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Management of Powdery Mildew on Wine Grapes: Evaluating Synthetic, Biological, and Organic Fungicides

2024 Field Trial

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Background and Introduction:

Powdery mildew, caused by the biotrophic fungus Erysiphe necator, is a major disease affecting grape production globally. It leads to substantial economic losses by reducing both the quality and yield of grapes, making its management a critical aspect of vineyard sustainability. This report presents the findings from the 2024 annual powdery mildew fungicide efficacy trial conducted at the Plant Pathology Field Station, University of California, Davis (38°31'21.3" N, 121°45'38.6" W). The trial was conducted from April to July 2024 on 13-year-old vines of the Chenin Blanc cultivar, which is highly susceptible to powdery mildew, similar to other cultivars such as Chardonnay, Muscat Blanc, Roussanne, and Carignane. Treatments were applied to the point of runoff using mist blower backpack sprayers (Stihl SR 430). The experimental design was a randomized complete block setup with five replicates, each comprising two adjacent vines. Fungicide treatments were categorized into two groups: **Group I: Synthetic fungicides and their combinations with soft chemistry products. Group II: Soft chemistry fungicides, including biologicals, sulfur, nutrients, oils, and other materials**. Applications were performed at intervals of 7 to 14 days, beginning on April 18th and concluding on June 28th, depending on berry maturity. Disease incidence and severity were assessed on July 9th, 2024, providing insights into the efficacy of various management approaches under real vineyard conditions.

Materials and Methods

A. Experimental design

Table 1. Details of the experimental design, vine spacing, spray volumes and equipment utilized in the trial.

Experimental design	Randomized complete block design with 5 replicates		
Experimental unit	2 adjacent vines = 1 plot		
Row and tree spacing	11 ft (row) and 7 ft (vine)	Plot unit area	154 ft^2
Area**/**treatment	770 ft^2 or 0.0177 acre**/**treatment (5 replicates = 1 treatment)		
Volume water/acre	50 gallons = 0.88 gal**/**5 reps 100 gallons (mid May) = 1.77 gal**/**5 reps 150 gallons (early June) = 2.65 gal**/**5 reps		
Equipment	Stihl SR 430 mist blower backpack sprayers		

B. Experimental treatments

The treatments outlined in this report were designed for experimental purposes and should be interpreted accordingly. It is important to note that crops subjected to similar treatment protocols may not meet the requirements for commercial production or other applications. The results provide insights into the potential efficacy of the treatments under controlled experimental conditions but do not guarantee suitability or compliance with commercial standards.

Acknowledgments

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Infested cluster with powdery mildew from untreated control (**A**). Berries treated with Luna Experience (**B**). The left vine (white flag) represents untreated control, and the right vine (blue flag) treatment with synthetic fungicide (**C**).

