Influence of Crop Load on 'Chambourcin' Yield, Fruit Quality, and Winter Hardiness under Midwestern United States Environmental Conditions

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Abstract

The effects of various crop levels on vegetative growth, yield components, fruit composition and winter hardiness of 'Chambourcin' grapevines were evaluated in Illinois and Ohio for two and four years, respectively. In the Illinois study, treatments consisted of three pruning levels (15, 20 and 25 nodes retained for each 0.454 kg of dormant prunings) and three cluster-thinning levels (1, 2 and 2+ clusters (no thinning) per shoot in year one and 1, 1.2 and 1.5 clusters per shoot in year two). Treatments consisted of three cluster-thinning levels of 10, 20, and 30 clusters retained per vine in Ohio. As the number of clusters retained per vine increased, yield increased. Total soluble solids and pH of the grape juice decreased as the number of clusters retained per vine increased. As the number of clusters retained per vine increased, the number of ripened nodes and bud cold hardiness (measured as LT50) decreased. There was little interaction between pruning and cluster thinning treatments in both years of the study in Illinois. 'Chambourcin' grapevines were most affected by cluster thinning treatments in both states. Crop load varied with vineyard geographical location. It was concluded that 'Chambourcin' grapevines grown at a wider spacing and longer growing season in southern Illinois had higher crop load ratios (10 to 14) than those grown at a narrower spacing and shorter growing season in northeast Ohio (4 to 8).

INTRODUCTION

Crop load, the ratio of crop weight and pruning weight, is a practical and reliable indicator of vine balance status between shoot and fruit production (Bravdo et al., 1984; 1985; Howell, 2001; Naor et al., 2002). Crop load is affected by crop level, which is primarily determined by cluster number per vine and vegetative growth determined by node number per vine, retained after pruning. Kliewer and Dokoozlian (2000) defined well-balanced grapevines as those that do not overcrop and ripen their fruit to desired soluble solids with a given accumulation of degree-days. They found that optimum crop loads fall within a specific range of 4 to 10 in several *Vitis vinifera* cultivars. Reynolds et al. (1994; 1995) reported that crop load ratios were higher for the hybrid cultivars, 'Seyval' and 'Chancellor', than for *V. vinifera*. This is primarily due to the bud fruitfulness and larger clusters in most hybrids than in *V. vinifera* cultivars (Reynolds et al., 1986; 1994; 1995). 'Chambourcin' is a French hybrid cultivar with fruitful buds and thus it tends to overcrop (Ferree et al., 2003; Pool et al., 1978). It has a higher disease and winter resistance than *V. vinifera* cultivars, thus it is well adapted to Midwestern and Eastern US environmental conditions. Therefore, 'Chambourcin' is desired by grape producers and has emerged as one of the most promising red hybrid cultivar producing quality wine. However, there are no documented reports on the best methods of cropping this cultivar to achieve the highest sustainable yields and desired fruit quality without sacrificing winter survival. The goal of this study was to identify the optimum crop loads of 'Chambourcin' that can be recommended to grape producers in the Midwestern US. The specific objectives were to determine the effects of different cropping levels on yield, fruit composition and winter hardiness of Chambourcin grapevines grown in a cool, short growing season in Ohio and a warm, long growing season in southern Illinois.

MATERIALS AND METHODS

The climate and vineyard in each location are described in Table 1. In both locations, 'Chambourcin' grapevines were trained to a height of 1.8 m. In the Illinois study, treatments were arranged as a completely randomized design using three-vine plots and replicated four times. The factorial treatments consisted of three pruning levels of 15, 20 and 25 nodes retained for each 0.454 kg of dormant prunings and three cluster-thinning levels of 1, 2 and 2+ clusters (no thinning) per shoot in year one and 1, 1.2 and 1.5 clusters per shoot in year two. In the Ohio study, vines were pruned to 20 buds per vine. Treatments consisted of three cluster-thinning levels of 10, 20, and 30 clusters retained per vine. Each crop level treatment was established on six-vine plots replicated five times in a randomized complete block design. All vines were spur pruned and treatments continued on the same vines for two years in Illinois and four years in Ohio.

Crop weight and cluster number were recorded annually for each vine at harvest. A 100-berry sample was randomly collected from each treatment, weighed and crushed in a food strainer and soluble solids, pH and titratable acidity determined on the juice. Pruning weights per vine were also collected and used to calculate crop load, the ratio between cluster weight and pruning weight per vine. Whole-Vine Photosynthesis (PN) was measured in southern Illinois using an open gas exchange system as described by Miller et al. (1996). The open-top chamber, constructed of Mylar, was designed to accommodate a single vine and measurements were conducted between 1100 and 1400 h (Central daylight time) on cloudless days.

