Turkish Journal of Agriculture and Forestry

Volume 34 | Number 3 Article 5

1-1-2010

Effects of alternative spray programs and various combinations of green pruning on powdery mildew [Uncinula necator (Schw.) Burr.] in Karasakız (Kuntra) grape cultivar

İSMET YILDIRIM

ALPER DARDENİZ

Research Article

Turk J Agric For
34 (2010) 213-223
© TÜBİTAK
doi:10.3906/tar-0809-27

Effects of alternative spray programs and various combinations of green pruning on powdery mildew [*Uncinula necator* (Schw.) Burr.] in Karasakız (Kuntra) grape cultivar

İsmet YILDIRIM[1,*], Alper DARDENİZ[2]

[1]Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Plant Protection, 17020, Çanakkale - TURKEY

[2]Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Horticulture, 17020, Çanakkale - TURKEY

Received: 19.09.2008

Abstract: The effects of alternative spray programs, $NaHCO_3/K_2SiO_3$ + sulphur, KH_2PO_4/di - 1 - p – menthone, and a conventional spray program, penconazole/sulphur, as well as various levels of shoot toppings (to the 1st, 3rd, and 5th buds) on powdery mildew disease [*Uncinula necator* (Schw.) Burr.] and grape quality were investigated in this study. The study was carried out on grape variety Karasakız (*Vitis vinifera* L.) during 2003 and 2004 growing seasons.

The effectiveness of $NaHCO_3/K_2SiO_3$ + sulphur, KH_2PO_4/di - 1 - p - menthene alternate spray programs against powdery mildew was found as 74.8% and 70.7% on leaf and 65.7% and 62.1% on bunch in the 2003 vegetation period, which were close to the results (80.3% on leaf, 72.3% on bunch) obtained with the conventional control program (penconazole/sulphur). In 2004, $NaHCO_3/K_2SiO_3$ + sulphur (44.7%) was more effective for the control of leaf powdery mildew than penconazole/sulphur (29.0%). In addition, it also exhibited a similar effect on bunches.

$NaHCO_3/K_2SiO_3$ + sulphur and penconazole/sulphur treatments showed positive effects on the yield and quality of grapes. All spray programs demonstrated a better performance in the vineyards where pruning was practiced from the 1st and 3rd buds after the last bunch of the grapes rather than from the 5th bud.

According to the results of the study, $NaHCO_3/K_2SiO_3$ + sulphur spray program could be used in combination with the green pruning from the 3rd bud to control the disease in organic and integrated wine grapes, while KH_2PO_4/di - 1 - p - menthene spray program is more effective with the same pruning practice in the areas where climatic conditions are less favourable for *U. necator*, and pathogen-resistant grape varieties are grown.

Key words: Alternative spray program, shoot topping, *Uncinula necator, Vitis vinifera.*

Karasakız (Kuntra) üzüm çeşidinde alternatif ilaçlama programları ve yeşil budamanın çeşitli kombinasyonlarının bağ küllemesine [*Uncinula necator* (Schw.) Burr.] etkileri

Özet: Alternatif ilaçlama programları $NaHCO_3/K_2SiO_3$ + kükürt, KH_2PO_4/di - 1 - p -menthene ve penconazole/kükürt klasik ilaçlama programının, farklı uç alma seviyeleri (1 göz, 3 göz ve 5 göz) ile kombinasyonlarının bağ küllemesine

* E-mail: yismet@comu.edu.tr

[*Uncinula necator* (Schw.) Burr.] ve üzüm kalite kriterlerine etkisi araştırılmıştır. Araştırma 2003 ve 2004 yıllarında Karasakız (*Vitis vinifera* L.) üzüm çeşidi üzerinde yürütülmüştür.

$NaHCO_3/K_2SiO_3$ + kükürt, KH_2PO_4/di - 1 - p - menthene dönüşümlü ilaçlama programları 2003 yılında küllemeye karşı yaprak üzerinde sırasıyla % 74.8, % 70.7 ve salkımlar üzerinde sırasıyla % 65.7, % 62.1 ile klasik ilaçlama programı penconazole/kükürde (yaprak üzerinde % 80.3, salkım üzerinde % 72.3) yakın etkililik göstermişlerdir.

Külleme hastalığı 2004 yılında 2003 yılına göre daha şiddetli seyretmiştir ve ilaçlama programlarının etkililikleri daha düşük bulunmuştur. $NaHCO_3/K_2SiO_3$ + kükürt 2004 yılında, yapraklar üzerindeki küllemeye karşı % 44.7 etkililikle, penconazole/kükürt ilaçlama programından (% 29.0) daha yüksek etkililik gösterirken, salkımlar üzerinde benzer etkililik ortaya koymuştur.

$NaHCO_3/K_2SiO_3$ + kükürt ve penconazole/kükürt ilaçlama programları üzüm verim ve kalitesine (ortalama salkım ağırlığı, toplam suda çözülebilir kuru madde miktarı, titre edilebilir asit, olgunluk indisi) olumlu etki yapmışlardır. İlaçlama programları son salkımdan sonra 1. ve 3. gözler üzerinden budanan parsellerde, 5. göz üzerinden budanan parsellere göre daha yüksek bir performans ortaya koymuşlardır.

