HILGARDIA

A Journal of Agricultural Science Published by the California Agricultural Experiment Station

VOLUME 28 DECEMBER, 1958 NUMBER 7

RELATIONSHIPS AMONG PRUNING TIME RESPONSE, SYMPTOMS ATTRIBUTED TO GRAPE BUD MITE, AND TEMPORARY EARLY SEASON BORON DEFICIENCY IN GRAPES

MARTIN M. BARNES

UNIVERSITY OF CALIFORNIA · BERKELEY, CALIFORNIA

In studies over a five-year period, the development of abnormal growth formerly included under "grape bud mite injury," was found to be correlated with the effects of pruning time upon time of leafing of spur-pruned vines. Pruning times (e.g., early January) that resulted in early leafing were followed by abnormal growth in early season and resulted in a 39 per cent reduction in yield over a five-year period. The effect of time of pruning upon abnormal growth occurs in the absence of bud mites, a bud-inhabiting strain of *Eriophyes vitis* (Pgst.). Pruning times (e.g., late March) that resulted in late leafing were followed by virtually normal growth and normal yields. Such pruning-time responses have been observed in Mataro, Muscat of Alexandria, and Malaga grape vineyards subject to abnormal growth.

On Mataro vines, the period in winter in southern California during which buds responded to a nearby pruning wound by leafing very early and developing severe abnormal growth usually began about mid-December and extended through mid-January and, in some years, through the first part of February.

Evidence is presented which indicates that this abnormal growth is caused by a temporary early-season deficiency of boron. Soil applications of borax were followed by alleviation of symptoms, increased yield, and elevation of boron level in leaves above the deficiency range.

It is not inferred that these results show that grape bud mites can cause no injury. It is not known whether such pruning-time responses are in all cases related to temporary early-season boron deficiency, but this appears to be an excellent working hypothesis. Since pruning time responses have been recorded in northern California vineyards subject to "bud mite injury," this suggests that this abnormal growth be re-investigated in the light of the possibility of temporary early-season boron deficiency as a causal factor.

HILGARDIA

A Journal of Agricultural Science Published by the California Agricultural Experiment Station

VOL. 28 DECEMBER, 1958 No. 7

RELATIONSHIPS AMONG PRUNING TIME RESPONSE, SYMPTOMS ATTRIBUTED TO GRAPE BUD MITE, AND TEMPORARY EARLY SEASON BORON DEFICIENCY IN GRAPES[1]

MARTIN M. BARNES[2]

INTRODUCTION

For the past thirty years or more certain growth abnormalities hereinafter described have been observed in certain California vineyards (Smith and Stafford, 1948). Though some abnormal growth may be found each season in affected vineyards, the general severity in the incidence of these symptoms has been sporadic and subject to seasonal variation in intensity. Symptoms were widespread in Sonoma County in 1940, 1944, 1947, and 1950, for example. Statewide reduction in grape harvest attributed to this source during 1950 was evaluated at approximately $10,000,000 (Sisson, 1950).

Following initial observations and studies it was concluded that these growth abnormalities were caused by a bud-inhabiting strain of *Eriophyes vitis* (Pgst.), the grape erineum mite (Weinland, 1947; Smith and Stafford, 1948). The existence of a previously unrecognized bud mite strain of *Eriophyes vitis* (Pgst.) was demonstrated (Smith and Stafford, 1948). Furthermore, it was believed that abnormal growth was related to the extensive occurrence of these mites in vineyards. The following syndrome was listed as diagnostic of grape bud mite injury: "1) short basal internodes; 2) slight scarification of green bark of shoots; 3) flattened canes; 4) dead terminal buds on new canes; 5) witches-broom growth of new shoots; 6) zigzagged shoots; and 7) dead overwintering buds" (Smith and Stafford, 1948). These authors further noted that all seven types of symptoms are seldom found on a single vine or even in a single vineyard but that the occurrence of three types would suffice for a proper diagnosis. No other possible causes of this syndrome of abnormal growth were noted. This seemed to suggest that bud mites were the cause of generally occurring abnormal growth and were therefore an important factor in grape production. In the absence of other explanation, this view was widely accepted. Hence, these severe growth abnormalities came generally to be included under the designation "grape bud mite injury" in the belief that they were caused by bud mites.

[1] Received for publication January, 1958. Paper No. 1046, University of California Citrus Experiment Station, Riverside, California.

[2] Associate Entomologist in the Experiment Station, Riverside.

The studies reported here were begun on the "grape bud mite problem" in southern California in 1947, the premise of a causal relationship between grape bud mites and the syndrome then known as "bud mite injury" being accepted. All field experiments were conducted in wine grape vineyards in San Bernardino County.

The results of the studies reported herein show that a syndrome of abnormal growth of grapevines indistinguishable from the broad diagnostic pattern of symptoms originally set for "grape bud mite injury" occurs 1) in the absence of bud mites, 2) in correlation with the effects of pruning on time of leafing out, and 3) is apparently caused by a temporary, early-season deficiency of boron on the Mataro (Mourvèdre) grape variety.

The results herein presented do not show that bud mites do not cause injury in vineyards. There remains the possibility that bud mites may cause significant effects on vine growth, but evidence available at present is indeterminate.

The studies reported herein relate to the effects of pruning time in vineyards subject to the symptoms described. These results are thus discrete from the question of effects of pruning time on yield in normal vineyards.

GRAPE BUD MITES AND ABNORMAL GROWTH

The existence of a bud mite strain of the grape erineum mite has been demonstrated (Smith and Stafford, 1948) and an excellent study of the biology and seasonal abundance of this mite has been made (Stafford and and Kido, 1952; Kido and Stafford, 1955). It has been reported that "Field observations and laboratory studies conducted on Carignane grape buds . . . have shown grape bud mites to be capable of inflicting severe injury that may result in loss of crop and death of the infested vines" (Kido and Stafford, 1955). These authors state, however, that in the single field experiment reported there was "no relation between estimated degree of bud mite infestation and growth symptoms or yield." Also, no evidence is presented that the high populations of bud mites recorded in the study of seasonal abundance were followed by abnormal growth or reduced production. In contrast, it has been reported that high bud mite populations may be followed by normal production (Sisson, 1953).

Bud mites have been listed as a frequently serious pest of grapes (Smith and Stafford, 1955). This would appear to be open to question, since a cause and effect relationship between the presence of bud mites and deleterious abnormal growth in vineyards has not been established.

One experiment designed to alleviate these symptoms by chemical sprays directed against bud mites was reported from Sonoma County as follows:

"On the basis of reduction in bud mite symptoms, the writers have seen only one case of successful control in the field. In the fall of 1939, Mr. Weinland applied a spray composed of 3 gallons of oil emulsion and 5 gallons of lime-sulfur solution per 100 gallons of water. At the time of spraying in one section of the vineyard vines had lost their leaves, while in another section the leaves were still on the vines. When this vineyard was examined in May 1940, it appeared that where the spray had been applied to defoliated vines no bud mite control resulted. In contrast, where the spray had been applied to vines in foliage good mite control was achieved since this section showed very little dwarfing of shoots." (Smith and Stafford, 1948.)

As no data were presented showing reduction of mite population following treatment, there was only an assumed correlation between control of bud mites and reduction in shoot dwarfing. In the light of evidence presented in this paper on the effects of pruning time on these symptoms (see also Barnes, Hemstreet and Turzan, 1952), confirmed in Sonoma County (Sisson, 1953), the results may well be explained otherwise. It seems reasonable that these results may not be related at all to good mite control. The vines in foliage when sprayed may well have leafed out later than the defoliated vines the following spring. Chandler (1942) observes for deciduous fruit trees that those of the same variety which continue growth later will, under certain environmental conditions, tend to open later than others. Vines which defoliate early from drought (i.e., irrigated vines adjacent in any direction to eucalyptus hedge rows) have been observed to leaf out early the next spring. Hence vines in the spray plot which had defoliated early may have developed symptoms because of earlier leafing, not because of lack of mite control. It is shown herein that vines which leaf out late bear normal growth. The fact that attempts to duplicate the effect of a fall application of a petroleum oil and lime-sulfur spray have failed to prevent the injury supposed to be caused by bud mites is further evidence that some factor other than bud mites was responsible in the reported observation on control.

In this connection it was observed in 1948 that among the factors that have complicated attempts to control "bud mite injury" in vineyard spraying trials was the fact that "the symptoms appeared in some portion of the vineyard far removed from the bud mite [injury] location of the year before" (Smith and Stafford, 1948). Again it was observed in 1950 that often a severely damaged vineyard will be free from injury the following year (Smith and Stafford, 1950). This difficulty was again noted in 1955 (Kido and Stafford, 1955). From what is known concerning the relationship between pruning time and these symptoms, it seems entirely possible that this sudden disappearance of symptoms and the skipping about of symptoms from block to block might well be the result of chance block to block variation in the pruning time of the experimental vineyards and quite unrelated to infestation by bud mites. In no case are bud mite population occurrence data recorded which would account for symptoms skipping about from one block to another. In no instance is it recorded that the factor of pruning time was under control. In Sonoma County, where "grape bud mite injury" was originally described (Weinland, 1947; Smith and Stafford, 1948) pruning-time responses, i.e., reduction of symptoms, have been obtained irrespective of bud mite population (Sisson, 1953). This author reports that malformed growth often occurred in the absence of bud mites. Also in a Carignane vineyard plot where 72 per cent of the buds were infested with bud mites and 50 per cent of the buds had been penetrated to the embryo cluster, there was only a trace of malformed growth, and the plot produced the highest yield of those of this variety (Sisson, 1953).

The symptoms attributed to bud mites are noted to be "many and variable," and it is also noted that "some of these symptoms may be produced by other causes" such as "thrips, diseases, weather, soil and moisture" (Smith and Stafford, 1950). Similarly, it has been reported that determination of mite damage in the field is hampered by the fact that other factors cause gross symptoms similar to those inflicted by the mites. Such other factors are reported by Kido and Stafford (1955) to be: (1) abnormal growth related to pruning time, (2) fanleaf, a virus disease, (3) Pierce's disease, a virus disease, (4) dead arm, a fungus disease, (5) *Armillaria* root rot, (6) grape phylloxera, (7) nematodes, (8) the California grape rootworm, and (9) sodium arsenite injury. Bud mites are also said to produce leaf injury on shoots from infested buds growing on canes in water in the laboratory (Kido and Stafford, 1955). These leaf injuries were not described.

Close observation of symptom peculiarities and careful distinction between symptomological characteristics are generally accepted as essential requirements for an approach to problems in diagnosis of plant disease and abnormalities in plant growth. Comprehensive studies and observations by Du Plessis (1950) related to virus diseases and symptomologically related abnormalities in grapes in Europe and North America, including the effects of the eriophyid *Phyllocoptes vitis* [probably = *Calepitremerus vitis* (Can.)] led him to conclude that each of the diseases and abnormalities studied "shows general leaf symptoms which are very distinct and constant." He further notes that these are essentials which make these leaf symptoms reliable for identification and differentiation. He adds that possible varietal influences must also be taken into account.

In the author's opinion also, discriminating attention to leaf symptoms provides the soundest approach presently available for field diagnostics in vineyards. Presence of short internodes, zigzagged canes, breaking of laterals (witches-broom), and cane fasciation appear to be of little value in specifying any single causal factor (see Du Plessis, 1950).