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C. Map

	BLOCK 5						BLOCK 4					BLOCK 3					BLOCK 2					BLOCK 1					
ROW / VINE	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	ROW / VINE
-31	x	x	x	x	x		x	x	x	14-YD	x	7-O		27-RKS	x	29-G	43-PWS	13-Y		17-YKD	x	56-Pu+G	x	39-BKD	x	x	-31
-30	x	x	x	x	52-B+R	26-RKD	x	x	16-YC		4-KS		17-YKD		x				1-W		35-B		31-GS		15-YS	20-YRD	-30
-29	29-G	7-O	x	x			38-BC	8-OS+O		48-B+K		26-RKD		61-Y+R	21-YRS	43-PWS	61-Y+R	33-GKS		10-OKD		37-BS		57-Pu+O			-29
-28			x	2-K	27-RKS	32-GKD			24-RS+R		20-YRD		32-GKD			x			42-PWD		49-B+Y		x		60-Y+G	x	-28
-27	4-KS	x	60-Y+G				30-GD	17-YKD		52-B+R		x		44-PWC	6-BKS			21-YRS		37-BS		45-PKD	25-RC+R	32-GKD	41-Pu	-27
-26		21-YRS		x	44-PWC						35-B	36-BD	14-YD			51-B+O	25-RC+R	63-Y+W	5-KC	x	10-OKD				23-RD		-26
-25			x	28-RKC		13-Y	x	61-Y+R	21-YRS	44-PWC				58-Pu+R	x				20-YRD	x	x	8-OS+O	34-GKC	x		54-Pu+K	-25
-24	x	x	x		53-B+W		x				15-YS	46-PKS				56-Pu+G	3-KD	47-PKC		40-BKC	17-YKD	26-RKD	x	4-KS	x	x	-24
-23	x	18-YKS	34-GKC			9-OC+O	x		56-Pu+G	12-ONS		4-KS	57-Pu+O	30-GD	12-ONS	x	41-Pu	58-Pu+R	35-B	x	38-BC	38-BC	x	61-Y+R	63-Y+W	x	-23
-22	x			24-RS+R	42-PWD		57-Pu+O	x			9-OC+O		47-PKC	22-R	54-Pu+K	3-KD	2-K		26-RKD	49-B+Y	x	44-PWC	24-RS+R		6-BKS	3-KD	-22
-21	x	19-YKC	x	25-RC+R	62-Y+O	61-Y+R	46-PKS	47-PKC	54-Pu+K	19-YKC	41-Pu	25-RC+R	52-B+R	63-Y+W	59-Pu+W	62-Y+O	60-Y+G	45-PKD	9-OC+O	22-R	8-OS+O	1-W	40-BKC	12-ONS	2-K	x	-21
-20	54-Pu+K	30-GD	57-Pu+O	5-KC	31-GS	50-B+G	x	42-PWD	43-PWS	60-Y+G	x	60-Y+G	x	16-YC	40-BKC	13-Y	56-Pu+G	6-BKS	x	57-Pu+O	55-Pu+Y	18-YKS	13-Y	42-PWD	43-PWS	x	-20
-19	33-GKS	45-PKD	1-W	40-BKC	23-RD	20-YRD	37-BS	5-KC	33-GKS	10-OKD	3-KD	45-PKD	9-OC+O	x	42-PWD	55-Pu+Y	53-B+W	15-YS	29-G	12-ONS	31-GS	55-Pu+Y	53-B+W	5-KC	51-B+O	x	-19
-18	x	x	12-ONS	37-BS	41-Pu	16-YC	53-B+W	49-B+Y	25-RC+R	23-RD	63-Y+W	x	x	11-OKS	23-RD	37-BS	7-O	51-B+O	54-Pu+K	x	x	7-O	58-Pu+R	43-PWS	x	-18
-17	51-B+O	x				6-BKS	x		18-YKS	31-GS	x	5-KC	x	15-YS	18-YKS	48-B+K	27-RKS	48-B+K	24-RS+R	4-KS	52-B+R	29-G	9-OC+O	52-B+R	x	-17
-16	x	x	11-OKS	43-PWS	22-R	63-Y+W	x	50-B+G	62-Y+O	x	39-BKD	x	36-BD	x	18-YKS	x	44-PWC	32-GKD	16-YC	14-YD	36-BD	50-B+G	46-PKS	33-GKS	16-YC	x	-16
-15	36-BD		15-YS		x		x	58-Pu+R		13-Y	34-GKC	19-YKC	50-B+G	35-B	38-BC	31-GS	23-RD	39-BKD	30-GD	x	59-Pu+W	21-YRS	48-B+K	14-YD	16-YC	x	-15
-14	x	x	x	46-PKS	3-KD	x	2-K		45-PKD	32-GKD	29-G	20-YRD	39-BKD	26-RKD	2-K	31-GS	44-PWC	32-GKD	16-YC	39-BKD	36-BD	30-GD	x	62-Y+O	11-OKS	x	-14
-13	48-B+K	35-B	58-Pu+R	x	10-OKD	59-Pu+W		55-Pu+Y	51-B+O	6-BKS	40-BKC	1-W	49-B+Y	41-Pu	7-O	33-GKS	23-RD	46-PKS	62-Y+O	x	34-GKC	21-YRS	48-B+K	36-BD	x	-13
-12	8-OS+O	39-BKD	x	17-YKD	55-Pu+Y	38-BC	14-YD	22-R	27-RKS	59-Pu+W	28-RKC	53-B+W	8-OS+O	34-GKC	x	28-RKC	30-GD	x	11-OKS	x	x	19-YKC	27-RKS	59-Pu+W	x	x	-12
-11			x		x	47-PKC											19-YKC				x					-11
-10	x	x	x	x	49-B+Y	x	56-Pu+G	1-W	11-OKS	x	x	x	x	x	10-OKD	24-RS+R	28-RKC	x	50-B+G		18-YKS	x	22-R	47-PKC	28-RKC	x	-10
VINE / ROW	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	VINE / ROW

	BLOCK 5						BLOCK 4					BLOCK 3					BLOCK 2					BLOCK 1					

N ⇦

FLAG COLOR			
B	Blue	Pu	Purple
G	Green	R	Red
K	Black	Y	Yellow
O	Orange	W	White
P	Pink	N	Gray

FLAG PATTERN	
C	Checker
D	Dot
S	Stripe

D. Vine Management:

During the application period, the vines were maintained with a combination of drip and sprinkler irrigation to ensure optimal water supply. Vineyard management practices, including sucker shoot removal and leaf thinning, were performed on July 3rd to support vine health and improve air circulation.