Araştırma sonuçları $NaHCO_3/K_2SiO_3$ + kükürt ilaçlama programının üçüncü göz üzerinden uç alma ile kombine edilerek organik ve entegre şaraplık üzüm yetiştiriciliğinde kullanılabileceğini; KH_2PO_4/di - 1 - p - menthene ilaçlama programının ise, aynı budama şekliyle (üçüncü göz üzerinden) iklim koşullarının *U. necator* için daha az elverişli olduğu ve patojene dayanıklı çeşitlerin yetiştirildiği yerlerde kullanılabileceğini göstermiştir.

Anahtar sözcükler: Alternatif ilaçlama programı, uç alma, *Uncinula necator*, *Vitis vinifera*

Introduction

In Turkey, organic agriculture is carried out with 247 different types of agricultural products on a 141,752 ha field. Organic grape production and its exportation have a significant place in organic agriculture. 22,012 t of organic grapes were produced in 2008, and 554 t of them were exported (as raisin), thus providing 1,233,000 $ of foreign exchange earnings (Subaşı 2009). Increasing production and exportation of organic grape require the substitution of synthetic inputs and classical applications with natural chemicals and ecological programs.

Powdery mildew (*U. necator*) is a major fungal disease that affects a wide variety of grapes negatively. Leaves and grapes of many *Vitis vinifera* varieties are highly susceptible to this pathogen (Gadoury et al. 2001). 'Karasakız' grape cultivar, widely grown in the Marmara Region for fine quality cognac and wine production, is one of the most susceptible varieties. Growers prune grapevines from the 2^{nd} to the 6^{th} buds and use conventional spray programs including sulphur and systemic fungicides to control powdery mildew disease.

Conventional spray programs have only limited use due to the disadvantages including high cost, fungicide resistance, residue formation in the products, and environmental pollution. Resistance to the old and new systemic DMI (demethylation inhibitors) (Arı 1986; Savocchia et al. 1999; Northover and Homeyer 2000; Northover 2002) and QoIs (Quinone outside inhibitors) fungicides (Hollomon et al. 1999; Wilcox et al. 2003) were well documented by various studies. However, growing interest in organic grape production has recently increased the demand for environmentally-friendly chemical control programs to eliminate the risk of fungicide resistance (Steva and Clerjeau 1990; Ypema et al. 1997) and residue formation in the product (Dekker 1987).

In addition to the conventional spray programs (Delen et al. 1987) to control powdery mildew, subsequent studies recommended the use of vegetable oils (Cheah et al. 1995) and extracts as *Rheum undulatum* (Syn: *R. rhababarum*) (Paik et al. 1996), neem extract (Fiume 1997), organic and inorganic salts (Ziv and Zitter 1992; Collina 1996), silicates (Reynolds et al. 1996; Blaich and Grundhöfer 1998), micronutrient elements (Reuveni et al. 1997), and biopreparates (Daoust and Hofstein 1996; Hofstein et. al. 1996; MacDonald and Punja 1997; Wilson 1997). However, only a few studies dealt with alternative combinations of the cultural measures (pruning and leaf removal, shoot topping) and investigated the effects of such applications on the yield and wine quality. In these studies; K_2SiO_3, Na_2SiO_3, $NaHCO_3$, and KH_2PO_4 were found to be effective for the control of powdery mildew, but they had no effect on the quality of grapes and wines (pH, total acid, tartaric acid, sugar, aroma, taste, colour, etc.).

In addition to chemical application methods, reducing inoculum pressure by pruning heavily infected shoots, increasing air circulation, reducing shadowing and green pruning for the best spray penetration are among the other possible methods for the control of *U. necator* (Chellemi and Marois 1992).

The aim of this study was to investigate the effects of both alternative spray programs with different chemicals compatible with organic agriculture and also different levels of shoot topping application on the control of powdery mildew as well as grape yield and quality.

Materials and methods

Plant and chemicals

The study was conducted during 2003 – 2004 growing seasons on "Karasakız" (Kuntra) grape cultivar grown for 12 years according to goblet vineyard system in Çanakkale Province (Turkey). Certain specifications of environmentally-friendly chemicals and reference fungicides used in the trials are shown in Table 1.

During trials, potassium soap (0.2% w/v) was added to the liquid to achieve sticking and to ensure homogeneous distributions of $NaHCO_3$ and KH_2PO_4 on grape leaves and bunches.

Effects of cultural applications on the yield and quality of grape

Winter pruning of grapevines was performed from the 2nd bud in February. Green pruning was practiced at 2 different times, 3 – 5 days after the full blossom period and the beginning of the pea size of grape berries. During the 1st green pruning, shoots were removed with pruning shears from the 1st, 3rd, and 5th buds after the last bunch. While the shoot tops were pruned, bottom and water shoots were completely ripped off, and the aged leaves between the bottom and the first bunch were also removed. During the second green pruning, bottom and water shoots were removed from the grapevines, and outermost lateral shoots were pruned to 1 – 2 leaves left at the bottom.

Grape harvest and sampling were made at the 5th bud following shoot topping when grapevines reached the optimum ripeness for cognac production (average 9°Baumé). The effects of spray programs and shoot toppings at different levels on the yield and quality of grapes were determined by means of a series of criteria, such as average bunch weight, water-soluble dry substance content, percentile value of acidity, and maturity indices. Quality analyses were performed at Çanakkale Onsekiz Mart University, Faculty of Agriculture laboratories.