It has been reported that pruning-time studies in the San Joaquin Valley have not produced the same results as those in southern California and Sonoma County (Smith and Stafford, 1955), however, this has not been substantiated by any experimental evidence.

It appears that whatever the effects bud mites may have in vineyards these have not as yet been defined and that the importance of grape bud mites as a causal factor of abnormal growth in California vineyards is in need of re-evaluation.

SYMPTOMS ON VINES IN STUDY VINEYARDS

As will be shown presently, the severity of symptoms and accompanying crop reduction in susceptible vineyards varies in degree of severity depending on the season and the pruning time employed in a given season. Growth of a shoot which is to develop a cane with severe symptoms is slower than that of a normal shoot. Though starting growth early, the severely affected shoot may be outdistanced by normal shoots starting development somewhat later. The following description is based on observations of symptoms on the Mataro variety.

Cane Symptoms. The basal internodes of severely affected canes are short. Lateral (secondary) growth develops from the basal buds of the new shoot (fig. 1). In some cases, two or occasionally three shoots arise from the overwintering bud. The resulting early season growth appears bushy and stunted.

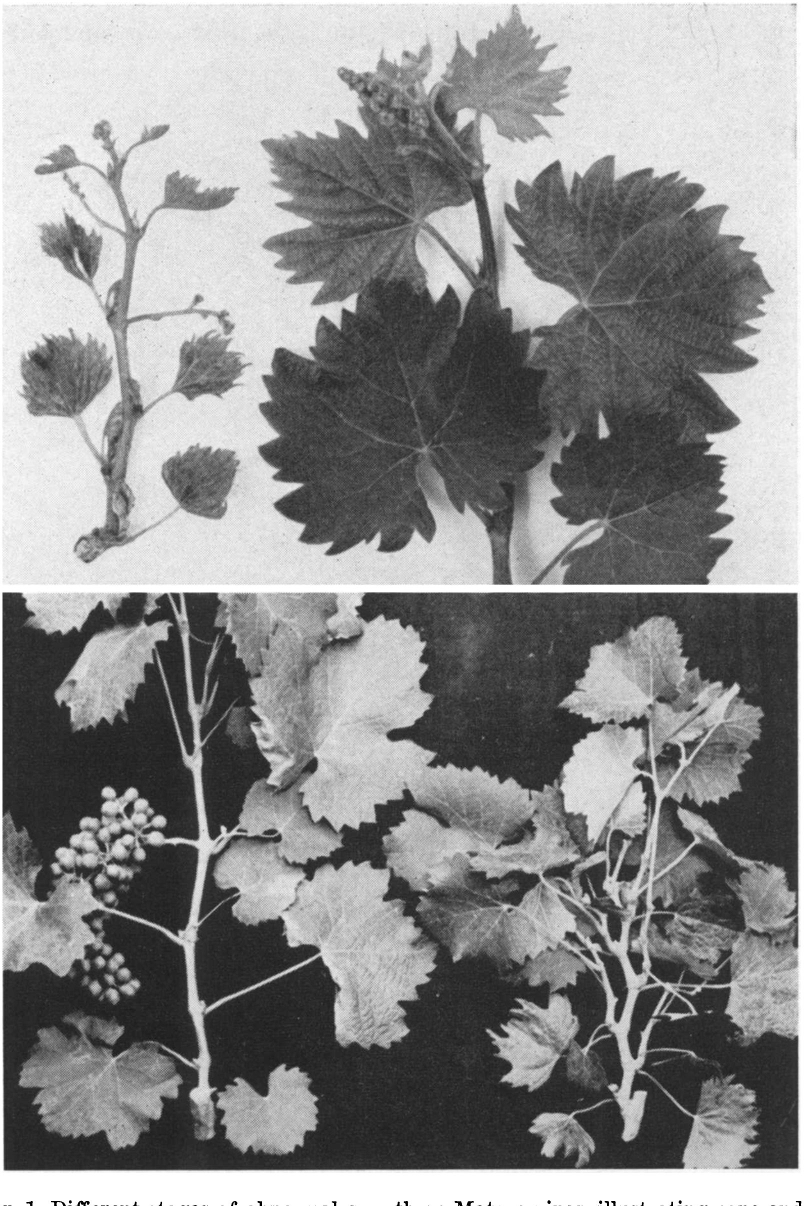

Fig. 1. Different stages of abnormal growth on Mataro vines, illustrating cane and leaf symptoms. Top: (left) affected shoot in early season; (right) normal shoot. Bottom: (left) normal cane in midseason; (right) affected cane. Affected growth from vines pruned in January.

The more severe the cane and leaf symptoms, the less likely it is that the cane will bear grapes. As many as 12 basal internodes have been observed to be abnormally short on severely affected Mataro vines, but all intergradations are present in vineyards and usually less than half this number are short. Leaves attached to nodes that are associated with shortened internodal spacing are virtually always distorted in shape. However, lateral shoots

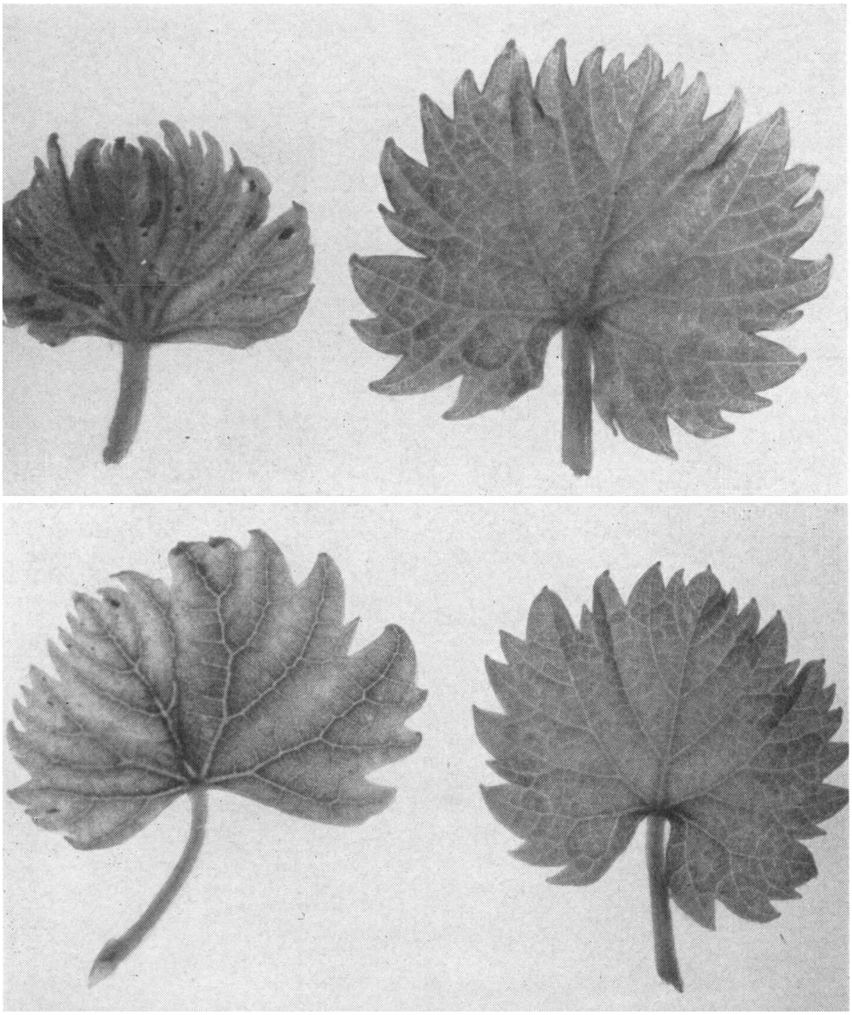

Fig. 2. Leaf symptoms, on Mataro grape (transmitted light). Top: (left) young leaf showing necrotic spots, prominent veins; (right) normal leaf. Bottom: (left) young leaf showing interveinal chlorosis, necrotic flecks, distortion in shape; (right) normal leaf. Severely affected leaves fall off in midseason.

developing early in the season from the axils of even severely distorted basal leaves bear normal leaves. When a long cane is left growing from the base of the vine, new growth from such a cane is virtually always normal, regardless of pruning time. These cane symptoms while unmistakably a part of this syndrome are not in themselves of specific diagnostic value.

Leaf Symptoms. It is emphasized that leaf symptoms vary greatly with variety. On Mataro vines, in addition to distortions in shape, young severely affected leaves may show necrotic spots and a chlorosis in the interveinal area (fig. 2). The severely affected mature leaf is somewhat fan shaped, has a petiolar sinus approaching 180°, and a more sharply and less regularly

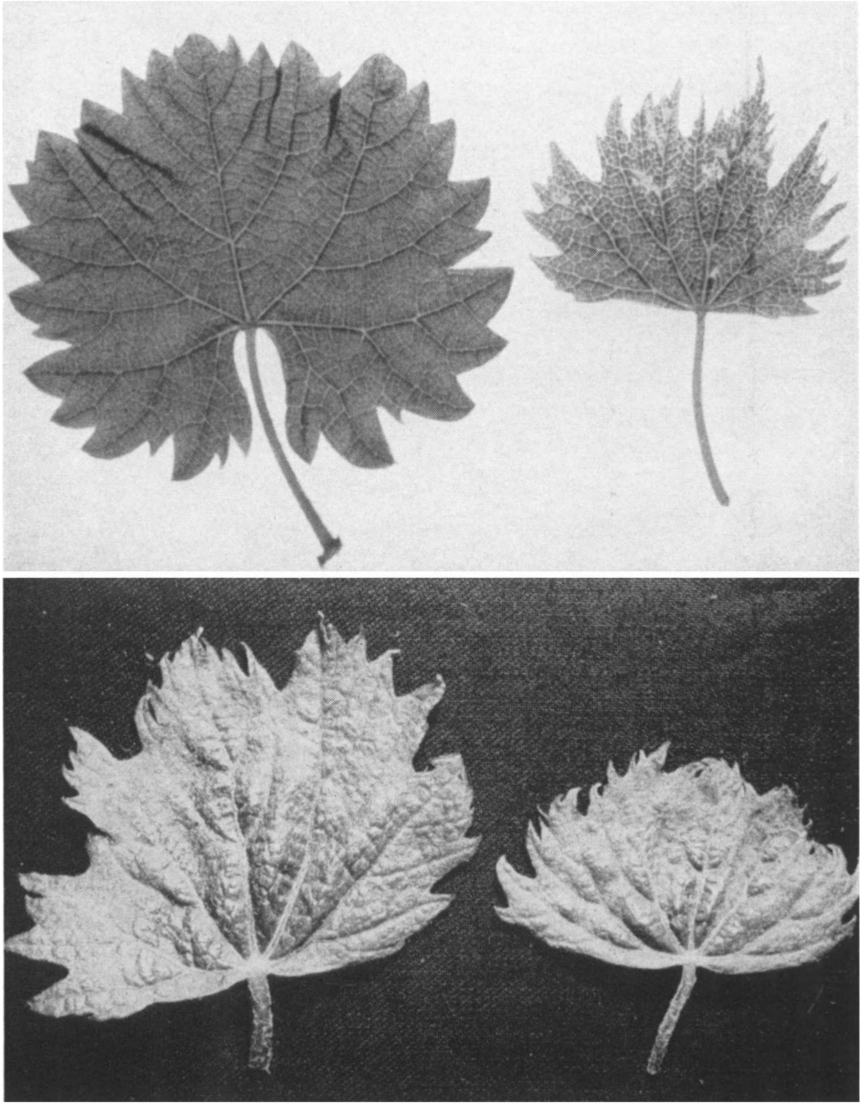

Fig. 3. Mataro grape leaves. Top: (left) normal leaf; (right) mature affected leaf showing abnormal petiolar sinus, irregular and sharply serrate margins. Bottom: mature affected leaves showing typical distortion in shape.