E. Data Collection and Statistical Analysis:

Daily temperature and precipitation data were obtained from the California Irrigation Management Information System (CIMIS) weather station (CI006) located in West Davis (Figure 1). The UC Davis Powdery Mildew Risk Assessment Index model, previously known as the Gubler-Thomas model, was employed to evaluate disease pressure throughout the season. Relevant data were sourced from the UC IPM website (https://ipm.ucanr.edu/weather/grape-powdery-mildew-risk-assessment-index/) and the calculated disease risk indexes are illustrated in Figure 2. The first signs of powdery mildew were observed on May 15th on berry clusters. Disease incidence and severity were evaluated by examining 25 random clusters per treatment in each of the five blocks (representing five replicates of each treatment). Incidence was quantified as the proportion of clusters exhibiting symptoms or signs of powdery mildew per treatment within each block. Severity was determined by estimating the percentage of the cluster area affected by powdery mildew, and averages were calculated for each plot. Statistical analysis of the data was performed using analysis of variance (ANOVA) with generalized linear models. Mean comparisons were conducted using Fisher's LSD test ($\alpha = 5\%$), utilizing the InfoStat version 2020 software to ensure robust statistical reliability.

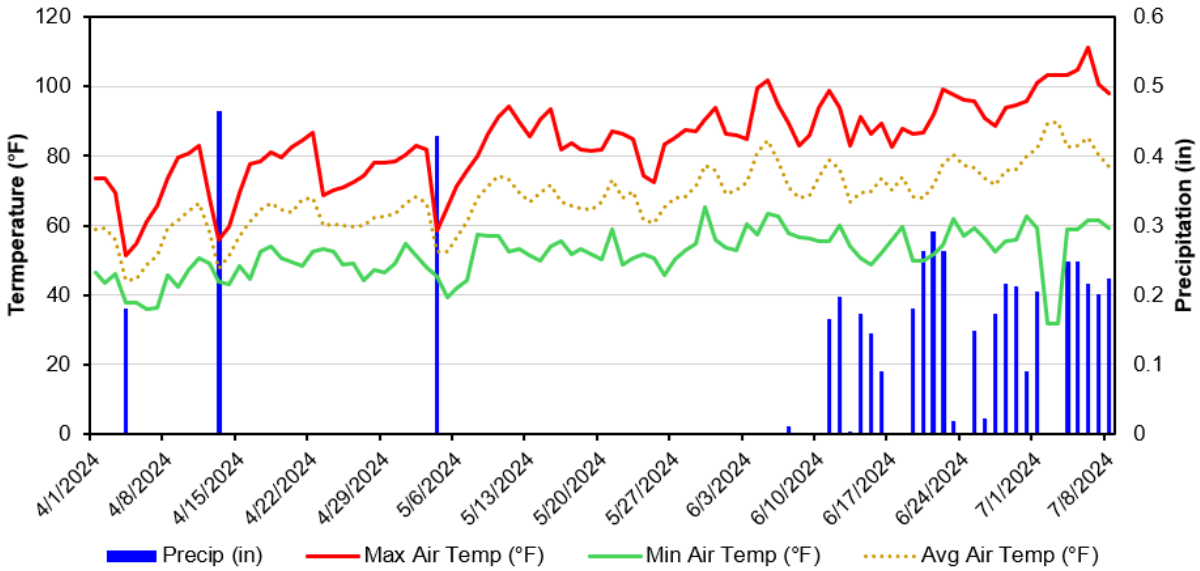
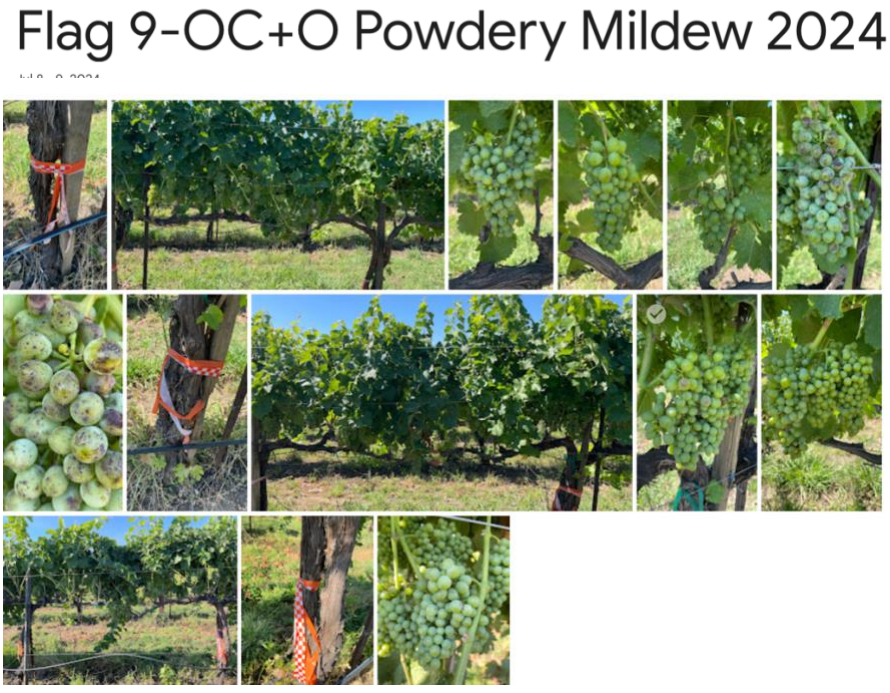