Total water-soluble dry substance content was measured using a handheld refractometer, percentile value of acidity by titration method (Çoban and Kara 2002), the rate of berry ripening by the "I = WSDS

Table 1. Specifications of the test materials.

Commercial Name	Active ingredients	Rate of active ingredients (%)	Formulation	Usage dose (%)	Manufacturing firm
Baking powder	$NaHCO_3$	99 - 100.5	WP	1.0	Carlo Erba
Water-Glass	$K_2O + SiO_2$	8.1 + 20.3	Liquid	1.0	Tunçtaş A.Ş.
Vapor-Gard	Di-1-p-menthene	96	EC	1.0	Hektaş A.Ş.
Potasium di-hydrogen phospate	KH_2PO_4	99.5	WP	0.75	Carlo Erba
Thiovit	Sulphur	80	MWP[a]	0.4	Novartis
Topas	Penconazole	100 (g L^{-1})	EC	0.025	Syngenta
Soft Soap	Vegetable oil + KOH		Liquid	0.2	Viking A.Ş.

[a] Micronized wettable powder.

(%)/Acidity (%)" formula, and the average bunch weight by dividing the yield of grape in each repetition to the number of bunches.

Effects of spray programs on disease severity of leaves and brunches

Alternating programs of KH_2PO_4/di-1-p-menthene and $NaHCO_3$ + potassium soap/K_2SiO_3 + sulphur were alternative programs, and the alternating penconazole/sulphur program was the classic spray program. Spraying was carried out using different spray programs (Table 2). Treatment intervals were determined considering the length of effectiveness period of chemicals used in organic production, and the spray programs including test chemicals were applied at 12-day intervals. The first spray was applied 11 days before the first shoot topping in the beginning of flowering (stage number 19 according to Eichorn-Lorenz Scale). In the first year of the experiment (2003), the treatments were initiated on 11 May; however, this date was postponed to 21 May in the second year (2004) due to the cooler climatic conditions. Chemicals were applied using a knapsack sprayer. Cardboard curtains were placed between plots to prevent contamination during spray applications. The disease severity on leaves and bunches were evaluated 12 days after the last application. Bunch infection was evaluated based on a scale of 0 – 4 (Delen et al. 1987) on 72 bunches for each replication, where 0 = no infection on the bunch (n_o), 1 = 25% infection (n_1), 2 = 50% infection (n_2), 3 = 75% infection (n_3), and 4 = more than 75% infection (n_4).

Leaf infection was evaluated based on a scale of 0 - 3 (Delen et al. 1987) on 150 leaves for each replication, where 0 = no colony on the leaf (n_0), 1 = 1 - 2 colonies per leaf (n_1), 2 = 3 - 10 colonies per leaf (n_2), and 3 = more than 10 colonies per leaf (n_3).

The experiments were established as randomized complete block design with 4 replications, and 8 plants were used for each plot. Main plots include spraying treatments, while the sub-plots include pruning. The distance between plots was 3 m.

Disease severity (%) was evaluated using Townsend-Heuberger formula. The effectiveness of spray programs was evaluated using the Abbott formula, and the resulting data were assessed using Minitab® Statistical Software Release 14. The mean values were compared by Duncan's multiple range test at $P < 0.05$.

Climatic data

Monthly climate data during the vegetation periods in 2003 and 2004 are given in Table 3. (Turkish State Meteorological Service, Ministry of Environment and Forestry).

Results

Effectiveness of organic spray programs on powdery mildew was compared to conventional spray programs. Effectiveness of spray programs on *U. necator* infections at different levels of shoot topping in "Karasakız" grape cultivar is shown in Tables 4 and 5.

Table 2. Spray programs.

Prog. no[c]	Spray Programs					
	First spray[a]	Second spray	Third spray	Fourth spray	Fifth spray	Sixth spray
0	Control	Control	Control	Control	Control	Control
1	$NaHCO_3$ + P-S[b]	K_2SiO_3 + Sulphur	$NaHCO_3$ + P-S	K_2SiO_3 + Sulphur	$NaHCO_3$ + P-S	K_2SiO_3 + Sulphur
2	KH_2PO_4	Di-1-p-menthene	KH_2PO_4	Di-1-p-menthene	KH_2PO_4	Di-1p-menthene
3	Penconazole	Sulphur	Penconazole	Sulphur	Penconazole	Sulphur

[a] First spray was applied in the beginning of flowering (stage no 19) according to Eichorn- Lorenz Scale.

[b] P-S., Potassium soap.

[c] Program no 3, classical spray program, programs no 1 and 2 alternative spray programs.

Table 3. Climate data during the vegetation periods[a].

Year	Climate Data	Months					
		April	May	June	July	August	September
2003	Average Maximum Temperature (°C)	19.6	24.7	30.1	30.9	32.3	25.7
	Average Minimum Temperature (°C)	5.49	12.7	17.8	19.2	20.8	13.7
	Average Temperature (°C)	14.7	18.0	24.0	25.6	24.8	20.2
	Average Relative Humidity (%)	77.8	69.2	58.4	61.2	56.2	63.4
	Average Precipitation (mm)	2.77	0.48	-	-	-	0.76
2004	Average Maximum Temperature (°C)	16.2	21.0	27.3	30.2	29.1	26.4
	Average Minimum Temperature (°C)	9.5	13.1	17.3	20.8	19.5	16.9
	Average Temperature (°C)	12.4	17.1	22.6	25.3	24.8	21.5
	Average Relative Humidity (%)	80	72.4	69.3	62.5	67.5	68.9
	Average Precipitation (mm)	1.71	0.45	0.73	0.04	0.14	0.01

[a] Climate data were obtained from the Turkish Sate Meteorological Service, Ministry of Environment and Forestry, Republic of Turkey.

