Effect of Crop Level on Growth, Yield and Wine Quality of a High Yielding Carignane Vineyard

B. BRAVDO[1], Y. HEPNER[2], C. LOINGER[3]
S. COHEN[4], and H. TABACMAN[5]

Three crop levels were induced by cluster thinning in a high yielding Carignane vineyard. Reduction of cluster number from about 60 to 40 per vine did not result in reduction of yield, since berry size and number per cluster were increased. Pruning weight of the thinned treatment was increased and so was the capacity of the vines. Further thinning to 20 clusters per vine reduced the yields since the increase in berry size and number was not sufficient to compensate for the reduced number of clusters. The yield to pruning weight ratio was found to be a good measure for crop load. Crop load reduction from 19.6 to 12.0 kg fruit per kg prunings increased wine quality and a further reduction to 8 did not. It was concluded that crop loads above 12 have conspicious effects of overcropping, *i.e.*, reduced wine quality, color quality and intensity and total ash, delayed maturation, reduced rate of sugar accumulation, must acid concentration at comparable sugar content, proline and amino acids content, bud fertility, and pruning weight. In high yielding cultivars, the crop load ratio has a more relevant effect on wine quality than the crop level as such.

The intensification of Israel's vineyards due to the introduction of drip fertigation and virus free plant material has increased the danger of overcropping, especially in highly productive cultivars like Carignane. The effect of crop levels on the growth of the vines and on the quality of the fruit and the wines was not always found to be consistent (8,12,13,15,23,24,26). Even within the same cultivar, higher crops were not always associated with lower quality (15,16,22,24). It may well be that various results reported were inconsistent because crop level alone is an insufficient measure for cropping. There is need for a measure which will clearly define overcropping, undercropping, or normal cropping. Such a measure should be related to the capacity, a term which represents both vegetative growth and crop yield (27). Since capacity is expressed as the total weight of the vine, it is not a practical measure for field use. Leaf area to fruit weight ratio was successfully used for the study of crop load effects on fruit quality (13,14,25). This also is an inconvenient measure for practical use. Pruning brush weight was measured and reported in several studies (7,10,17,24). This is an interesting measure, since it is correlated with leaf area (17) and linked to the capacity due to the relatively high fertility of grapevines compared to other fruit trees. When vines are properly pruned, the brush weight should be proportional to the number of spurs and canes retained, and therefore to crop yield. We have suggested the employment of the weight ratio of crop yield to prunings as a measure for crop load (2,3,9). Values of this ratio were reported in some studies (8,15,28), but no attempt was made to analyze this data in terms of crop load. High crop levels have been found to delay sugar accumulation in some studies (2,3,9,22,24,27), but no effect was found in others (8,15). High crop levels reduced total titratable acidity when harvested at sugar contents similar to lower crops (2,9,10,22), but in other reports (8,15) no such effect was observed. Wine color was not affected by crop levels (8,26), was reduced by high crop levels in Carignane but not in Cabernet Sauvignon (2,9), or was even found to increase in nonirrigated high cropped plots (15). Wine quality was found to be reduced at high crop levels (2,7,9,10), but in other studies no effect or even a positive one was reported for various cultivars (2,9,27). A better potential for aging was found in low cropped Carignane and Grenache vines, although no quality differences were reported (24). Loinger and Safran (16) reported that medium yields of Semillon produced better wines than high and low yields. Freeman *et al.* (8) found no effect of crop level on the quality of Carignane wines. We have found that high crop levels reduced wine quality of Carignane, but not of Cabernet Sauvignon (2,3,9). It seems, therefore, that a better knowledge of the mechanism of crop level effect on wine quality is needed in order to understand the reasons for the different results reported in literature. In this paper, we report the results of a six year experiment in which the effect of three levels of cropping on various parameters of growth and quality were studied.

Materials and Methods

A field experiment was conducted on virus free Carignane grafted on 110R rootstock, at Mazkeret Batya in the coastal plain of Israel during the years 1976 to 1981. The vineyard was planted in 1971 with 1630 vines per hectare (3.5 × 1.75 m) on deep brown to gray alluvial soil containing about 50% clay, 25% silt, and 25% sand with 1 to 1.5% organic matter in the upper layer and pH of 7.5 to 7.8. Water and fertilizers were applied by four L/h drippers spaced 1.5 m apart on a single lateral per row. Irrigation was applied weekly and totalled 200 mm per season, an average of 0.2 class A pan evaporation coefficient, and this in addition to 450 mm average winter rainfall. Ammonium nitrate and potassium chloride were applied weekly throughout April, totalling 120 kg/ha N and 100 kg/ha K, respectively.