Figure 1. Maximum, average, and minimum daily temperatures (°F) and total precipitation (inches) recorded from April 1 to July 8, 2024, in Davis, CA. Data were obtained from the CIMIS weather station CI006), providing essential environmental context for the powdery mildew trial.

Figure 2. Risk Assessment Index (RAI) for grape powdery mildew from March 15 to July 14, 2024. The red line represents the threshold for high disease pressure (RAI > 60), while the blue line indicates low to moderate disease pressure (RAI > 30). Data were sourced from the UC IPM website, highlighting seasonal variations in disease risk**.**

F. Pictures of Treatments

To view visual documentation of each treatment, click on the active links provided next to the trial numbers in the result tables. These images offer a detailed representation of the treatment effects and outcomes observed during the study.



G. Results

Trial Group I – Synthetic Fungicides

Disease incidence and severity data for synthetic fungicides and combinations of synthetic fungicides with soft chemistry products. Product names are listed alongside their application rates (per acre). Vertical means followed by the same letter are not significantly different according to Fisher's LSD test ($p > 0.05$)

Treatment			Application date	Powdery mildew on the cluster[X]	
Nº	Flag[Z]	Rate/A[Y]	(Julian day)	Incidence (%)	Severity (%)
57	Pu+O	Sulfur (5 lb/A) Aprovia Top (13.3 fl oz/A) + A9180A (1.0 oz/A) + DyneAmic (0.125% v/v) Quintec (6.6 fl oz/A) + A9180A (1.0 oz/A) + DyneAmic (0.125% v/v) Miravis Prime (13.4 fl oz/A) + A9180A (1.0 oz/A) + Dyn-Amic (0.125% v/v) Inspire Super (20.0 fl oz/A) + A9180A (1.0 oz/A) + Dyn-Amic (0.125% v/v)	109, 115, 127 136 145 152 172	1.6 a	0.0 a
29	G	Regev (8.5 oz/A) + DyneAmic (0.125% v/v)	109, 115, 123, 128, 136, 144, 151, 157, 165, 173, 179	1.6 a	0.1 ab
10	OKD	Wettable Sulfur (5 lb/A) V6M-5-14 (27.4 fl oz/A) + DyneAmic (0.0625%)	109,115,127 136,152,165,180	2.0 ab	0.1 ab
24	RS+R	Scala DFO (17 fl oz) + DyneAmic (6.4 fl oz)	110, 127, 136, 152, 165, 179	3.2 ab	0.2 ab
9	OC+O	Luna Experience (4.3 fl oz) + Kitae (6 fl oz) Pristine (11.5 oz) + Kitae (6 fl oz) Endura (0.8 oz) + Kitae (6 fl oz) Trojan (1.15 fl oz) + Kitae (6 fl oz) Quintec (3 fl oz) + Kitae (6 fl oz)	109, 144, 179 115, 151 123, 157 128, 165 136, 173	4.0 ab	0.2 ab
38	BC	Luna Experience (8.6 fl oz) + DyneAmic (0.125% v/v) Quintec (6.6 fl oz) Mevalone (55 fl oz/A + OSS 6 fl oz/A Miravis Prime (13.4 fl oz) + DyneAmic (0.125% v/v)	110 127 137, 165 152, 180	5.6 ab	0.2 ab
59	Pu+W	Luna Experience (8.6 fl oz/A) Pristine (23 oz/A) Endura (1.6 oz/A) Trojan (2.3 fl oz/A) Quintec (6 fl oz/A)	109, 144, 179 115, 151 123, 157 128, 165 136, 173	4.8 ab	0.2 ab