serrate margin than normal (fig. 3). Veins in affected leaves are somewhat prominent. Frequently many basal leaves are distorted in shape where there is no apparent shortening of associated internodes, i.e., leaf development is more sensitive to the causal factor than is internode elongation. Some vineyards show only mild leaf symptoms with no cane symptoms except for reduced yield. If leaves are affected but internodes are normal, leaf symptoms are milder and fewer leaves distorted than when internodes are also affected. Petiole length is not apparently modified. On mildly affected Mataro leaves very little distortion in leaf shape is present. Instead, these leaves show chlorotic spotting (fig. 4). This chlorotic spotting may

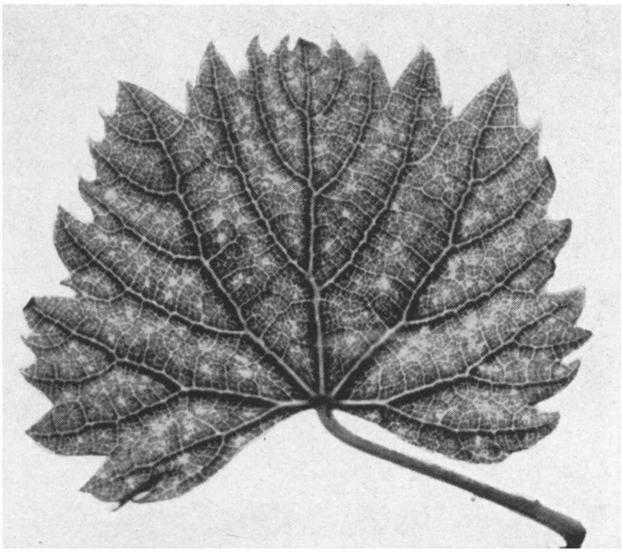

Fig. 4. Mataro grape leaf showing chlorotic spots.

occasionally be the predominant symptom present in some Mataro vineyards. That it is related to the syndrome as a whole is indicated by its general presence in association with other symptoms in all affected Mataro vineyards in which observations were made.

Late spring growth is always normal, i.e., symptoms are confined to the region of the lower nodes, 1–12 according to severity. As previously noted, lateral and terminal growth from the affected basal portion of the cane is normal. Thus, the affected plants appear to recover in late spring. The affected parts do not recover except for fading of the chlorotic spotting. Normal and affected shoots occur on the same plant though all spurs are pruned at the same time, the relationship being simply that adverse pruning times cause a far greater proportion of the shoots to develop more severe symptoms than a favorable pruning time. Normal and affected shoots may grow from the same spur.

The writer has observed this complete syndrome with identical leaf malformations on the Mataro variety and responding to pruning time in plots in Sonoma County conducted by Sisson (1952).

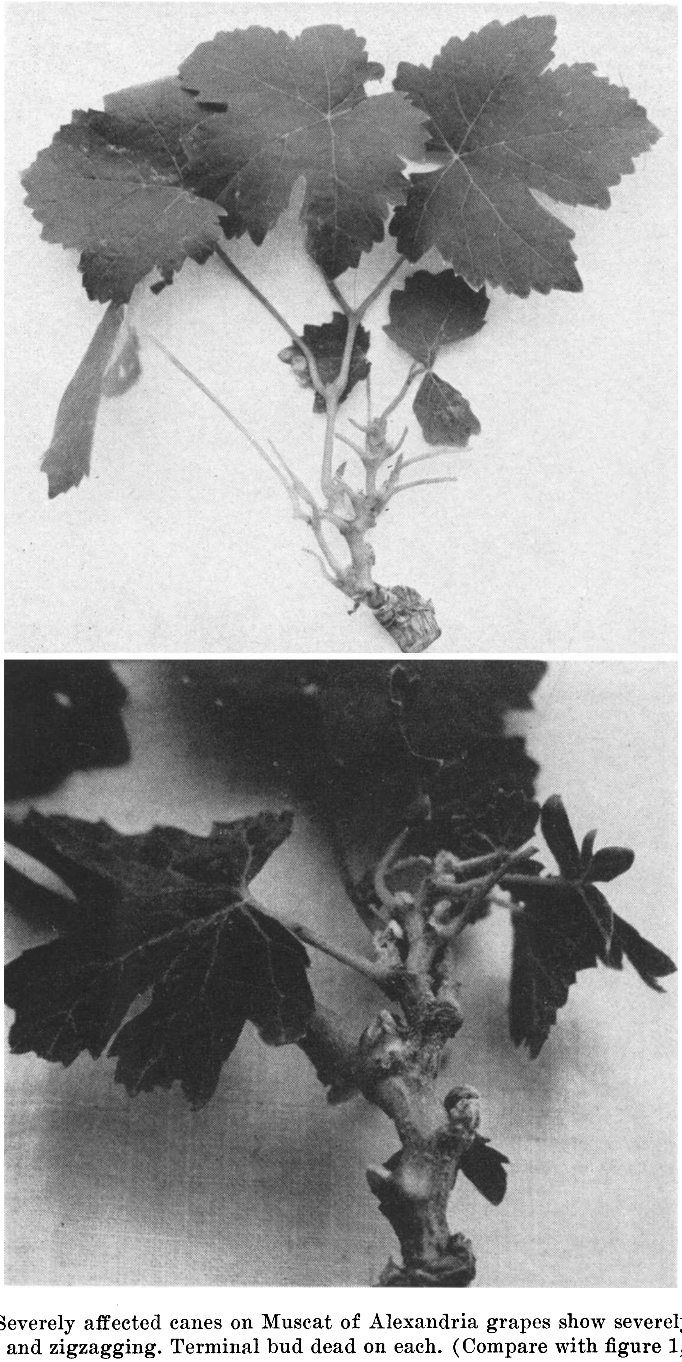

Fig. 5. Severely affected canes on Muscat of Alexandria grapes show severely shortened internodes and zigzagging. Terminal bud dead on each. (Compare with figure 1, Smith and Stafford, 1948.) This abnormal growth responds to pruning time (see table 6).

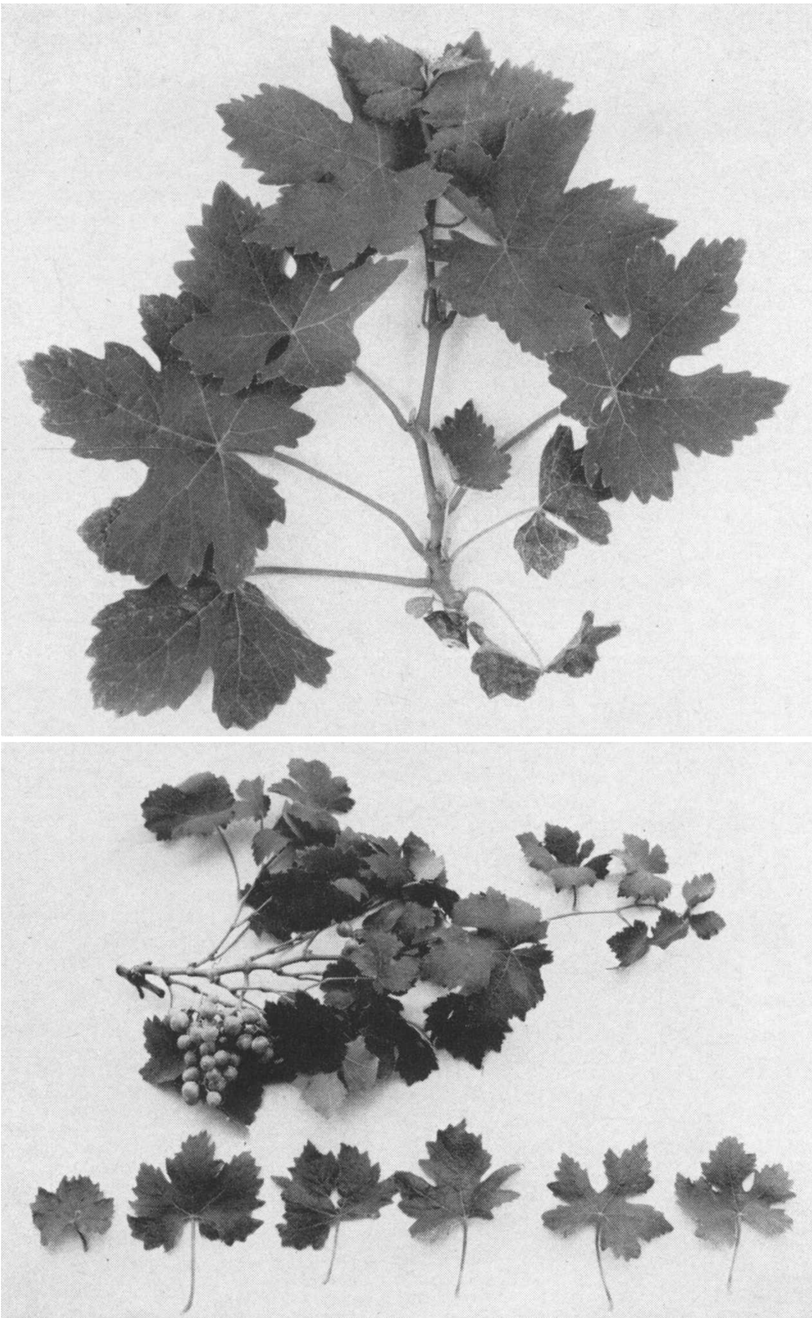

Fig. 6. Abnormal growth on Muscat of Alexandria from vines pruned in early January. Top: note grossly misshapen basal leaves, shortened basal internodes (chlorotic flecking caused by variegated grape leafhopper). Bottom: basal leaves in order from left to right. Note irregular shape of leaves 1–4, and widened petiolar sinus, also shortened basal internodes and lateral development of cane.

Symptoms on Other Varieties. Muscat of Alexandria shows cane symptoms similar to Mataro (fig. 5) but leaf symptoms differ. Affected Muscat leaves show no chlorosis but are irregular in shape (figs. 5 and 6). The gross irregularities found on Muscat leaves were first thought to be caused by a physical factor such as windwhipping, but these occur in association with shortened internodes and respond each season to pruning time.