Three crop load treatments by cluster thinning were established immediately after blooming as follows: Treatment 1 (UT) - unthinned control, about 60 to 70 clusters per vine; Treatment 2 (MT) - moderately thinned, 40 clusters per vine retained; Treatment 3 (ST) - severely thinned, 20 clusters per vine retained. Each treatment

[1,2]The Hebrew University of Jerusalem, Faculty of Agriculture, P. O. Box 12, Rehovot, Israel 76100. [3,4,5]Israel Wine Institute, Rehovot, Israel.

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consisted of four replicates in a randomized block design, 10 vines per replicate. Each plot was harvested when the fruit sugar content reached 21.5° to 22.0° Brix.

One hundred berries were periodically sampled for berry weight and composition determination. The berries were crushed by a Waring blender, filtered through cheese cloth, and the resultant juice was used for qualititative analyses. A pH meter was used for determining the end point of total acid titration with NaOH at pH = 8.3. About 25 kg fruit per plot were sampled at harvest, and wine was made by standard minivinification techniques at the Israel Wine Institute. Potassium of musts and wines was assayed after HCl digestion (21), proline by colorimetry using ninhydrin reaction (18). Amino acids (AA) were quantified by AA analyzer, starch was measured as glucose after enzymatic hydrolysis (6), tannins as general polyphenols (19,20). Wine color was tested colorimetrically as absorbance at 420 and 520 nm, color intensity as sum of readings at 420 nm + 520 nm, and color quality as the absorbance ratio of 420/520 nm. The total extract was computed by deducting the density of water plus ethanol from that of wine, reduced extract by a further deduction of wine sugar. Tartaric, malic, and lactic acids were determined by paper chromatography.

Wine quality was expressed on a 0 to 20 tasting score system (5), integrating color, aroma, taste, and harmony scores. The tasting was performed by the regular panel of the Israel Wine Institute. The data were subjected to analysis of variance followed by multiple range test, according to Student-Newman-Keuls.

Treatment means not marked by a common letter differ significantly at P = 0.05 in the Figures and Tables, unless stated otherwise.

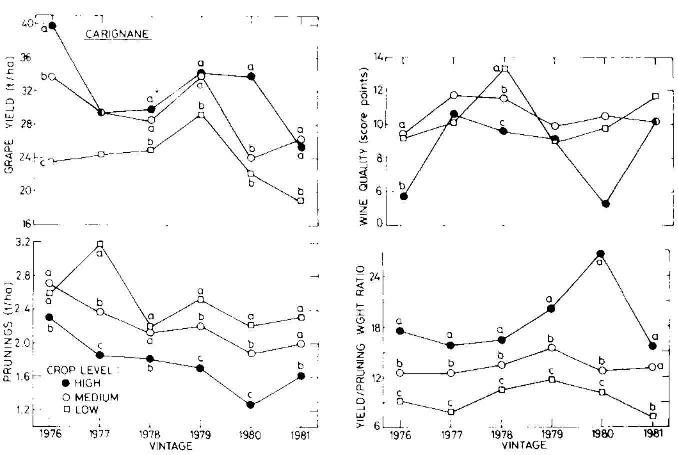

Fig. 1. Effect of crop levels induced by cluster thinning on annual yields, pruning weight and wine quality of Carignane vines. Treatment means not marked by a common letter differ significantly at P = .05.