The number of ripened (lignified) nodes determines the extent of periderm formation on a shoot and is visually evaluated by the color change of nodes and internodes from green to brown. Ripened nodes per vine were counted after a killing frost. Bud cold hardiness was determined using the method described by Howell et al. (1978) and Stergios and Howell (1972). Values of LT50 were calculated using a modified Spearman-Karber equation (Bittenbender and Howell, 1974).

The data were analyzed using the MIXED procedure of SAS (SAS Institute, Cary, NC). Means within each treatment were separated by Duncan's multiple range test at the 5% level. Single degree of freedom polynomial contrasts were used to test the trend response of variables to the treatments imposed.

RESULTS AND DISCUSSION

'Chambourcin' did not respond to different levels of balance pruning (data not shown). Therefore, only the effects of cluster thinning (crop levels) are discussed. The response of 'Chambourcin' grapevines to cluster thinning was similar at both locations. Crop weight per vine decreased linearly as cluster thinning increased (Table 2). As a result, yield also decreased and ranged from 11.1 t ha^{-1} to 17.3 t ha^{-1}. These results corroborate previous findings on other grape cultivars (Howell, 2001; Kliewer and Dokoozlian, 2000; Miller and Howell, 1998; Naor et al., 2002; Reynolds et al., 1994). Furthermore, it is noted that even though vine density in Ohio was twice as high as that in Illinois, the yield per hectare was similar. Pruning weights per vine also followed a linear trend and increased as clusters per vine were reduced (Table 2). Reports on the response of pruning weight to crop levels has varied; some authors have reported an increase in pruning weight as crop levels were reduced (Bravdo et al., 1985) while others reported no effect (Naor et al., 2002; Reynolds et al., 1994; Wample and Wolf, 1996). Crop load increased linearly as clusters per vine increased (Table 2). At both locations and throughout the duration of the experiments, crop load ratios varied from 4 to over 30, which would indicate an over-cropping situation (not all data shown). Crop loads between 4 and 10 were considered ideal to produce optimum wine quality in *V. vinifera* cultivars (Kliewer and Dokoozlian, 2000). Grapevines with crop loads greater than 10 were considered over-cropped with the exception of some hybrid cultivars. Reynolds et al.

(1994; 1995) reported crop loads of 10 to 17 in 'Chancellor' and 18 to 28 in 'Seyval'. In our study, grapevines were considered over-cropped with a crop load greater than 8 and 14 in Ohio and Illinois, respectively. We suggest that the variation in crop load between the two regions is due to vine spacing as reported by Reynolds et al. (1994; 1995) and length of growing season and heat unit accumulation as indicated by Howell (2001).

Cluster thinning did not affect PN at the four phenological stages of development it was measured (Table 3). This agrees with similar findings on 'Seyval' grapevines (Edson et al., 1993). However, PN varied from berry touch (bunch closure) to one week post-harvest in a similar fashion at two vineyards in southern Illinois. PN increased as vines approached fruit ripening at which time PN was at its maximum in both vineyards (Table 3). However, PN decreased drastically one week post-harvest. Petrie et al. (2000) reported similar observations.

Soluble solids increased linearly as crop levels were reduced (Table 4). Similar findings have been reported in other cultivars (Naor et al., 2002; Kliewer and Dokoozlian, 2000). In general, total titratable acidity did not respond to different crop levels over the years at either location. Whereas pH was inconsistent but tended to increase with a lower crop level. These responses have been previously reported (Naor et al., 2000) and are typical of increasing crop levels, which generally result in delayed fruit ripening. Furthermore, it is noted that soluble solids and pH in 'Chambourcin' grown in Illinois were always higher and TA lower than those in Ohio. This is another typical response of fruit composition under a longer growing season with more growing degree-days. Therefore, fruit maturity of 'Chambourcin' is better suited in a longer season with more heat degree-days.

Ripened (lignified) nodes per vine increased linearly as crop levels decreased at both locations (Table 5). Ripe nodes in Ohio were much lower than those in Illinois. This may be explained by the longer growing season in Illinois as compared to Ohio. Furthermore, the Ohio vineyard experienced an earlier than normal killing frost which may have stopped further node lignification. Crop levels affected bud cold hardiness measured as LT50 in both vineyards. Grapevines with the highest crop levels had the highest LT50, or were the least cold hardy (Table 5). In Illinois, there was a linear trend between clusters per vine and LT50 (Table 5). Furthermore, cold hardiness seemed to increase as more nodes were lignified in both vineyards. The findings are somewhat different than those by Wample and Wolf (1996) who reported no effect of crop levels on ripe nodes and cold hardiness was only affected early in cold acclimation.