Table 4. Effects of chemical spray programs and shoot topping on powdery mildew in grapevines during 2003 and 2004.

Programs	Shoot topping levels	2003								2004							
		Leaf				Bunch				Leaf				Bunch			
		Severity (%)[a]		Efficacy[b]		Severity (%)[a]		Efficacy[b]		Severity (%)[a]		Efficacy[b]		Severity (%)[a]		Efficacy[b]	
$NaHCO_3$/	1	18.0		76.4		34.4		62.6		55.2		43.5		26.2		73.3	
K_2SiO_3+Sulphur	3	24.8	22.2[b]	73.6	74.8	30.6	31.7[bc]	67.5	65.7	56.2	54.6[c]	43.4	44.7[a]	33.8	32.6[c]	65.9	67.0[a]
	5	23.8		74.2		30.0		67.2		52.5		47.1		37.9		61.8	
KH_2PO_4 /	1	18.7		72.4		26.2		71.2		60.8		37.7		52.8		46.4	
di1p-menthen	3	23.6	25.0[b]	74.6	70.7	41.9	35.2[b]	56.2	62.1	74.8	73.3[b]	42.2	25.8[b]	52.8	59.1[b]	46.6	40.2[b]
	5	32.6		65.2		37.5		59.0		84.2		15.2		71.8		27.5	
Penconazole /	1	15.0		78.2		18.1		79.6		59.5		39.1		35.4		70.6	
Sulphur	3	14.8	16.6[b]	84.3	80.3	28.4	25.5[c]	68.9	72.3	69.3	70.2[b]	30.2	29.0[b]	34.9	40.0[c]	64.7	61.8[a]
	5	20.1		78.4		30.0		67.2		81.9		17.6		49.7		50.0	
Control	1	75.8				89.7				97.0				98.3			
	3	93.8	87.8[a]			94.4	91.6[a]			99.2	98.5[a]			98.8	98.7[a]		
	5	93.9				90.6				99.2				99.1			
Programs		*		NS		*		NS		*		*		*		*	
Shoot Topping[c]		*		NS		NS		NS		NS		NS		*		*	
Programs × Shoot Topping		NS		NS		NS		NS		NS		NS		NS		NS	

[b] The efficacy of the program is expressed as mean percentage reduction in severity relative to control. [a,b] Values are the mean of 4 replicates, and numbers followed by the same letter within the same column are not significantly different according to Duncan's multiple range test (P = 0.05), NS not significant. * Significant at the 0.05 probability level.
[c] The effects of various levels of shoot topping on disease severity and the success of spray programs are shown in Table 4.

Table 5. Effects of various levels of shoot topping on disease severity and the success of spray programs.

Level of shoot topping	2003				2004			
	Foliage		Clusters		Foliage		Clusters	
	Disease severity (%)[a]	Efficacy[c] (%)[b]	Disease severity (%)[a]	Efficacy (%)[b]	Disease severity (%)[a]	Efficacy (%)[b]	Disease severity (%)[b]	Efficacy (%)[b]
1st bud	31.9 b	75.7 ns[b]	42.1 ns	71.2 ns	68.1 ns	40.1 ns	53.2 b	63.4 a
3rd bud	39.3 a	77.5 ns	48.8 ns	64.5 ns	74.9 ns	32.8 ns	55.1 b	59.1 a
5th bud	42.6 a	72.6 ns	47.0 ns	64.4 ns	79.5 ns	26.6 ns	64.6 a	46.4 b

[b] The efficacy of the program is expressed as mean percentage reduction in severity relative to control.
[a, b] Values are the mean of 4 replicates and the numbers followed by the same letter within the same column are not significantly different according to Duncan's multiple range test (P = 0.05), NS not significant.

Disease severity was determined much lower on treated grapevines than control grapevines. Despite the differences in disease severity, the effectiveness of various spray programs on *U. necator* was not significantly different in 2003. However, the disease followed a more severe course in 2004, and spray programs displayed some differences in terms of effectiveness against *U. necator* (Table 4). Disease severity of control treatment was 87.8% in leaves and 91.6% in bunches in 2003, while it was 98.5% and 98.7%, respectively, in 2004. Climatic conditions such as monthly average precipitation (mm), average relative humidity (%), and temperature (monthly average, max. and min.) affected the disease severity (Table 3). During the 1st year of the experiment, no rainfall was observed in June, July, and August, while 0.73, 0.04 and 0.14 mm precipitations were recorded, respectively, for the same months in the 2nd year, and this caused an increase in the atmospheric humidity that was necessary for the germination of *U. necator* conidia, and therefore played an important role in the increase of disease severity. Although the average relative humidity in 2003 was recorded as 77.8%, 69.2%, 58.4%, 61.2%, and 56.2% from April to August, respectively; it was observed higher in 2004 as 80.0%, 72.4%, 69.3%, 62.5%, and 67.5% for the same period. On the other hand, maximum, minimum, and mean temperature degrees were higher (30.1, 17.8 and 24.0 °C, respectively) in June, 2003, the most critical month considering the effect of disease on bunches; however, the same temperature parameters were closer to the optimum degrees in 2004 (maximum 27.3 °C, minimum 17.3 °C, and mean 22.6 °C) for the growth of *U. necator*.