Results

Fruit yields of the unthinned (UT) and the moderately thinned (MT) treatments were almost identical in four out of the six experimental years, and only in the first and fifth year was a higher yield obtained in the UT treatment (Fig. 1). The smaller number of clusters in MT was largely compensated for by the increase in the number of berries per cluster and their size (Table 1, Fig. 2). Severe cluster thinning (ST) yielded significantly less fruit than the other two treatments every year (Fig. 1), since the

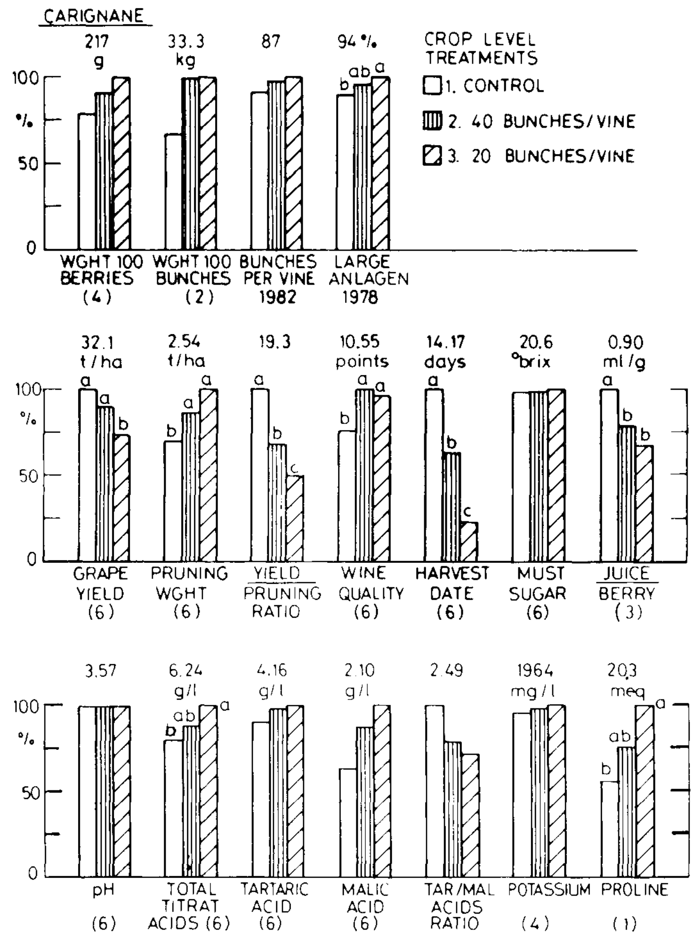

Fig. 2. Effect of crop levels induced by cluster thinning on some growth, yield, quality and composition parameters of Carignane (Multiannual means. Number of years is indicated in parenthesis. The highest mean presented as 100% and its absolute value appears above the columns). Statistics as in Fig. 1.

Table 1. Effect of crop levels induced by cluster thinning on some yield parameters of Carignane in 1979[3].

Crop level treatment	Yield		Berry weight		Bunch weight		Bunch/vines		Berries/bunch	
	t/ha	%[2]	g	%	g	%	no.	%	no.	%
UT (High Crop)	a 34.3	100.0	2.20	100	c 356	100	a58	100	162	100
MT (Medium Crop)	a 33.8	98.5	2.44	111	b 555	156	b 37	64	227	140
ST (Low Crop)	b 29.3	85.5	2.55	116	a 617	173	c 29	50	242	149
F significance[1]	**		+		***		***		+	

[1] significance level of .05*, .01**, .001***, not computed+

[2] relative to 100% levels in UT treatment

[3] Numbers not followed by a common letter differ significantly.

Table 2. Effect of crop levels induced by cluster thinning on amino acid content of Carignane must in 1979.

Crop level treatment	glycine GLY	alanine ALA	valine VAL	isoleucine ILE	leucine LEU	tyrosine TYR	arginine ARG	proline PRO	asperagine ASP	threonine THR	glutamine GLU
	AMINO ACIDS (mmol/L)										
UT (High Crop)	b0.09	1.58	0.39	a0.11	a0.14	b0.04	1.07	5.41	0.36	0.92	b0.88
MT (Medium Crop)	a0.16	1.96	0.36	b0.07	a0.11	a0.08	1.60	7.39	0.41	1.11	a1.64
ST (Low Crop)	a0.15	2.08	0.33	c0.03	b0.07	a0.06	1.66	6.17	0.59	1.10	a1.43
average	0.13	1.88	0.36	0.07	0.11	0.06	1.45	6.33	0.45	1.05	1.32
F	8.42*	2.41	0.82	53.2***	12.2**	5.53*	1.18	1.04	2.97	0.61	6.67*
S.E.	.013	.169	.029	.005	.010	.009	.299	.981	.072	.135	.152

Statistics symbols as in Table 1.