On the Malaga variety, the cane symptoms are very similar to those previously described, but leaf symptoms are different. Affected Malaga leaves (fig. 7) are severely crinkled and the margins appear irregularly shorn,

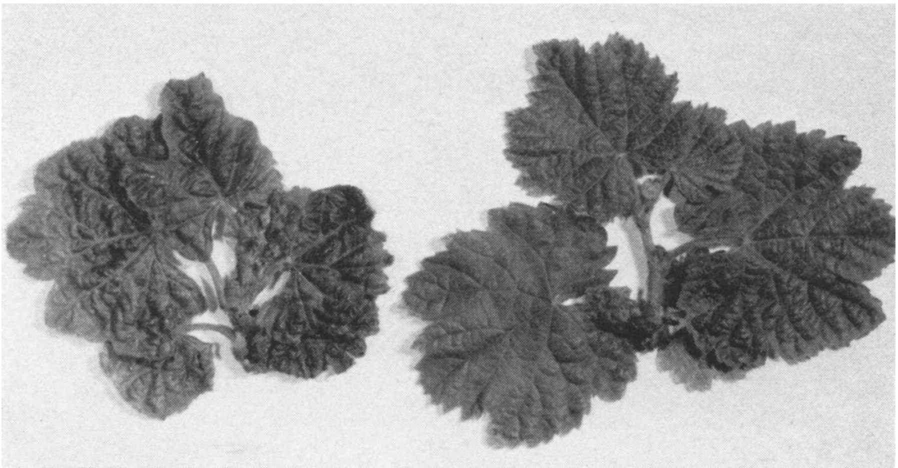

Fig. 7. Young shoots of White Malaga grape. (Left) Affected shoot showing crinkled, misshapen leaves and stunted growth; (right) normal shoot. This abnormal growth responds to pruning time.

being almost devoid of normal serration. Affected leaves may in some instances be a somewhat darker green than normal.

Leaf symptoms on the varieties illustrated in figures 8, 9, and 10, are reported from vines in the vicinity of Mataro, Malaga, or Muscat vineyards which were subject to abnormal growth and responded to periodic pruning. Burger, Tokay, and Black Malvoisie varieties were pruned commercially and were not adequately tested for a pruning-time response. The abnormal growth observed on them was sufficiently similar to that observed on vines which responded to adverse pruning time as to indicate a common relationship.

Tokay vines show cane symptoms similar to those on Mataro. Leaf symptoms were exhibited as an irregular margin and distortion in leaf shape (fig. 8). Affected Burger shoots are illustrated in figure 9. Black Malvoisie shows an interesting, highly irregular leaf shape (fig. 10). Only on the Mataro variety have chlorotic symptoms and fan-shaped leaves been seen.

While no data are offered in support, the general observation has been made that the effects of adverse pruning time are accentuated by the age of the vine. Older vineyards are more likely to show severe symptoms than young vineyards. Young replant vines in old severely affected vineyards may show very little abnormal growth, frequently none at all. Also, vines along the border of the vineyard suffer somewhat less than those within the vineyard.

ACARICIDE INVESTIGATIONS

As has been noted, studies were begun on this vine condition based upon the presumption that these symptoms were caused by bud mites. During the period 1947 to 1950, 46 spray treatments with different toxicants, dosages, or schedules of application were tested in southern California on 55 acres of

Fig. 8. Abnormal growth on Tokay. Note the misshapen leaves, short basal internodes, laterals, and lack of crop. Chlorotic spotting was caused by the variegated grape leafhopper.

vineyards subject to symptoms. These applications were usually made in the fall or late winter prior to breaking of dormancy. An occasional plot apparently showed some response, but this could not be duplicated. Usually, either symptoms vanished from all plots, unsprayed checks included, or were present to a similar degree in all plots. These results are similar to those reported by other investigators in other California grape-growing areas, except in one instance where successful reduction in symptoms was reported following fall application of petroleum oil and lime sulfur (Smith and Stafford, 1948). Since this response has not been duplicated following similar treatments and since evidence reported in this paper shows that other factors cause these symptoms, spray applications do not appear to have resulted in reduction of symptoms.

Fig. 9. Burger grape shoots. (Left) Mildly affected shoot; (right) severely affected shoot.

PRUNING-TIME INVESTIGATIONS

Symptoms were widespread and generally severe in many vineyards in San Bernardino County in the spring of 1949. In April, Mr. A. A. McCornack called to the writer's attention a Malaga vineyard near Verdemont where approximately half of a 6-acre block which had been pruned in January was much more severely affected than the remainder of the vineyard which had been pruned in March. Inquiry as to other possible differential treatments in the vineyard led to the conclusion that there were none. Records were made of the incidence of symptoms in each block and 41 per cent of vines in the area pruned in January were rated as severely affected, while only 4 per cent of late-pruned vines were so classified. The predominant symptoms in this vineyard consisted of shortened basal internodes, severe witches-broom growth, zigzagged shoots, and notable lack of crop. Basal leaves on affected

Fig. 10. Abnormal growth on Black Malvoisie grape. Note highly irregular shape of basal leaves, zigzagging, laterals with normal leaves as on Mataro.

shoots were severely crinkled. Populations of bud mites, which were presumed at the time to be the causal agent, were low, ranging from 0 to 11 mites per bud. Predacious mites were also present and the initial interpretation was that these predators accounted for the low eriophyid population at the time of these observations.

In the same locality a Muscat of Alexandria vineyard was also observed in which a portion of the vineyard pruned in January was severely affected. Subsequently, inquiries were made in the Guasti-Cucamonga grape-growing area and it was found generally that where vineyards were pruned late they were not affected, or only moderately so. All of these were non-irrigated, wine-grape vineyards and were head pruned, leaving two to three buds per spur.

Monthly Pruning-Time Experiment. Accordingly, an experiment was set up to study the relationship between pruning time and what was then referred to as "grape bud mite injury." Since the general incidence of this syndrome had a history of sporadic seasonal occurrence, this experiment was designed to cover a five-year period. The experimental block, approximately 7 acres, was in a 44-acre block of 55-year-old Mataros having a history of very severe symptoms, belonging to Garrett and Company, and located near Alta Loma. Vines in this vineyard are planted 7×7 feet, own-rooted, and non-irrigated. Vineyard topography provides a 2° slope to the south and the soil is a Hanford sand. Rainfall is largely confined to the period October through April and averaged 17.85 inches per year in this vineyard for the period 1950 to 1953. A 6–9–6 fertilizer application at 200 pounds per acre was routinely applied by the owners during late winter each year. This vineyard had shown very severe symptoms in 1949 and yielded but 52 tons on 44 acres.

In the fall of 1949, the trial area was divided into six blocks of 1,000 vines each. Two hundred vines in each of the six blocks were pruned during the first part of each of the following months: November, December, January, February, and March. The assignment of pruning time to plots within the blocks was at random. The plots were head pruned by a single pruning crew leaving approximately eight spurs per vine and two buds per spur on the dates indicated in table 1.

A generally existing relationship between time of pruning and time of leafing has long been recognized. In brief, if vines are pruned very late, they tend to leaf out later than those pruned in midwinter. Vines pruned very early, prior to leaf fall, also leaf out later in the spring than those pruned in midwinter (Winkler, 1934). Observations made on the status of bud and shoot development in the experimental blocks during the first week in April, 1950, showed that there was a considerable difference in the status of bud and shoot development, depending on pruning time. Vines pruned in midwinter, January and February, leafed out considerably ahead of vines pruned in November or March.

Results, 1950. During the last week in May each vine was rated as to incidence of abnormal growth into one of three classifications: (1) severely affected, (2) moderately affected, or (3) not affected. At harvest, records were made of the yields of each of the 30 plots. The injury and yield records from all plots were averaged for the different pruning dates and are presented in table 1.

The results of this trial show a relationship during the 1949–50 season between time of pruning and the incidence of abnormal growth (Barnes and McCornack, 1951). Vines pruned in March yielded from 80 to over 100 per cent more grapes than those pruned in January or February. Vines pruned in January or February showed much more severe symptoms than vines pruned in November or March. Vines pruned in December showed more symptoms than those pruned in November or March, but there was no significant difference in yield in the plots pruned in these months. It will be noted that there was observed a relationship between effects of pruning time on sequence of shoot development in the spring and the incidence of symptoms, i.e., pruning times resulting in late leafing out were related to low incidence of symptoms and a normal crop.

TABLE 1

RATING OF SYMPTOMS ON VINES AND YIELD OF PLOTS PRUNED ON FIVE DIFFERENT DATES, MATARO VARIETY, ALTA LOMA, 1950

Date	Rating of symptoms (Per cent of vines)			Average yield (Tons per acre)
	Severely affected	Moderately affected	Not affected	
November 14, 1949	3	17	80	5.5
December 6, 1949	5	46	49	4.9
January 4, 1950	23	60	17	2.7
February 2, 1950	43	46	11	3.0
March 3, 1950	1	24	75	5.6
Least significant difference at 99:1				1.3

Results, 1950–51. Since November and March pruning times had provided a favorable response and improved yields as compared with those of January and February for the 1950 season, it was decided to continue to prune one-half of each plot pruned during these 4 months, 6 replications of 100 vines

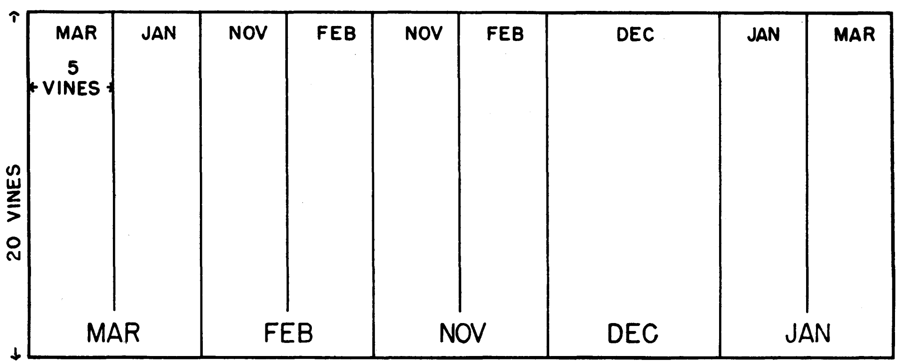

Fig. 11. Plot layout of one of six replications in five-year monthly pruning-time trial. First year pruning time as shown at bottom, second year at top, third year at bottom, etc.

each, at these same pruning times for the course of the experiment. This would determine the consistency with which such results would be produced. The remaining half of the same plots would be pruned alternately at times which had previously been "favorable" or "unfavorable" for the first season of the trial. December plots were pruned at the same time throughout the experiment. Typical block layout is illustrated in figure 11.

Timing of the pruning was usually during the first week of the corresponding month with the exception of March. These were pruned just after shoot growth had begun, usually toward the latter part of the month.

Detailed records were made of the results of the second year of this trial. On April 12, 1951, the percentage of buds showing green tissue was recorded to provide evidence of the relationship between time of beginning of growth and symptoms. Also, a record was made of the number of spurs per vine left by the pruning crew to ascertain whether this was a factor. When elongation of the first 12 internodes was virtually complete, records were made of the incidence of symptoms which followed the various pruning times. It is desirable in recording the degree of incidence of symptoms to express this numerically, avoiding subjective error and implementing statistical comparison. Records were therefore made of (1) the number of distorted leaves per cane, (2) the number of laterals or secondary shoots per cane, and (3) the length of the shoot from the base to the fifth node. Enumeration of distorted leaves was the most readily obtained objective record. At harvest, yield records were made from all plots. A sample of ten boxes was weighed from each plot, or the total box yield was weighed, whichever was the smaller.

