; larger vines would tend to be less severely pruned and smaller vines more severely pruned.

Pruning non-daminozide treated vines in vineyard 2 according to the 30 + 2 formula, over a 4 year period, increased the average pruning weight from 1.07 to 1.39 kg/vine (Table 5). This increase was not strongly related to initial vine size. Average production also increased during this 4-year period (Table 2). In both vineyards those vines with the greatest initial pruning weight tended to decrease when balanced-pruned, while those with the lowest initial pruning weight generally increased in size.

A decrease in pruning weight due to daminozide was noted in all vineyards and was greatest for vines that had the largest initial pruning weight and least for the smallest vines (Table 5, Fig. 4). It must also be noted that daminozide effect on vine size varied from year to year depending on crop load. Thus, this response was, at least in part, the result of increased crop load that the treated vines were carrying.

In vineyard 2, changing some of the treatments from year to year produced some responses that helped to further characterize the effect of daminozide on 'Concord' grapes (Tables 1 and 2, see footnotes). For example, the "carry-over" effects appear to be minimal as indicated by an increase in weight of pruning wood produced when daminozide was not applied in 1968. Increased fruitfulness (Table 1) and yield per vine (Table 2) did not occur in 1968. The re-application of daminozide to both foliage and flower clusters in 1969, at either the 500 or 1000 ppm rate, was again observed to produce an increase in both fruitfulness and yield and a reduction in pruning weight. These results are in agreement with those reported elsewhere (8, 12). The greatest reduction in vine size due to daminozide tended to occur during the first year of application. There was no indication, at the concentrations used, that continued applications would eventually result in an undesirable vine size or reduced production. The data presented show that response to daminozide generally decreased as vine vigor decreased.

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