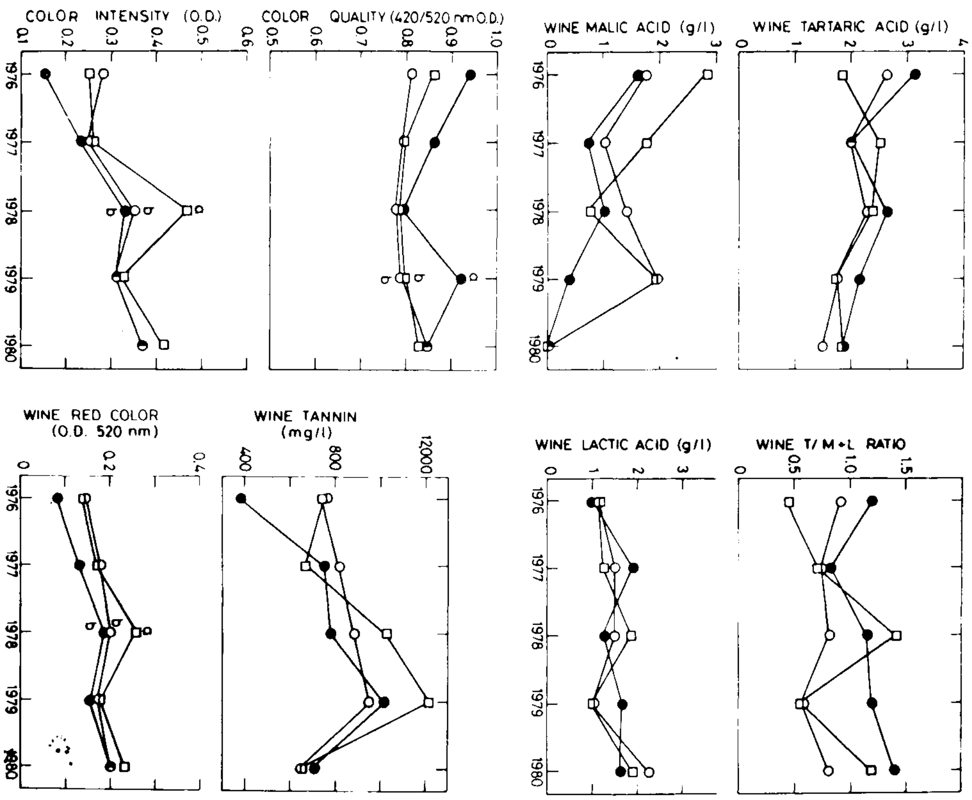

Fig. 3. Effect of crop levels induced by cluster thinning on the content of some acids tannin and on the color of the wines (annual averages). Statistics as in Fig. 1.

number and weight of berries only partially compensated for the reduced number of clusters (Table 1, Fig. 2). The larger clusters of the thinned treatments have already been observed in the relative size of the anlagen in bud analysis carried out in the winter prior to the 1979 season (Fig. 2). Moreover, the number of clusters per vine in the spring of 1982 prior to thinning was found to be significantly higher in the MT and ST treatments than in the control.

The differences in pruning weights between the treatments were greater than in the crop yields and fluctuated in opposite directions (Fig.1). Moreover, MT was closer to ST in pruning weight and closer to UT in yields throughout the entire experimental period. Crop load, expressed as yield to pruning weight ratio, was greatly affected by the cropping treatments (Fig. 1). The crop load varied from 16 to 27 in UT, from 12 to 15 in MT, and from 8 to 12 yield to pruning weight ratio in the ST treatment (not shown).

The quality of wines produced from the UT treatment was significantly inferior to that of the other two treatments (Figs. 1, 2). In this treatment, unlike the others, seasons with the highest crop loads had the lowest wine quality, and *vice versa* (Fig. 1). Moderate thinning (MT) caused less fluctuations in pruning weight, crop load and wine quality than the unthinned (UT) and severely thinned (ST) treatments.

Relative mean levels of various parameters for the entire six year period are presented in Figures 2 and 5. Fruit thinning treatments reduced yields, crop load (yield/pruning weight ratio), juice/berry ratio and advanced the harvest date (Fig. 2). Significant differences were obtained between crop load and harvest date in all the treatments. Crop yield was significantly lower only in ST, and pruning weight and wine quality only in the UT treatment. Total titratable acids and proline in the must rose significantly with thinning, while tartaric, malic acids, and potassium tended to rise (insignificant). No treatment effects on must sugar and pH were observed (Fig. 2). The tartaric to malic acid ratio tended to rise with the increase in crop load.