TABLE 2

RESULT OF PRUNING TIME TRIALS, MATARO GRAPES, 1951

Pruning time (1950)	Pruning time 1951	No. spurs vine*	% Bud emergence* 4/12	% Canes affected†	Average length to fifth node† cm.	Per 100 canes† Laterals	Per 100 canes† Distorted leaves	Yield tons/acre‡
(Nov.)	Nov. 3	8.6	6	10	12.4	5	42	4.3
(Dec.)	Dec. 5	7.9	12	26	11.9	40	120	3.7
(Jan.)	Jan. 3	7.3	57	50	10.9	84	241	3.2
(Feb.)	Feb. 6	7.8	53	60	10.5	112	329	3.4
(Mar.)	Mar. 26	7.9	1	8	13.0	12	49	4.3
(Feb.)	Nov. 3	8.0	5	13	12.0	9	50	4.9
(Mar.)	Jan. 3	7.3	61	41	11.3	96	245	2.9
(Nov.)	Feb. 6	7.9	55	54	11.0	132	255	3.1
(Jan.)	Mar. 26	7.9	0	2	13.2	5	9	4.0

* Each figure from records on 120 vines (spurs per vine) and all spur buds on 60 vines (per cent bud emergence). Bud emergence refers to green tissue showing.
† All spur nodes examined on five vines in each of three replicates. Records made July 25 to August 10.
‡ Least significant difference at 99:1, —0.5 ton per acre.

The records on the number of spurs left per vine, bud emergence, symptoms, and yield are presented in table 2. These data show that for the season of 1951: (1) the pruning crew left approximately the same average number of spurs at each pruning time; (2) leafing out was markedly advanced by pruning times during the forepart of January and February; (3) symptoms were again predominant in January- and February-pruned plots and occurred in these to a similar degree irrespective of the pruning time or yield history for the 1950 season; (4) November- and March-pruned plots leafed out late and had a low incidence of symptoms; and (5) improvement in yields ranged up to 1.1 tons per acre favoring pruning times resulting in late leafing out (Barnes, Hemstreet, and Turzan, 1952).

Results, 1952–54. Following the results of the first two years the monthly pruning-time experiment was continued an additional three seasons. The alternation of pruning times was continued, but with half of each plot being continuously pruned during the same month as previously described. The pruning dates and yield records for the period 1952–54 are summarized in table 3, together with those of the previous two seasons.

TABLE 3

PRUNING TIMES AND YIELD DATA FROM FIVE-YEAR PRUNING-TIME TRIAL IN A MATARO VINEYARD SUBJECT TO ABNORMAL GROWTH*

Schedule†	Plot pruning time for season of					Average yield tons per acre‡				
	1950	1951	1952	1953	1954	1950	1951	1952	1953	1954
A	Nov. 14	Nov. 3	Nov. 7	Nov. 3	Nov. 2	5.5	4.3	3.6	1.6	2.1
B	Dec. 6	Dec. 5	Dec. 3	Dec. 2	Dec. 2	4.9	3.7	4.7	1.7	2.0
C	Jan. 4	Jan. 3	Jan. 3	Jan. 5	Jan. 5	2.8	3.2	2.6	1.0	2.3
D	Feb. 2	Feb. 6	Feb. 4	Feb. 4	Feb. 3	3.0	3.4	5.4	2.2	2.4
E	Mar. 3	Mar. 26	Apr. 1	Mar. 17	Mar. 2	5.6	4.3	4.7	2.7	2.2
F	(Nov. 14)	Feb. 6	Nov. 7	Feb. 4	Nov. 2	5.5	3.1	4.4	2.2	2.1
G	(Jan. 4)	Mar. 26	Jan. 3	Mar. 17	Jan. 5	2.8	5.0	2.1	3.0	2.2
H	(Feb. 2)	Nov. 3	Feb. 4	Nov. 3	Feb. 3	3.0	4.9	4.8	1.6	2.3
I	(Mar. 3)	Jan. 3	Apr. 1	Jan. 5	Mar. 2	5.6	2.9	5.6	0.8	2.5

* For statistical analysis of yield data, see table 4.
† Each schedule replicated 6 times, at least 100 vines per replicate as described in text.
‡ Yields for 1950 based on 200-vine plots subsequently split as indicated in text. Average yield for 1950 based on box count. In subsequent years, yields are based on net weight of a sample of 10 field boxes per plot or of the entire crop, whichever was the smaller.

A split-plot analysis of variance was applied to these data in order to make allowance for the effect of correlation between yields on the same plot in successive years. The results of application of Duncan's multiple range test (Duncan, 1953) for treatment mean differences is shown in table 4. The five-year average yields for plots pruned each year during the same month are also compared in table 4. This table provides statistical comparisons among yields from different pruning times for any one year and for the five-year period.

In interpreting the results of the monthly pruning-time trial (tables 3 and 4), it must be recognized that pruning time affects yield in vineyards to the extent that it corrects abnormal growth which varies not alone with pruning time, but in general intensity from year to year. Severity of symptoms in the experimental vineyard may be briefly summarized as follows: 1950, severe; 1951, moderate; 1952, severe; 1953, moderate; and 1954, very light. Thus, in 1954 there was the least difference in yield among plots. Hence, an objective record of intensity of symptoms during the season of trial should be made in trials conducted on the influence of pruning time (or of any other factor) upon yield in affected vineyards. Also, in vineyards subject to abnormal growth, studies of pruning time as a factor are best conducted over a period of several years. Plots involving other corrective measures should be crossed with different pruning times in experimental designs offering pertinent combinations.

The results of this five-year trial show that a late pruning time (March) is superior to others in securing normal yields in affected vineyards. For the five-year period, January pruning times resulted in an average of 39 per cent lower yields than March pruning times. November-pruned plots did not show symptoms to any extent in any year. That yields from November-pruned plots were significantly lower than March-pruned plots in 1952 and

TABLE 4

APPLICATION OF DUNCAN'S MULTIPLE RANGE TEST TO YIELDS OVER A FIVE-YEAR PERIOD IN MONTHLY PRUNING-TIME PLOTS IN A MATARO VINEYARD SUBJECT TO ABNORMAL GROWTH

Year	Average yield in tons per acre*									Significance level
	Jan.	Feb.	Dec.	Nov.	Mar.					
1950	2.8	3.0	4.9	5.5	5.6					0.01
	MJ	NF	J	F	D	N	M	FN	JM	
1951	2.9	3.1	3.2	3.4	3.7	4.3	4.3	4.9	5.0	0.01
	JMJ	J	N	NFN	D	M	FNF	F	MJM	
1952	2.2	2.4	3.7	4.4	4.6	4.7	4.8	5.4	5.6	0.01
	MJMJ	J	D	N	FNFN	F	NFNF	M	JMJM	
1953	.8	1.0	1.5	1.6	1.6	2.1	2.2	2.7	3.0	0.01
	D	N	NFNFN	JMJMJ	M	J	FNFNF	F	MJMJM	
1954	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.5	0.05

Five-year average yields for non-alternating pruning time plots

Jan.	Feb.	Dec.	Nov.	Mar.	Significance level
2.5	3.2	3.6	3.8	4.2	0.05 0.01 0.01

* Yields occurring above the same line do not differ significantly. Yields not above the same line differ at the significance level .05 or .01, as indicated. 1950 data are from 200 vine plots, six replications. Later data are based on 100 vine plots as described in text. Letter series indicate pruning time history. Last letter indicates month in which plot was pruned for the year of the yield data.

1953, with a trend in the same direction for 1954, may be related to the adverse effects on yield and vigor of such an early pruning time for normal vinifera vines as reported on nine varieties by Singh and Dikshit (1952). The increasing effect on yield by a favorable pruning time was greater following a low yield and the decreasing effect of an unfavorable pruning time greater following a high yield.

Other Trials, Mataro Variety. Pruning time trials were carried out by A. A. McCornack, in Mataro vineyards in 1951. The vineyards were all known to be subject to abnormal growth. Results reported in table 5 show that yield was reduced about 25 per cent on the average by pruning in January.

TABLE 5

YIELD RECORDS IN ADDITIONAL PRUNING-TIME TRIALS ON MATARO VINES SUBJECT TO ABNORMAL GROWTH, 1951*

Vineyard	Pruning time	No. replications	Size of plots (No. of vines)	Yield (Tons/acre)
A...........	11/15/50	2	204	2.6
	1/15/51	2	153	1.3
	3/2/51	2	136	3.1
B...........	11/10/50	4	60	1.6
	1/25/51	4	60	1.7
	3/17/51	4	60	2.0
C...........	11/7/50	4	60	2.6
	1/8/51	4	60	1.9
	3/15/51	4	60	3.1
D...........	11/4/50	3	120	5.6
	1/18/51	3	120	5.0
	3/15/51	3	120	5.5
E...........	11/4/50	3	96	4.7
	1/18/51	3	96	4.6
	3/15/51	3	96	5.1
F...........	11/26/50	2	140	2.5
	1/27/51	2	140	2.1
	3/24/51	2	140	2.6
A–F	(Average of all vineyards)	November....................		3.3
		January......................		2.8
		March........................		3.6

* Data from A. A. McCornack; vineyards located in the Guasti-Cucamonga area of southern California. None of these vineyards were so susceptible to appearance of severe symptoms as the vineyard in which the five-year study was made.

Other Trials, Muscat of Alexandria. Of other varieties subject to abnormal growth, Muscat of Alexandria is frequently found affected. It is interesting to note that Professor Hilgard (1884) directed his attention to declining Muscat vineyards in southern California. He concluded that failure to set fruits was related to soil fertility.

In an affected Muscat vineyard near Verdemont, four replicates of 80 vines each were pruned in November, January, or March for the 1951 season. Results are shown in table 6. These again show a relationship in which January-pruned vines are most affected. The yield data show a trend toward reduced yield in the January plots, but this difference is diminished by the fact that the number of spurs left per vine were fewer in the case of the January plots.

TABLE 6
PRUNING TIME AND ABNORMAL GROWTH ON MUSCAT OF ALEXANDRIA, 1951*

Pruning time	No. spurs left/vine	Laterals/100 shoots†	% Canes not affected	Yield tons/acre
Nov. 20, 1950.....	12.6	28	84	1.2
Jan. 15, 1951......	9.0	41	68	1.0
Mar. 15, 1951......	10.8	7	94	1.5

* Four replicates of 80 vines each for each pruning time.
† Lateral buds at the basal nodes of affected shoots tend to break, hence this was used as an index of symptoms.

Weekly Trials, 1951–52. Field observations in 1951 in several vineyards not affected by abnormal growth indicated that the effect of pruning time upon time of leafing out may abruptly change. It was noted that sharply defined portions of a vineyard known to have been pruned within a single week in midwinter leafed out at significantly different times in the spring. This suggested the existence of fairly sharply defined periods during which buds were susceptible to the stimulus of a nearby pruning wound, responding by early leafing. To investigate this and to study its relationship to the development of abnormal growth, 180 Mataro vines adjacent to the large-scale pruning-time trial were used in a weekly pruning-time trial in 1951–52.