Disease severity was found to be lower in grapes treated in 2003 than control plants, whereas no significant difference was observed between the effects of the programs on the disease. However, the lowest disease severity (25.5%) was detected in penconazole/sulphur spray program, which was followed by $NaHCO_3$/K_2SiO_3 + sulphur spray program with 31.7% disease severity and KH_2PO_4/di - 1 - p – methane spray program with 35.2% disease severity (Table 4).

While $NaHCO_3$ /K_2SiO_3 + sulphur spray program showed a higher effect with 44.7% on leaves compared to conventional (29%) and other organic spray (25.8%) programs, its effectiveness on bunches (67%) was similar to that of the conventional spray program (penconazole/sulphur) (61.8%). On the other hand, the effect of KH_2PO_4/di - 1 - p - menthene against powdery mildew was lower (40.2%) compared to the other 2 spray programs in 2004 (Tables 4).

Interaction between application programs and shoot topping levels on leaf disease and leaf efficiency was found statistically insignificant for 2003 and 2004 (Table 4). The effects of spray programs on the disease did not differ with different levels of pruning (Table 4).

While the different pruning levels affected the disease severity on leaf in 2003, they were effective on the bunch in 2004 (Table 5). The disease followed a more severe course in grapevines pruned from the 3rd and 5th buds, which were 39.3% and 42.6%, compared to those (31.9%) pruned from the 1st bud during the 1st year of the trial (2003). However, it did not cause any variation in terms of the effectiveness of the spray programs. On the other hand, different levels of shoot topping on bunches did not affected the disease severity and the success of the spray programs. In 2004, different levels of shoot topping significantly reduced the disease severity and the effectiveness of different spray programs on bunches. Disease severity on bunches of grapevines pruned from the first and third buds was determined as 53.2% and 55.1%, which were lower compared to the value (64.6%) of the 5th bud shoot topping procedure. Spray programs, on the other hand, showed higher performance in grapevines where bunches were pruned from the 1st and 3rd buds (Table 5).

Based on different levels of shoot topping during 2003 and 2004 vegetation periods, various spray programs had different effects on average bunch weight, total water-soluble dry substance content (%), titratable acidity (%), and maturity indices (Table 6). Owing to berry development and climate conditions, the yield of grape in experimental area showed a substantial decrease in 2004 with an average of 109.8 g/bunch compared to 2003 (240.8 g/bunch) (Table 7). Average bunch weight in 2003 was found significantly higher (P = 0.05) in grapevines treated using a conventional spray program (penconazole/sulphur) with 276.2 g compared to those treated by other programs. This conventional spray program was followed by $NaHCO_3/K_2SiO_3$ + sulphur treatment with 248.7 g, and KH_2PO_4/di - 1 - p - menthene treatment with 219.6 (Table 6). The average bunch weights displayed significant differences with different spray programs in 2004, as well (Table 6). Furthermore, bunch weights of the grapevines treated with conventional sprays and $NaHCO_3/K_2SiO_3$ + sulphur were 137.7 and 133.4 g, respectively, in 2004, which were higher than control grapevines (75.3 g) and vines treated with KH_2PO_4/di - 1 - p – menthene (92.8 g).

Table 6. Effects of various spray programs on mean values of yield and quality.

Programs	Shoot Topping	2003								2004							
		Average bunch weight (g)[a]		Water-soluble dry substance content (%)		Acidity (%)[a]		Rate of berry ripening		Average bunch weight (g)[a]		Water-soluble dry substance content (%)[a]		Acidity (%)		Rate of berry ripening[a]	
$NaHCO_3/K_2SiO_3$ + sulphur	1	227.8		15.97		1.068		14.94		127.7		12.79		1.123		11.40	
	3	246.3	248.7[b]	17.56	17.46	1.000	1.045[a]	17.57	16.73	137.6	133.4[a]	14.13	14.7[b]	1.056	1.032	13.39	14.51[b]
	5	272.1		18.84		1.067		17.68		135.0		17.18		0.917		18.73	
KH_2PO_4/di-1-p-menthene	1	200.1		15.66		0.997		15.72		86.4		15.14		1.104		13.75	
	3	223.7	219.6[c]	16.44	16.45	0.973	0.970[b]	16.95	17.03	105.1	92.8[b]	16.56	17.1[a]	0.991	1.014	16.74	17.05[a]
	5	234.9		17.24		0.939		18.41		86.9		19.50		0.946		20.65	
Penconazole/ sulphur	1	266.9		16.35		1.016		16.09		136.4		12.93		1.159		11.19	
	3	270.1	276.2[a]	17.06	17.09	1.025	1.018[ab]	16.71	16.83	154.4	137.6[a]	14.98	15.1[b]	1.052	1.065	14.25	14.37[b]
	5	291.5		17.87		1.012		17.68		122.0		17.35		0.983		17.66	
Control	1	198.6		15.53		1.066		14.57		72.4		15.60		1.171		13.49	
	3	219.9	218.7[c]	17.18	16.98	1.054	1.056[a]	16.47	16.14	77.1	75.3[b]	17.39	17.1[a]	1.109	1.100	15.92	15.83[ab]
	5	237.7		18.22		1.049		17.38		76.3		18.30		1.016		18.09	
Programs	*		NS		*		NS		*		*		NS		*		
Shoot Topping[b]	*		*		NS		*		*		*		*		*		
Programs × Shoot Topping	NS		NS		NS		NS		NS		NS		NS		NS		

[a] Values are the mean of 4 replicates, and the numbers followed by the same letter within the same column are not significantly different according to Duncan's multiple range test (P = 0.05), NS not significant. [b] The effect of various levels of shoot topping on yield and quality of grapes is shown in Table 7.
* Significant at the 0.05 probability level.