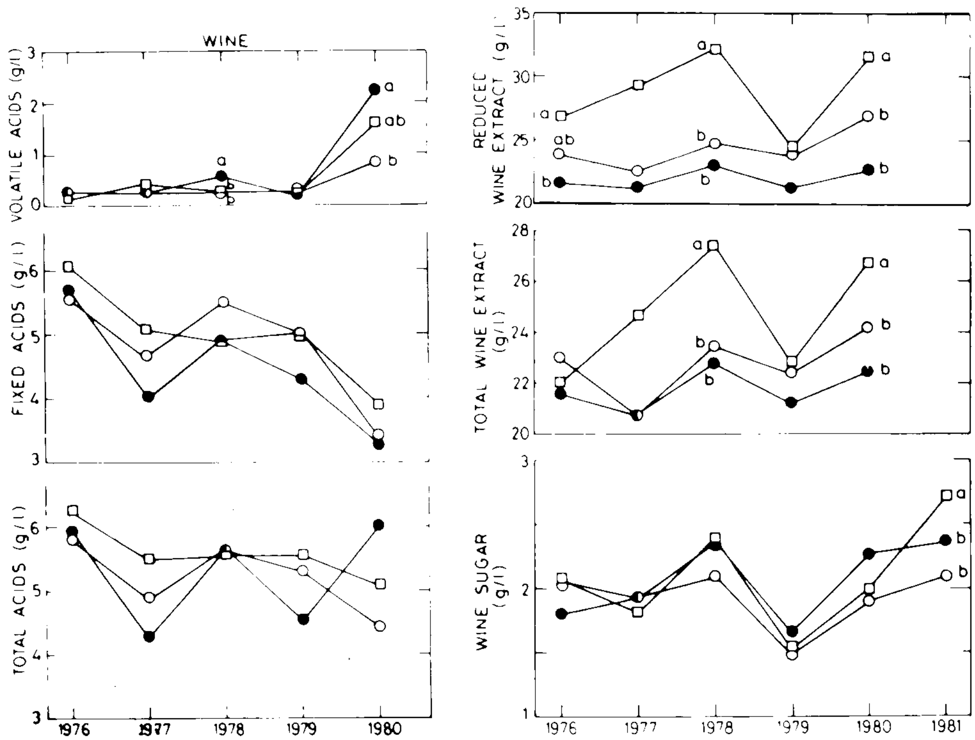

Fig. 4. Effect of crop levels induced by cluster thinning on sugar and extract content and some acids of the wines (annual averages). Statistics as in Fig. 1.