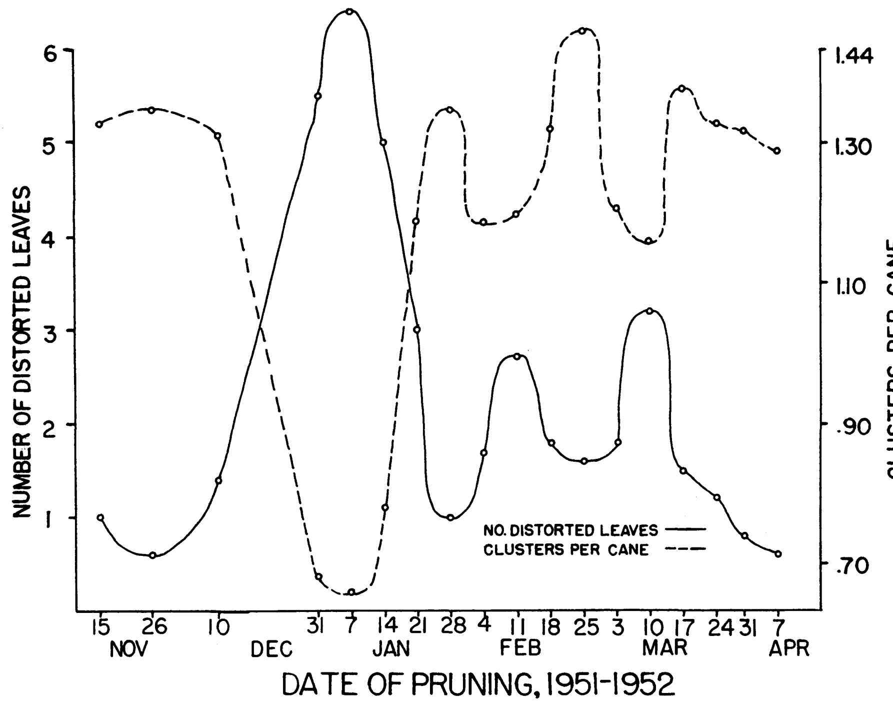

Fig. 12. Number of distorted leaves per cane as an index of other symptoms; relationship with cluster count.

Ten vines were pruned to two bud spurs on each of 18 dates. Single vine plots were used in ten blocks, each consisting of 18 randomized plots.

Averaged data on the weekly pruning time trial of 1951–52 are shown in table 7 and in figures 12–14. The higher the incidence of distorted leaves, the lower the cluster count (fig. 12) and the higher the incidence of multiple shoots per spur bud (table 7). The number of distorted leaves per cane is therefore a quite satisfactory index to the severity of symptoms.

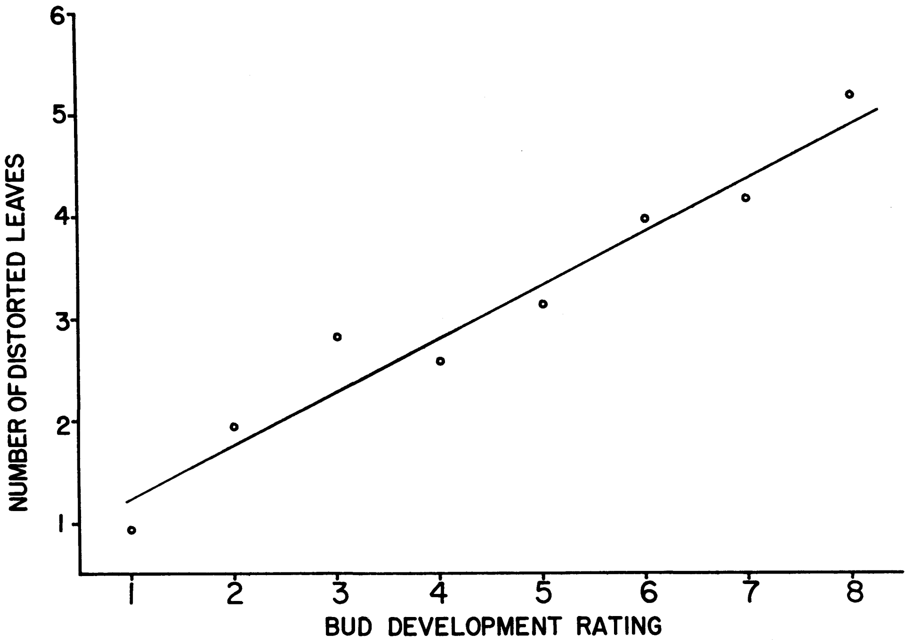

Fig. 13. Relationship between bud development in April and symptoms (number of distorted leaves per cane) in June. Bud development ratings as follows: (1) dormant, (2) bud slightly protruded, (3) bud completely protruded, (4) first leaf beginning to separate, (5) one leaf unfolded, (6) two leaves unfolded, (7) three leaves unfolded, etc.

The previously observed relationship between time of leafing and symptoms is substantiated by results of the 1951–52 weekly pruning-time experiment. Shortly after the vines began to show growth, bud and shoot development was recorded on each spur bud of all vines on April 8, 1952. Bud and shoot development was again recorded on April 24. Each bud was tagged and symptoms were recorded in June. Taking data from all buds, we see a close relationship between bud advancement on April 8 and the number of distorted leaves on the cane in June (fig. 13). The earlier visible bud development began, the more severe the symptoms. There are exceptions to this general rule, however, as discussed below.

Records were also made of the size of the cluster or inflorescence, these being classified as large, medium, or small. The percentage of small clusters is invariably high when cluster count is low. Therefore, the number of clusters per cane does not reflect effects upon yield adequately.

As previously mentioned, bud and shoot development records were taken on two dates. When records taken on April 24 are compared with those taken on April 8 it will be seen that affected shoots develop more slowly than normal shoots (table 7). For example, records on bud emergence made on April 24, taken alone, would indicate that vines pruned on December 10 leafed out ahead of those pruned on December 31 while the April 8 record is inconclusive. Hence, comparisons on the time of initiation of bud growth based on length of shoot growth are not entirely reliable when the abnormal growth factor is present.

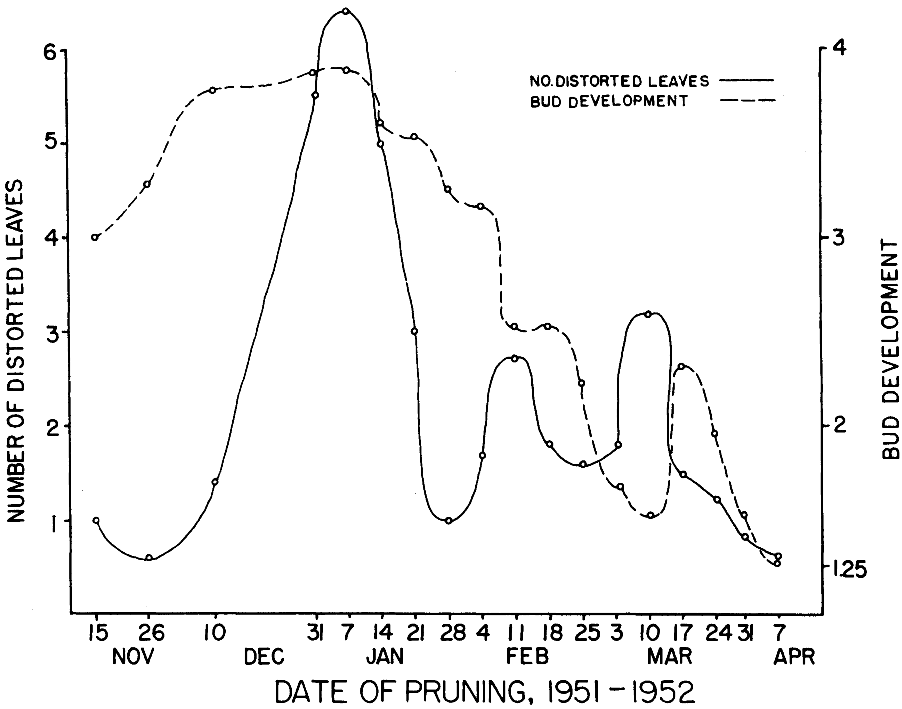

Fig. 14. Relationship between pruning time, number of distorted leaves per cane and bud development, weekly pruning-time trial, 1951–52. See legend of figure 13 for ratings of bud development.

From the monthly pruning time plots in both 1950 and 1951 it was learned that pruning times during the forepart of January and the forepart of February were "unfavorable," leading to development of abnormal growth and lowered production in a vineyard subject to abnormal growth. In the 1951–52 season it will be noted from figure 14 that vines became susceptible to an adverse pruning-time response sometime between December 10 and December 31, 1951. This adverse response reached a peak on January 7, 1952, was still severe on January 14, then tapered off to about normal response 14 days later.

There were two peaks of later adverse response, February 11 and March 10, 1952. The incidence of distorted leaves on these latter dates is significantly greater than that of weekly pruning times immediately before or after. The odds are 99:1 or greater. Though the response in symptoms is significant on the two latter dates, there was no correlated effect on time of leafing out so far as can be detected by bud development records (table 7). It has previously been noted that there is a correlation between early leafing and symptoms. There can be little doubt, however, that vines pruned on

TABLE 7

EFFECTS OF PRUNING TIME ON SYMPTOMS AND CONCOMITANT EFFECTS UPON TIME OF BUD DEVELOPMENT, MATARO GRAPES, 1952

Pruning		Bud development*		No. distorted leaves/cane†	Clusters per cane†	Shoots per node‡
No.	Date	4/8	4/24			
1	11/15/51	3.0	6.9	1.0	1.33	1.12
2	11/26/51	3.3	7.0	0.6	1.35	1.12
3	12/10/51	3.8	7.9	1.4	1.31	1.08
4	12/31/51	3.9	6.6	5.5	0.68	1.40
5	1/7/52	3.9	7.1	6.4	0.66	1.44
6	1/14/52	3.6	6.9	5.0	0.78	1.42
7	1/21/52	3.5	7.0	3.0	1.19	1.24
8	1/28/52	3.3	7.4	1.0	1.35	1.08
9	2/4/52	3.2	7.1	1.7	1.19	1.13
10	2/11/52	2.5	6.4	2.7	1.20	1.11
11	2/18/52	2.5	6.9	1.8	1.32	1.11
12	2/25/52	2.2	6.2	1.6	1.47	1.10
13	3/3/52	1.7	5.2	1.8	1.21	1.14
14	3/10/52	1.5	4.6	3.2	1.16	1.21
15	3/17/52	2.3	6.1	1.5	1.38	1.12
16	3/24/52	2.0	5.6	1.2	1.33	1.13
17	3/31/52	1.5	4.7	0.8	1.32	1.14
18	4/7/52	1.3	3.4	0.6	1.29	1.05
Least significant difference at .01				0.9	....	....

* Each spur bud on 10 vines (averaging 14 per vine) was rated as follows: (1) dormant, (2) bud slightly protruded, (3) bud completely protruded, (4) first leaf beginning to separate, (5) one leaf unfolded, (6) two leaves unfolded, (7) three leaves unfolded, etc.
† Data taken June 1.
‡ Number of shoots per replacement spur bud.

March 10 were considerably delayed in beginning growth as compared with those pruned on January 21 (see table 7) yet each developed an equivalent number of distorted leaves with correspondingly low cluster count and high incidence of multiple shoots per node. Since the March 10 pruning time was followed by a distinctly later leafing out than the January 21 pruning time, in fact leafing out at the same time as vines pruned on March 31, yet resulted in an equivalent degree of abnormal growth as vines pruned on January 21, it may be inferred that the March 10 pruning time was causally related to abnormal growth through some other relationship than resulting in an unusually early time of leafing out. This is probably related to climatic conditions at a critical time in bud development and may represent an example on a small scale of a seasonal effect. Symptoms are much more severe in some seasons than others, though resulting from pruning during adverse periods.

Weekly Trials, 1952–53. A weekly pruning time experiment was also conducted in the same vineyard in 1952–53 using a different set of vines, the latter having received a uniform pruning time the previous year. Ten single vine replicates were pruned on 16 different pruning dates. Records were made of the number of distorted leaves per cane and number of clusters per cane on June 16, 1953. Results are shown in figure 15. These results show an unfavorable period beginning before December 15 and ending January 12. After the latter date results were rather evenly more favorable from January 19 to March 23, there being a gradual reduction in number of distorted leaves per cane and a gradual increase in the number of clusters per cane.