Table 7. Effects of various levels of shoot topping on yield and quality of grapes.

Level of shoot topping	2003				2004			
	Average bunch weight (g)[a]	Water-soluble dry substance content (%)[a]	Acidity (%) NS	Rate of berry ripening	Average bunch weight (g)[a]	Water-soluble dry substance content (%)[a]	Acidity (%)[a]	Rate of berry ripening[a]
1	223.4 c	15.9 c	1.07	15.3 c	105.7 b	14.1 c	1.139 a	12.5 c
3	240.0 b	17.1 b	1.013	16.9 b	118.6 a	15.8 b	1.052 b	15.1 b
5	259.1 a	18.0 a	1.017	17.8 a	105.1 b	18.1 a	0.966 c	18.8 a
Average	240.8	17.0	1.033	16.7	109.8	16.0	1.052	15.5

[a] Values are the mean of 4 replicates, and the numbers followed by the same letter within the same column are not significantly different according to Duncan's multiple range test (P = 0.05), NS not significant.

Although there was no difference among various spray programs in 2003 considering water-soluble dry substance content, titratable acidity (%), which is inversely proportional to water-soluble dry substance, was higher in both $NaHCO_3$/K_2SiO_3 + Sulphur spray program (program no 1) (1.045%) and control parcels (1.056%) (Table 6). On the other hand, in 2004, the water-soluble dry substance in the parcels sprayed with KH_2PO_4/di - 1 - p - menthene was found statistically higher (17.1%) than other spray programs (programs no.1 with 14.7% and 3 with 15.1%), but applications did not display significant differences considering titratable acidity (%) (Table 6).

No significant difference was observed between grape ripening levels of control and spray programs during 2003. In 2004, however, grape berries ripened earlier on vines treated with KH_2PO_4/di - 1 - p - menthene (program no 2) compared to other spray programs (programs no: 1 and 3).

Discussion

In this study, the joint effect of different combinations of spray programs and pruning levels on powdery mildew and grape yield and quality was investigated, and consequently no statistically significant effect was determined. However, spray programs were found effective on disease severity in both years (Tables 4 and 5). In addition, different levels of shoot topping were effective only on disease severity of leaves in 2003, while they were effective both on disease severity in bunches and the efficiency of spray programs in 2004 (Table 5).

Climate conditions are effective in disease severity and the efficiency of spray programs. For instance, free water causes conidia burst and poor or abnormal germination, and heavy rainfall causes the absence of conidia and the destruction of micelles, whereas atmospheric moisture has a positive effect on conidia formation and germination speed (Pearson 1988). Parameters, such as temperature (min. 12.7 °C, max. 30.9 °C and average 18.0 - 25.6 °C in 2003; min. 13.1 °C, max. 30.2 °C and average 17.1 - 25.3 °C in 2004) and average relative humidity (RH) (58.4% - 69.2% in 2003; 62.5% - 72.4%) were close to the optimum development conditions of *U. necator* between May and July during 2003 and 2004 (Table 3). Temperature was closer to 20 – 27 °C in the 2nd year of the experiment (2004) than the 1st year, which was the optimum temperature for the growth of powdery mildew disease (Pearson 1988). Therefore, this factor played an important role in the increase of disease severity. Optimum climate conditions, reported as 25 ± 2 °C and 85% RH (Carroll and Wilcox 2003), incited powdery mildew to follow a more severe course (98.5% - 98.7%) especially in the control parcels, and disease pressure affected the success of spray programs negatively (Table 4). Due to the higher RH and precipitation in 2004, disease became more severe than 2003 (Table 3). Carroll and Wilcox (2003) reported a strong and positive linear relationship between humidity level and frequency of conidium germination. Higher humidity facilitates the release and germination of powdery mildew spores and encourages the development of infections (Trdan et al. 2004). Increasing infection pressure in 2004 reduced efficiency of spray programs on *U. necator* both on leaves and bunches. In the same period, long shoot pruning (at the 5th bud) negatively affected the efficiency of spray programs, causing higher humidity, and lower temperature and radiation inside canopy, which were all favourable for the development of *U. necator* (Zahavi et al. 2001). The disease severity on bunches of grapevines pruned from the 1st and 3rd buds were higher compared to the ones pruned from the 5th bud in 2004. Thus, effectiveness of spray programs on bunches of grapevines pruned from the 1st and 3rd buds was found as 63.4% and 59.1%, respectively, which were better than the 5th bud (46.4%) (Table 5).