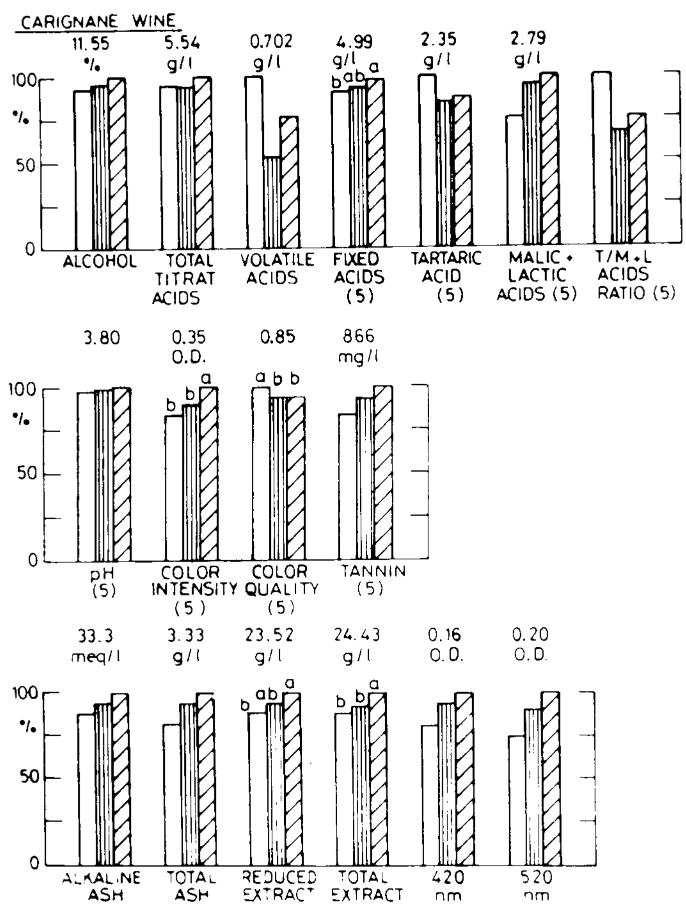

Fig. 5. Effect of crop levels induced by cluster thinning on the composition of wines (Six year averages except when number of years are indicated in parenthesis. See Fig. 2 for additional information). Statistics as in Fig. 1.

The amino acid content in the must was found to be lower in high crop treatment UT, although significance was recorded only for glycine, tyrosine, and glutamic acid (Table 2). Leucine and isoleucine were present in very low concentrations but increased with crop load.

The effects of cluster thinning on wine composition are presented in Figures 3, 4, and 5. Fixed acids and wine extracts were increased with thinning. Volatile acids were high in the UT wines in two years, but the five year average did not vary significantly (Figs. 3 and 5). The exceptionally high volatile acid content in 1980 coincides with the low quality wine score (Fig. 1). The UT wines tended to maintain a relatively high level of tartaric acid and a low level of malic acid (Figs. 4 and 5), and this led to a relatively high ratio of tartrates to malates + lactates. Malic and tartaric acids tended to decrease during the years, whereas color intensity increased. The UT wines had poor color intensities, particularly red color, and their color qualities were inferior (Figs. 4 and 5). The ST wines had a very high color intensity and T/M+L acid ratio in 1978 (Fig. 4), when they attained an exceptionally good wine quality (Fig. 1). The MT wine parameters were less subjected to fluctuations throughout the years than UT and ST (Figs. 3 and 4).

Treatment means for the entire period show that UT wines had less fixed acids, color intensities and extracts and tended to have less alcohol, tannin, ash, red and yellow color than wines from the thinned treatments (Fig. 5). No effect of cluster thinning on the pH was observed.

Discussion

The thinning of whole clusters immediately after bloom caused a significant reduction in yields only when two thirds or more of the clusters were removed (Figs. 1

and 2). The vines reacted to cluster thinning by an increase in berry size, number of clusters formed, and the number of berries per cluster (Figs. 1 and 2, Table 1). It seems that in addition to the direct effect on berry size, there was an indirect and cumulative effect on fertility. This is supported by the enlarged size of anlagen primordia found in microscope examination and by the tendency for a greater number of cluster production by thinned vines than by unthinned ones (Fig. 2). Moreover, the increase in the number of clusters formed exceeded the increase in the number of spurs left at pruning (not shown).

In spite of the fact that the yields of MT were almost the same as of UT, the pruning weight in MT increased significantly, and the ratio of crop yield to pruning weight decreased (Figs. 1 and 2). It appears, therefore, that the ratio of crop yield to pruning weight rather than the yield level *per se* affected most of the yield, growth, and quality parameters presented in this paper. This is consistent with the results obtained with leaf area to fruit ratio experiments (11,12,14,27), and seems to be a more practical and easier measure. Both ratios well represent the crop load, *i.e.*, the fruit yield relative to the vegetative growth of the vine. Pruning weight is a similar measure to leaf area, since both were found to be correlated (11,14,17,23,27).

The fact that cluster thinning reduced the crop load without reducing the fruit yield in MT also indicates that probably most of the negative effects of overcropping occur during early summer, when several important physiological functions, like linear shoot growth, phase 1 of berry growth, and fruit bud differentiation take place.

The unthinned UT treatment was undoubtedly overcropped. This is confirmed by low acid content at comparable Brix levels, low proline, low potassium content of the must and leaves, reduced growth and yield levels and delayed ripening, as found elsewhere (7,23,24). It is also reflected by the mirror image curves of annual variations in UT crop load and wine quality (Fig. 1) which demonstrate the inverse relations between them at this range of crop load values. Such a relationship is not apparent when wine quality variations are compared to variations in yield and pruning weights. The reduction in crop load from about 13 yield/pruning weight ratio in MT to 10 in ST did not improve the average wine quality for the six years. Some very good ST wines were obtained in 1978 and 1981, but quality fluctuations in this treatment were considerable and no relationship to crop load fluctuations was apparent (Fig. 1). This shows that ST was not undercropped. Its vigor, which was expressed in the 2.5 t/ha pruning weight, did not compete with the clusters for sugar accumulation or consumption.