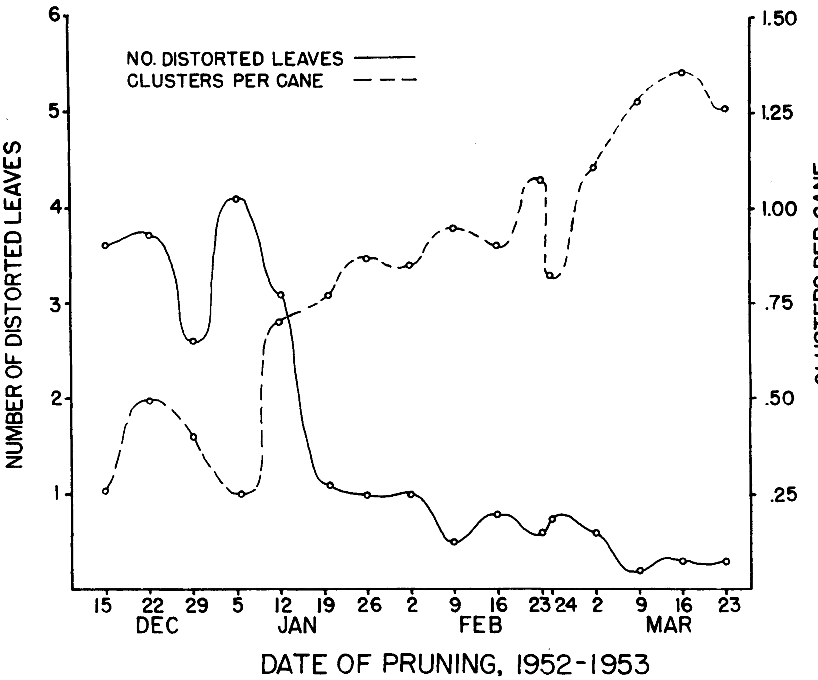

Fig. 15. Results of weekly pruning-time trial, 1952–53.

Relationship of Pruning Wound to Start of Growth. Chandler and Brown (1951) state that deciduous tree buds respond to the stimulus of a nearby pruning wound by leafing out early only after they have had some chilling. Pruning wounds made before satisfaction of the chilling requirement is begun or after this requirement is complete do not result in early leafing out by adjacent buds. These authors also state that pruning wounds tend to delay opening if inflicted after the buds have been chilled enough to break the rest period completely.

There is an apparent analogy between these observations by Chandler and Brown and the experience with grapevines. Pruning-time effects on time of leafing of grape buds follow a similar pattern. Pruning wounds made in November do not result in so early leafing in adjacent buds as those in January (fig. 14). The period of response to pruning wounds by markedly early leafing out of adjacent buds begins in December. Pruning wounds made in early January consistently resulted in very early leafing of adjacent buds on Mataro. The length of the period of time in winter during which most of the buds responded by leafing very early (and developing severe abnormal growth and with poor yield) varies from year to year. In some years this response extends into early February and perhaps longer as seen in the results of 1950 and 1951 (tables 1 and 2). In other years, 1952 and 1953, this response had tapered off in January (figs. 14 and 15).

If the response of early leafing by grape buds to nearby pruning wounds is indeed related to completion of rest period or chilling requirements as indicated by Chandler and Brown for deciduous fruit trees, then the sequence of events observed on grape buds might be expected to occur. If different varieties of grapes have different chilling requirements as suggested by Chandler and Brown (1951), different varieties may accordingly vary in their time of leafing response in relation to pruning time. Difference in chilling requirement between two adjacently planted varieties could then be used to determine whether this is the factor.

Evidence Separating the Syndrome from Bud Mite Infestation. Following the pruning-time results of the second season, it became apparent that the observed responses to pruning time were best referred to vine physiology and ecology (Barnes, Hemstreet, and Turzan, 1952). Nevertheless, it seemed necessary to obtain further data to separate this abnormal vine condition from that presumed to be caused by bud mites, since, as previously noted, the symptoms were included in a syndrome presented as diagnostic for "grape bud mite injury." Beginning in November of 1951, a weekly sample of 50 buds was taken in the experimental Mataro vineyard and examined for presence of bud mites. A total of 700 buds from all portions of the vineyards were thus examined during the following winter. No bud mites (*Eriophyes vitis*) were found. Abnormal growth, however, was severe in the spring of 1952 (see fig. 14) and was in association with pruning time. Since extensive sampling failed to detect the presence of this eriophyid, yet vines pruned at unfavorable times were severely affected in spring, this would appear to establish that the symptoms under study are not related to the presence of bud mites. As will be presently shown, application of borax corrects the symptoms, and this constitutes further evidence that eriophyid mites are not involved.

Observations on Cuttings. The fan-shaped leaves on affected Mataro canes somewhat resemble the effects of the fanleaf virus on grape, which produces a wide basal sinus and distortion of leaves on some but not all grape varieties. In November, 1951, three cuttings were taken from each of 10 of the Mataro vines in the pruning time plots. Canes were selected which showed moderate to severe shortening of the basal internodes. These were forwarded to Dr. W. B. Hewitt, University of California, Davis. The cuttings were rooted and during the first two seasons growth appeared normal for the variety.[3]

[3] Private communication, W. B. Hewitt, Department of Plant Pathology, University of California, Davis, California.

OTHER INVESTIGATIONS

Results of pruning-time experiments, while demonstrating the value of late time of pruning in affected vineyards, are not an entirely satisfactory practical solution and have little explanatory value. Some symptoms remain even on late-pruned vines, and yield may possibly be affected though cane and leaf symptoms are slight. Vineyardists find it difficult to prune affected vineyards during the consistently favorable period in late March because of the relatively short duration of this period in relation to the acreage which must be pruned. Demonstration of pruning time as a factor provides a key to the solution of the problem, since severe symptoms may be produced consistently and the efficacy of corrective measures may thereby be more readily tested.

Varying the Length of the Spur. The experimental vines of the 1952 weekly pruning trial were pruned to two-bud spurs. When records for the apical buds are compared with the lower buds, we find the following: bud emergence in spring occurred at the same time regardless of position; the total bud development ratings (see legend, fig. 13) on April 8 for apical buds being 3,195, for the lower buds, 3,215. However, there were consistently more distorted leaves on shoots arising from the lower buds—a total of 2,724, as compared with 2,222 for the apical buds. This latter relationship was consistent in direction for 16 of the 18 pruning times. Since shoots arising from the apical bud position are apparently less susceptible to development of symptoms than the lower bud, perhaps this relationship extends outward so that a longer spur would give rise to more normal growth from the apical buds than in the case of a two-bud spur, irrespective of pruning time.

TABLE 8

A COMPARISON BETWEEN VINES PRUNED TO FOUR-BUD SPURS AND THOSE PRUNED TO TWO-BUD SPURS, MATARO GRAPES SUBJECT TO ABNORMAL GROWTH

Pruning*	Total no. of buds	Average bud denelopment 4/6/54	Average distorted leaves/cane	Clusters cane	Per cent clusters		
					Normal	Medium	Small
2-bud spur	79	7.6	1.14	0.72	11	39	51
4-bud spur†	77	7.5	0.58	1.14	19	51	30

* January 18, 1954.
† Data from top two buds only.

Additional information on this was obtained as follows. Ten vines were pruned on January 18, 1954, to four-bud spurs; at the same time ten were pruned to the standard two-bud spur. Results are shown in table 8. These data indicate that though the buds leafed out at the same time, shoots from the top two buds of a four-bud spur are less subject to abnormal growth than those from a two-bud spur, having half the incidence of distorted leaves, 37 per cent more bunches per cane, and larger bunches. Since trial of this variable was carried out in only one instance, the results are but an indication. As has been previously noted, however, long canes left growing from the base of Mataro vines bear normal growth regardless of pruning time. It is of interest to note that R. A. Break, formerly farm advisor, Fresno County, suggested long pruning as a remedy for the "grape bud mite" syndrome several years ago. It should be recognized, however, that long pruning hazards overproduction when symptoms are mild. That longer pruning reduces symptoms may be of value in interpretations of the cause of this abnormal growth.

Application of Zinc Sulfate. Applications of zinc sulfate solution were made to the freshly cut ends of spurs during the season 1953–54. This was done on ten Mataro vines in the experimental vineyard at three different pruning times. Ten other vines pruned at the same times served as controls. Single vine plots in ten blocks were used. Results are shown in table 9. These show that in each case swabbing spurs with zinc sulfate—the usual practice for curing zinc deficiency on grapes—resulted in a distinct increase, averaging 37 per cent, in number of distorted leaves. Similarly, such treatment resulted in a 20 per cent reduction in number of clusters, and a substantial increase in proportion of small clusters. Apparently, application

TABLE 9

EFFECT ON SYMPTOMS FROM APPLICATION OF ZINC SULFATE TO FRESHLY CUT SPURS*

	Pruning time		Distorted leaves/ cane	Clusters per cane	Size clusters		
					Normal	Medium	Small
A	12/21/53	Treated	1.68	1.13	9	43	48
	12/21/53	Untreated	0.95	1.37	18	53	29
B	12/28/53	Treated	1.85	0.77	11	36	52
	12/28/53	Untreated	0.87	0.85	26	42	32
C	1/11/54	Treated	2.24	0.71	2	34	63
	1/11/54	Untreated	1.80	1.04	9	41	50
Average		Treated	1.92	0.87	7	38	54
		Untreated	1.21	1.09	18	45	37

* Ten vines treated, ten untreated, each date; treatment, 2 pounds zinc sulfate per gallon of water; records taken 6/23/54.

of zinc sulfate is in some manner deleterious to vines with this abnormal growth, enhancing symptoms. This may simply be a matter of slightly advancing time of leafing. This occurred two out of three times, following application of zinc sulfate.

Soil Application of Borax. Although not recognized in California prior to these studies, boron deficiency has been reported in grapes in several other areas, e.g., South Carolina (Scott, 1941), Australia (Jardine, 1946), Germany (Wilhelm, 1952; Gärtel, 1953), Portugal (Dias, 1953), and other countries.

A study was initiated to correlate soil application of boron with pruning time to find out if applications of boron would reduce symptoms. Borax was applied to a block of 32 vines. Leaving two buffer rows between, 20 check vines were located on each end of the treated block. The treated vines received two soil applications of borax at 1 ounce per vine. The first application was January 19, 1952. No data were available as to the first-year results of this treatment, since it was not known at that time that only early January pruning times consistently result in severe symptoms. All vines, treated and untreated, received a favorable February pruning time in 1952 and very few symptoms were present in 1952 on any of the vines. No further observations were made until the 1956 season. A second treatment at the same rate of application was made on November 2, 1955. This was followed by a midwinter pruning time, January 9, 1956, on all vines. Severe symptoms developed only on vines which did not receive boron, growth on treated vines being practically normal. All vines leafed out early, as compared with adjacent vines which were pruned in March (Barnes and Jones, 1956).