Although powdery mildew disease followed a less severe course on leaves than bunches, the spray programs were more effective on bunches with a more severe disease course. In a similar study, Yıldırım et al. (2002) reported that spraying programs, Na_2SiO_3 + sulphur, K_2SiO_3 + sulphur, KH_2PO_4 + sulphur, $NaHCO_3$, KH_2PO_4/di-1-p-menthen, and penconazole/sulphur showed less efficiency against leaf infection compared to bunch infection. $NaHCO_3/K_2SiO_3$ + sulphur spray program was found more effective (44.7%) against powdery mildew on leaves than other spray programs in 2004, during which the disease severity was especially higher (Table 4). However, the spray program penconazole/sulphur showed similar efficiency on bunches. In 2004, KH_2PO_4/di-1-p-menthen spray program was found as effective as penconazole/sulphur program on leaves and less effective than $NaHCO_3/K_2SiO_3$; however, it was more effective than both programs on bunches. Yıldırım et al. (2002) reported that spray programs, $NaHCO_3$ and K_2SiO_3 + sulphur treatment, which were separately tested in the program, were less effective against powdery mildew in the vineyard with high disease incidence, while the alternate KH_2PO_4/di-1-p-menthen and the mixture of KH_2PO_4 + sulphur were found as effective as the alternate application of penconazole/sulphur against *U. necator*.

In 2004, different levels of green shoot topping were found very effective ($P < 0.05$) in suppressing powdery mildew disease (*U. necator*) and the efficiency of spray programs on bunches (Table 5). Short green pruning, especially from the 1st and 3rd buds, supplied significantly more ventilation and sun penetration in grapevines than the pruning from the 5th bud. Green pruning, removal of the lateral shoots and leaves under bunches plays a significant role in reducing the severity of powdery mildew disease, and thus increasing the success of spray programs with alternative chemicals. Kliewer et al. (1988) determined that the removal of bottom leaves reduced the severity of powdery mildew disease. Pruning systems affect the development of *U. necator*, and especially high intensity of light produces an inhibitive effect on disease severity (Zahavi et al. 2001). However, short green pruning performed on shoots (from the 1st bud) could cause burns on grape berries due to exposure to sunlight and eventually leads to lower yield and quality (Table 7). Therefore, the best shoot topping procedure should be determined to provide successful control of the disease without affecting the yield and quality.

The spray programs used in this study was found to have different effects on grape yield, quality, and early ripening (Table 6). While the average cluster weight was increased by $NaHCO_3/K_2SiO_3$ + sulphur and the conventional spray program (penconazole/sulphur), water-soluble dry substances were found higher in control and spray programs of KH_2PO_4/di - 1 - p – menthen in 2004. In the same plots, berries also were ripened earlier than other spray programs. Acidity of berries was not affected in 2004, but $NaHCO_3/K_2SiO_3$ + sulphur and penconazole/sulphur treatments had a positive effect on the acidity of berries in 2003. In the previous studies, similar spray programs were reported to have negative effects on acid, tartaric acid, and sugar compositions of the grape berries and grape ciders (Reh and Schloesser 1995; Reynolds et al. 1996).

Considering the grape yield, wine quality and efficiency against *U. necator*, $NaHCO_3/K_2SiO_3$ + sulphur spray program and combination of pruning procedures from the 3rd bud were found successful. In addition, it was also determined that an environmentally friendly spray program and pruning could be combined with other cultural procedures and used in organic and integrated grape productions. Although the application of alternate KH_2PO_4 and di - 1 - p - menthene spray programs displayed lower efficiency than other spray programs during 2003 and 2004, they can be used with the same cultural procedures in areas with less favourable conditions for *U. necator* and for disease-resistant grape varieties.

Acknowledgement

This research was conducted as a part of Project No. 2002/22 funded by the Research Foundation Project of Çanakkale Onsekiz Mart University. In addition, the authors also wish to thank Dr. H. Kocabıyık and Dr. A. Özarslan Parlak for performing statistical analyses.

References

Arı M (1986) Ege Bölgesinde bağ küllemesi [*Uncinula necator* (Schwein) Burr.]'nin önerilen sistemik fungisitlere karşı dayanıklılığı üzerinde araştırmalar. Doktora Tezi. Ege Üniversitesi, Fen Bilimleri Enstitüsü, p. 55.

Blaich R, Grundhöfer H (1998) The influence of Si fertilization on resistance of grapevines to powdery mildew. Vitis 37: 21-26.

Carroll JE, Wilcox WF (2003) Effects of humidity on the development of grapevine powdery mildew. Epidemiology 93: 1137-1144.

Cheah LH, Cox JK, Popay AJ (1995) Screening of plant extracts for control of powdery mildew in squash. In: Proceeding of the 48th New Zealand Plant Protection Conference, New Zealand, pp. 340-342.

Chellemi DO, Marois JJ (1992) Influence of leaf removal, fungicide applications, and fruit maturity on incidence and severity of grape powdery mildew. Am J Enol Vitic 43: 53-57.

Collina M (1996) Natural products against powdery mildew. Colture Protette 25: 39-42.

Çoban H, Kara S (2002) Studies on the effects of different crop loads on yield and quality in round seedless cultivar (*Vitis vinifera* L.). Asian J Plant Sci 4: 414-416.

Daoust RA, Hofstein R (1996) *Ampelomyces quisqualis*, a new biofungicid to control powdery mildew in grapes. In: Brighton Crop Protection Conference-Pests and Disease, UK. British Crop Protection Council, Vol. 1, Farnham, pp. 33-40.

Dekker J (1987) Build-up and persistence of fungicide resistance. In: Rational Pesticide Use (Eds. KJ Brent, EK Atkin), Cambridge University Press, Cambridge, pp. 153–168.