The larger juice content per gram of fruit in the overcropped treatment UT (Fig. 2) is probably due to thinner skin and fewer seeds than in the low crop load treatments, but this is not certain. Amino acid content of the must was low in the UT musts which produced inferior wines, and this is consistent with the findings of others (1) where higher amino acid contents, especially arginine and proline, increased the fermentation rate and produced a more intensive aroma. Nevertheless, it cannot be concluded that amino acid content is always correlated with quality since it was found that certain irrigation treatments increased the amino acid content of must and reduced wine quality (2).

The present study shows that crop load is a dominant factor in producing must and wine quality. A comparison with other studies of crop level effect is possible only where pruning weight data were reported. Carignane in California (15) attained a crop yield similar to that of the present experiment, about 32 t/ha, in the unthinned treatment, but due to a wider spacing the capacity of the vines in their experiment was much higher and the crop load much lower. Plots yielded 30.6 kg/vine in their experiment, while ours yielded 19.4 kg/vine only. Nevertheless, the unthinned UT in Mazkeret Batya, Israel, was overcropped, and the corresponding treatment C2 in California was not. Cluster thinning reduced crop load in the present experiment from 19 to about 12 and 10, and consequently many typical overcropping phenomena were eliminated and wine quality improved. When crop load was reduced from 6.7 to 4.6, wine quality was not improved, and other typical overcropping phenomena were not conspicuous (15). It appears that at low crop load values (below 10), the crop yield level is not a dominant factor for wine quality. Van Zyl *et al.* (28) have raised yields of Chenin blanc in South Africa by about 50 percent without affecting the crop load (which remained around 7 to 8) and the wine quality. Kasimatis (10) showed that when the crop load of Zinfandel vines was reduced from 14.3 and 10 to values below 10 a considerable increase in aroma quality and taste intensity was recorded, but no differences in quality were obtained at crop loads between 4.24 and 7.48, and this is similar to the results of Kliewer *et al.* (15). Fisher *et al.* (7) found in de Chaunac vines that cluster thinning did not change the yield level of 8.8 kg/vine, but increased vigor, reduced crop load from 11.2 to 6.9 and resulted in a superior fruit quality. Weaver *et al.* (24) found no effect of overcropping on wine quality of Carignane and Grenache in California. We have calculated their crop load values to range between 4.5 to 13.2 and from 2.2 to 7.9 yield/pruning weight ratio in Carignane and Grenache, respectively. Most of their figures, however, were below 10 and are comparable to the range in which we also did not observe any crop load effects. Weaver and Pool (26) studied cropping level effects induced by pruning severities. The crop load values (our calculations) for Thompson seedless, Carignane, and Ribier were 3.7 to 8.8, 6.0 to 10.9, and 9.3 to 18.1, respectively. The authors concluded that all three cultivars were resistant to overcropping since three years of overcropping did not weaken the vines. Nevertheless, characteristic symptoms of overcropping, like delayed maturation, straggly clusters with small berries and reduced levels of carbohydrates in the roots were apparent. According to our scale of crop load, only Ribier was overcropped. Unfortunately, no wine was made from these varieties, quality values are absent, and it is therefore difficult to estimate the effect of overcropping in this case.

Conclusions

Crop yield level is not a sufficiently good measure for overcropping. The crop yield to pruning weight ratio seems to be a more reliable measure for cropping effects.

Overcropping effects in Carignane start to appear at crop load values above 10 to 12 yield to pruning weight ratio. The main effects are: reduced wine quality and color; delayed maturation; reduced titratable acids at comparable Brix levels; reduced must proline concentrations; increased juice per gram of fruit; and reduced vegetative growth, expressed as pruning weight.

Delayed maturation due to slowing down of sugar accumulation is a very sensitive measure for crop level and appears also at low crop load ranges where wine quality is not affected. Reduced titratable acid at optimal or comparable sugar content is a good measure for overcropping.

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