TABLE 10

EFFECTS OF SOIL APPLICATION OF BORAX ON LEAF SYMPTOMS AND NUMBER AND SIZE OF FRUIT FORMS, MATARO GRAPES, ALTA LOMA*

	Number of distorted leaves per 100 shoots	Number of fruit forms per 100 shoots	Size of fruit forms (per cent)			Yield tons per acre
			Large	Medium	Small	
Plus borax	98†	93	22	26	52	3.3
Untreated	405	41	1	18	81	2.3

* Records, except for yield, taken May 16, 1956. Yield records taken October 15, 1956.
† Difference highly significant (99:1) as compared with untreated. Leaves from borax treated plot classified as "distorted" even when a trace of malformation present. Difference in symptoms best shown in fig. 16.

Figure 16 shows the response obtained by borax application. This response viewed in early spring was more dramatic than records on leaf distortion taken in May would indicate. These records on leaf symptoms together with number of fruit forms are presented in table 10.

Treated vines had over twice as many inflorescences per cane and these were larger than those on untreated vines. Analyses by W. W. Jones of the boron content in samples of the second basal leaves taken from treated and untreated vines on May 2, 1956, are as follows:

	p.p.m. Boron
Plus borax	78.5
Untreated	23.0

This amount of boron in the leaves from untreated vines is in the deficiency range for this element (Scott and Schrader, 1947).

It should be noted that it is not possible to tell whether the vines were responding in 1956 to the borax applied in 1952 or to that applied in the fall of 1955.

Again in 1957, these plots were pruned at an unfavorable time, January 7. As before, all vines leafed out early, the treated vines growing normally in early season, while untreated vines displayed moderate to severe abnormal growth. Leaf samples (the second basal leaf) were taken on April 16 and analyzed for boron by W. W. Jones. The results are as follows:

Fig. 16. Mataro grapevines. Top: untreated vine. Bottom: vine in plot receiving soil treatment of borax. Each vine pruned January 9, 1956. Vines leafed out at the same time.

	p.p.m. Boron
Plus borax	92, 85
Untreated	27, 30, 25, 25

This response to soil application of borax providing practically normal early-season growth, and the attendant increase in boron in the leaves of treated vines above the deficiency range constitutes good evidence that this abnormal growth is caused by a temporary, early-season deficiency of boron. Scott (1944) observed throughout his studies with grapevines that boron deficiency symptoms developed early in the growing season but failed to appear in later growth of the shoot. This fits well with observations on the experimental Mataro vines and on other varieties. His observations strongly suggested a "very close relationship between boron nutrition and fruit setting of the grape." He asks whether it is possible that millerandage of grapes and the related physiological trouble, coulure, are related to boron nutrition. Gartel (1954) records an hypothesis that boron deficiency is related to coulure and parthenocarpy through its effects upon pollen germination. Early season boron deficiency on pear is also of interest (Batjer, Rogers, and Thompson, 1953).

With evidence of a response to borax application from but one area, it may not be considered finally established that abnormal growth which responds to pruning time in other areas is caused by early-season boron deficiency. However, since identical symptoms have been observed elsewhere on Mataros, this appears to be an excellent working hypothesis. If true, there appears to be a great deal of early-season boron deficiency in Sonoma County (Sisson, 1950; 1952; 1953). Additionally, the writer has seen early-season abnormal growth (referred to locally as "bud mite injury") in Tokay vineyards near Lodi and on Muscat of Alexandria near Fresno which he believes would respond to pruning time and which, therefore, may be related to poor boron nutrition in early season.

SUMMARY

It is shown that a syndrome of abnormal growth on spur-pruned vinifera grapes in California, formerly included under "grape bud mite injury," is related to the effects of pruning time upon time of leafing and occurs in the absence of the bud mite, a bud-inhabiting strain of *Eriophyes vitis* (Pgst.).

Evidence is presented which indicates that this vine condition is caused by a temporary, early-season deficiency of boron. Soil applications of borax resulted in virtually normal growth and elevated the boron content of leaves above the deficiency range.

Applications of zinc sulfate solution to cut ends following pruning increased severity of symptoms.

In affected vineyards, pruning times which cause early leafing result in shortened basal internodes, excessive laterals, reduced crop, and leaf abnormalities. Leaf abnormalities vary greatly with variety and apparently are of good diagnostic value. The number of distorted or abnormally shaped leaves per cane was shown to be correlated with other symptoms, including crop reduction, and is therefore a good objective index. In affected vineyards,

length of shoot after growth has started is a less reliable index of time of leafing than bud development records. This is so because affected shoots grow slowly and though leafing early, may be outdistanced by normal shoots leafing later.

From replicated monthly and weekly pruning time studies, it was shown that the length of the winter period during which buds on the Mataro variety respond to a nearby pruning wound, by early leafing and developing severe symptoms, varies from season to season. Generally, this response begins about mid-December and extends through mid-January and in some years through the first part of February. Pruning times which result in late leafing, e.g., late March, are followed by virtually normal growth.

Pruning time responses, i.e., alleviation of symptoms by late pruning times resulting in late leafing, were also observed on Muscat of Alexandria and White Malaga.

It is not known whether such pruning-time responses are in all cases related to temporary early-season boron deficiency, but this appears to be an excellent working hypothesis. Since pruning time responses have been recorded in northern California vineyards subject to "bud mite injury," this suggests that this abnormal growth be re-investigated in the light of the possibility of temporary early-season boron deficiency as a causal factor.

ACKNOWLEDGMENTS

The author is indebted to Mr. Edward Meyer, who recalled the locations of his pruning crew in his 400-acre vineyard during the winter of 1948–49, and thus provided the clue which initiated these studies and to Mr. Homer Washburn of Garrett and Company for his unfailing cooperation in organizing pruning and harvesting operations in the five-year experiment. W. W. Jones and R. T. Wedding, University of California Citrus Experiment Station, suggested the application of boron. Professor A. J. Winkler, University of California, Davis, provided advice, interest, and support in these studies. A. A. McCornack, formerly farm advisor, San Bernardino County, and C. E. Hemstreet of the same office, and C. L. Turzan, R. D. Garmus, and C. R. Ash, formerly Senior Laboratory Technicians, University of California Citrus Experiment Station, assisted on many occasions in the gathering of records and the making of observations relating to these studies. Jeanne Titus, formerly Statistician, University of California Citrus Experiment Station, carried out the statistical analyses on the five-year yield data. To all of these individuals, the author wishes to express his thanks and appreciation.

LITERATURE CITED

BARNES, M. M., and A. A. McCORNACK
1951. Grape bud mite injury. California Agr. **5**(1) : 5.
BARNES, M. M., C. L. HEMSTREET, and C. L. TURZAN
1952. Pruning time studies on grapes. California Agr. **6**(2) : 6, 14.
BARNES, M. M., and W. W. JONES
1956. Boron deficiency in grapes. California Agr. **10**(8) : 12.
BATJER, L. D., B. L. ROGERS, and A. H. THOMPSON

1953. "Blossom blast" of pears; an incipient boron deficiency. Amer. Soc. Hort. Sci. Proc. **62**: 119–22.

CHANDLER, W. H.
1942. Deciduous Orchards. 438 pp. (see pp. 58–9), Lea & Febiger, Philadelphia.

CHANDLER, W. H., and D. S. BROWN
1951. Deciduous orchards in California winters. California Agr. Ext. Serv. Circ. **179**: 1–38.

DIAS, HUMBERTO FRANCISCO
1953. Informacao sobre a "maromba" do Douro. Federacao dos Vinicultores da Regiao do Douro. Bol. da Casa do Douro, No. 85. *Abstracted in:* Rev. Appl. Myc. **33**: 336–37. 1954.

DUNCAN, D. B.
1953. Significance tests for differences between ranked treatments in an analysis of variance. Va. Poly. Inst., Dept. Statis., Tech. Rpt. No. 3.

DU PLESSIS, S. J.
1950. Virus diseases and some symptomologically related abnormalities of the vine. Stellenbosch Univ. Ann. **26**, sec. A (13): 1–33.

GÄRTEL, WILHELM
1953. Symptoms of boron deficiency in vine. Rhein. Weinz. 3: 64 *Abstracted in:* Hort. Abs. 24: (abs. no. 2404). 1954.
1954. Les effets de la carence en bore sur la vigne. Progrès Agr. et Viticole 142: 273–79.

HILGARD, E. W.
1884. The muscat in the southern mesa. California Agr. Exp. Sta. Bul. **17**: 1.

JARDINE, F. A. L.
1946. The use of borax on Waltham Cross grapes in the Stanhope district. Queensland Agr. Jour. **62**: 74–78.

KIDO, HIROSHI, and E. M. STAFFORD
1955. The biology of the grape bud mite *Eriophyes vitis* (Pgst.). Hilgardia **24**: 119–42.

MAIER, W.
1936. Boron deficiency symptoms in vine seedlings grown in water cultures. Gartenbauwissenschaft **11**: 1–16. *Abstracted in:* Herb. Abs. **7**: 121 (abs. no. 322). 1937.

SCOTT, L. E.
1941. An instance of boron deficiency in the grape under field conditions. Amer. Soc. Hort. Sci. Proc. **38**: 375–78.
1944. Boron nutrition of the grape. Soil Sci. **57**: 55–65.

SCOTT, L. E., and A. L. SCHRADER
1947. Effect of alternating conditions of boron nutrition upon growth and boron content of grapevines in sand culture. Plant Physiol. **22**: 526–37.

SINGH, L. B., and N. N. DIKSHIT
1952. Studies in introducing earliness in maturity of grapes (*Vitis vinifera* Linn.). I. Effect of early pruning on the growth of vines and maturity of fruits. Indian Jour. Hort. **9**(3): 20–25. *Abstracted in:* Herb. Abs. **23**: 240 (abs. no. 1599). 1953.

SISSON, R. L.
1950. The grape bud mite in Sonoma County. California Agr. Ext. Serv., Sonoma County. 5 pp. (Processed.)
1952. The effect of differentially timed pruning on grape vines in Sonoma County and further observations on the grape bud mite. California Agr. Ext. Serv., Sonoma County. 6 pp. (Processed.)
1953. Vineyard pruning time effects. California Agr. Ext. Serv., Sonoma County. 8 pp. (Processed.)

SMITH, L. M., and E. M. STAFFORD
1948. The bud mite and the erineum mite of grapes. Hilgardia **18**: 317–34.
1950. Grape bud mite problem. California Agr. **4**(9): 3–4.
1955. Grape insects in California. California Agr. Ext. Serv. Circ. **445**: 1–62.

STAFFORD, E. M., and HIROSHI KIDO
1952. Grape bud mite studies. California Agr. **6**(4): 4.

WEINLAND, H. A.
1947. Erinose mite, a major pest. The Grape Grower **1**(5) : 17.
WILHELM, A. F.
1952. Bormangel bei der Weinrebe *Vitis vinifera* L. Phytopath. Ztschr. **19**: 129–59. *Cited in:* Christ, E. G., and Albert Ulrich, "Grape Nutrition," *in* Mineral Nutrition of Fruit Crops, Hort. Pubs., Rutgers Univ., 1954.
WINKLER, A. J.
1934. Pruning vinifera grapevines. California Agr. Ext. Serv. Circ. **89**: 1–68.

4m-12,'58(5649)JW 141

The journal *Hilgardia* is published at irregular intervals, in volumes of about 600 pages. The number of issues per volume varies.

Subscriptions are not sold. The periodical is sent as published only to libraries, or to institutions in foreign countries having publications to offer in exchange.

You may obtain a single copy of any issue free, as long as the supply lasts; please request by volume and issue number from:

Agricultural Publications
University of California
Berkeley 4, California

The limit to nonresidents of California is 10 separate issues on a single order. A list of the issues still available will be sent on request.