CONCLUSIONS

'Chambourcin' grapevines require cluster thinning in addition to balance pruning in order to optimize yield, fruit quality and winter hardiness. Optimum crop loads developed for Midwestern US conditions should take into account not only fruit quality but also bud cold hardiness. Crop loads varied with vineyard geographical location and optimum levels ranged between 4 and 8 in Ohio and 10 and 14 in Illinois. It is concluded that 'Chambourcin' grapevines grown at a wider spacing with a longer growing season (southern Illinois) were able to sustain a higher crop load than those grown in a narrower spacing and shorter season (Ohio).

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Tables

Table 1. The description of vineyard sites at the two experimental locations used in the study.

	Southern Illinois	Northeast Ohio
Climate Description		
Macroclimate	Continental	Continental
Growing season length (0°C basis)	195 (Long)	160 (Short)
Growing degree days (10°C basis)	2180	1590
Climatic growing region class	Region IV (Hot)	Region II (Cool)
Vineyard Description		
Spacing (vine x row) (m)	2.4 x 3.0	1.2 x 3.0
Vine density (per hectare)	1362	2722
Training system	High bi-lateral cordon	High simple cordon
Duration of study	2 years	4 years

Table 2. The effects of crop level on yield, pruning weight and crop load of 'Chambourcin' grapevines grown at two locations. Crop load is cluster weight divided by pruning weight.

	Clusters	Cluster wt. (kg $vine^{-1}$)	Yield (t ha^{-1})	Pruning wt. (kg $vine^{-1}$)	Crop load
Ohio 2002	12 c[1]	4.14	11.1	0.32	14
	23 b	5.82	15.9	0.19	31
	31 a	6.32	17.3	0.20	34
Linear Regression[2]		***	***	**	**
Illinois 2003	45 c	8.73	11.8	0.87	10
	54 b	10.5	14.3	0.84	13
	61 a	12.27	16.6	0.72	17
Linear Regression		***	***	*	**

[1]Means separation within columns at $P \leq 0.05$ by Duncan's multiple range test.
[2]*, **, ***, and ns indicate statistical significance at $P \leq 0.05$, 0.01, 0.001 and not significant, respectively.

Table 3. Whole vine photosynthesis (PN) measured at different phenological stages of 'Chambourcin' grapevines grown in Illinois in 2003. Other information is as given in Table 2.

	PN (µmoles CO_2 $vine^{-1}$ s^{-1})	
Phenology	Vineyard 1	Vineyard 2
Berry touch	4.4 b	3.1 bc
Veraison	5.8 b	4.1 b
Harvest	8.9 a	7.1 a
One week post harvest	4.8 b	2.8 c

Table 4. The effect of crop levels on fruit composition of 'Chambourcin' grapevines grown at two locations. Other information is as given in Table 2.

	Clusters $vine^{-1}$	°Brix	pH	TA (g L^{-1})
Ohio 2002	12	21.3	3.22	10.0
	23	19.7	3.14	8.8
	31	19.8	3.13	8.6
Linear Regression[2]		**	**	ns
Illinois 2003	45	23.4	3.43	6.3
	54	23.0	3.42	6.4
	61	22.9	3.42	6.4
Linear Regression		*	ns	ns

Table 5. Effects of crop levels on node lignification and bud cold hardiness (LT50) of 'Chambourcin' measured in two locations. Note that data from Ohio is from 2003 and not 2002 as found in previous tables. Buds were collected on 23 Dec. 2003 in OH and 14 Jan. 2004 in IL. Other information is as given in Table 2.

	Clusters vine^{-1}	Shoots vine^{-1}	Lignified nodes vine^{-1}	LT50 (C)	% Bud injury at -17.5°C
Ohio 2003	14 c	22	59	-18.3 b	22 b
	23 b	22	41	-17.5 a	60 a
	32 a	21	35	-17.7 ab	44 ab
Linear Regression		ns	**	ns	ns
Illinois 2003	46 b	37	577	-25.1 b	
	49 ab	38	452	-25.1 b	
	56 a	37	203	-21.9 a	
Linear Regression		ns	***	**	