Delen N, Onoğur E, Mustafa Ö (1987) Asma küllemesi (*Uncinula necator* (Schw.) Burr.)'nin kimyasal savaşımı üzerinde çalışmalar. Doğa, Tu Tar. ve Or. D. C. p. 11.

Fiume F (1997) Therapeutical or protective effects of two new fungicides against powdery mildew on sweet pepper and their physiological implications. In: Proceedings of the 49th International Symposium on Crop Protection, Vol 62, Gent, Belgium, pp 1141-1150.

Gadoury DM, Seem RC, Pearson RC, Wilcox WF, Dunst RM (2001) Effects of powdery mildew on vine growth, yield, and quality of Concord grapes. Plant Dis 85: 137-140.

Hofstein R, Daoust RA, Aeschlimann JP (1996) Constraints to the development of biofungicides: the example of "AQ10", a new product for controlling powdery mildews. BioControl 41: 455-460.

Hollomon DW, Wheeler I, Dixon K, Longhurst C, Skylakakis G (1999) Defining the resistance of the new powdery mildew fungicide quinoxyfen. Pesticide Science 51: 347-351.

Kliewer MW, Marois JJ, Bledsoe AM, Smith SP, Benz MJ, Silverstoni O (1988) Relative effectiveness of leaf removal, shoot positioning, and trellising for improving wine grape composition. In: Proceedings of the Second International Cool Climate Viticulture and Oenology Symposium (Eds. R Smart, R Thornton, S Rodrigez, J Young). Auckland, New Zealand, pp.123-126.

MacDonald L, Punja ZK (1997) Biological control of rose powdery mildew with the antagonist yeast *Tilletiopsis pallescens*. HortScience 32: 262-266.

Northover J (2002) Optimum timing of Stylet-Oil for control of powdery mildew and European red mite without affecting juice sugars in Canadian grapes. In: Spray Oils Beyond 2000 (Ed. GAC Beattie, DM Watson, ML Stevens). University of Western Sydney Pres. pp. 402-408.

Northover J, Homeyer CA (2000) Fungicidal control of powdery mildew of grape bunchs and leaves, 1999. Fungic. Nematicide Tests 55: 102.

Paik SB, Kyung SH, Kim JJ, Oh YS (1996) Effect of a bioactive substance extracted from *Rheum undulatum* on control of cucumber powdery mildew. Korean J Plant Pathol 12: 85-90.

Pearson RC (1988) Powdery mildew. In: Compendium of Grape Diseases (Ed. RC Pearson, AC Goheen) APS Press, Minnesota, pp. 9-11.

Reh I, Schloesser E (1995) Control of powdery mildew on grapevine with sodium hidrogen carbonate. In: 47th International Semposium on Crop Protection, Vol. 60 (2a), Belgium, pp. 321-327.

Reuveni M, Agapov V, Reuveni M (1997) A foliar treatment of micronutrient solutions induces local and systemic protection against powdery mildew (*Sphaerotheca fuliginea*) in cucumber plants. European J Plant Pathol 103: 581-588.

Reynolds AG, Veto LJ, Sholberg PL, Wardle DA, Haag P (1996) Use of potassium silicate for the control of powdery mildew [*Uncinula necator* (Schwein) Burrill] in Vitis vinifera L. cultivar Bacchus. Am J Enol Vitic 47: 421-428.

Savocchia S, Stummer B, Scott E, Wicks T (1999) Detection of DMI resistance among populations of powdery mildew fungus. The Australian Grapegrower and Winemaker, September 1999, No. 429. pp. 39–41.

Subaşı DK (2009) Organik tarım ürünleri. T.C. Başbakanlık Dış Tic. Müşteşarlığı İhracatı Geliştirme Etüt Merkezi.

Steva H, Clerjeau M (1990) Cross resistance to sterol biosynthesis inhibitor fungicides in strains of *Uncinula necator* isolated in France and Portugal. Meded. Fac. Landbouwwet. Rijksuniv Gent 55: 983–988.

Trdan S, Valic N, Jerman J, Ban D, Znidarcic D (2004) Efficacy of three natural chemicals to reduce the damage of *Erysiphe cichoracearum* on chicory in two meteorologically different growing seasons. J Phytopathol 152: 567-574.

Wilcox WF, Burr JA, Riegel DG (2003) Practical resistance to Qol fungicides in New York populations of *Uncinula necator* associated with quanitative shifts in pathogen sensitivities. Phytopathology 93: 90.

Wilson M (1997) Biocontrol of aerial plant diseases in agriculture and horticulture: current approaches and future prospects. J Industrial Microbiol and Biothecnol 19: 188-191.

Yıldırım İ, Onoğur E, Irshad M (2002) Investigation on the efficacy of some natural chemicals against powdery mildew [*Uncinula necator* (Schw.) Burr.] of grape. J Phytopathol 150: 697-702.

Ypema HL, Ypema M, Gubler WD (1997) Sensitivity of *Uncinula necator* to benomyl, triadimefon, myclobutanil, and fenarimol in California. Plant Dis 81: 293-297.

Zahavi T, Reuveni M, Scheglov D, Lavee S (2001) Effect of grapevine training systems on development of powdery mildew. Eurpean J Plant Pathol 107: 495-501.

Ziv O, Zitter TA (1992) Effects of bicarbonates and film-forming polymers on cucurbit foliar disease. Plant Dis 76: 513-517.