56	Pu+G	Sulfur (5 lb/A) Aprovia Top (13.3 fl oz/A) + DyneAmic (0.125% v/v) Quintec (6.6 fl oz/A) + DyneAmic (0.125% v/v) Miravis Prime (13.4 fl oz/A) + DyneAmic (0.125% v/v) Inspire Super (20.0 fl oz/A) + DyneAmic (0.125% v/v)	109, 115, 127 136 143 152, 180 172	4.8 ab	0.2 ab
43	PWS	OxiDate 5.0 (0.5% v/v) + Luna Experience (8.6 fl.oz/A)	110, 127, 137, 152, 172, 180	8.0 abc	0.3 ab
12	ONS	UC-70 (9.1 fl/oz)	110, 127, 136, 151, 165, 179	7.2 abc	0.3 ab
11	OKS	UC-70 (4.7 fl/oz)	110, 127, 136, 151, 165, 179	2.0 ab	0.4 ab
42	PWD	Inspire Super 16 fl oz/A + OxiDate 5.0 (0.5% v/v) Luna Experience 8.6 fl oz/A+ OxiDate 5.0 (0.5% v/v) Pristine (23 oz/A)+OxiDate 5.0 (0.5% v/v) Miravis Prime (13.4 fl oz/A) + OxiDate 5.0 (0.5% v/v) Quintec (4 fl oz/A)+OxiDate 5.0 (0.5% v/v) Aprovia Top (13.3 fl oz/A) + OxiDate 5.0 (0.5% v/v)	110 127 137 152 165 180	8.0 abc	0.4 ab
2	K	Inspire Super (16 fl oz) Luna Experience (8.6 fl oz) Pristine (23 oz) Miravis Prime (13.4 fl oz) Quintec (4 fl oz) Aprovia Top (13.3 fl oz)	110 127 136 152 165 180	5.6 ab	0.4 ab
40	BKC	Luna Experience (8.6 fl oz) + DyneAmic (0.125% v/v) Quintec (6.6 fl oz) Sa-0650004 (28 fl oz/A) Miravis Prime (13.4 fl oz) + DyneAmic (0.125% v/v)	110 127 137, 165 152, 180	6.4 ab	0.4 ab
5	KC	ALD1901 (0.23 lb) Luna Experience (8.6 fl oz) Miravis Prime (13.4 fl oz) Quintec (4 fl oz) Aprovia Top (13.3 fl oz)	110, 136 127 152 165 180	7.2 abc	0.5 ab
4	KS	Luna Experience (8.6 fl oz)	110, 127, 136, 152, 165, 180	12.8 abc	0.6 ab
16	YC	Amara (2 qt) + DyneAmic (0.125% v/v) Luna Experience (8.6 fl oz)	109, 115 127, 137, 152, 165, 180	12.8 abc	0.7 ab
55	Pu+Y	Sulfur (5 lb/A)	109, 115, 127	12.0 abc	0.8 ab

		Inspire Super (20.0 fl oz/A) + DyneAmic (0.125% v/v)	136		
		Aprovia Top (13.3 fl oz/A) + DyneAmic (0.125% v/v)	143		
		Quintec (6.6 fl oz/A) + DyneAmic (0.125% v/v)	152		
		Miravis Prime (13.4 fl oz/A) + DyneAmic (0.125% v/v)	172, 180		
41	Pu	Luna Experience (8.6 fl oz) + DyneAmic (0.125% v/v)	110	14.4 abc	0.8 ab
		Quintec (6.6 fl oz)	127		
		Inspire Super (20 fl oz) + DyneAmic (0.125% v/v)	137		
		Quintec (6.6 fl oz) + DyneAmic (0.125% v/v)	152		
		Vivando (15.4 fl oz) + DyneAmic (0.125% v/v)	172		
		Pristine (23 oz) + DyneAmic (0.125% v/v)	180		
62	Y+O	Romeo (0.23 lb/A) + EMBRECE-EA (1 pt/100gal)	127	12.8 abc	0.9 ab
		BAJA (14 fl oz/A) + EMBRECE-EA (1 pt/100gal)	137, 165		
		SPARRA (44 fl oz/A) + EMBRECE-EA (1 pt/100gal)	152		
		Fervent 475 SC (8.5 fl oz/A) + EMBRECE-EA (1 pt/100gal)	180		
52	B+R	Luna Experience (8.6 fl oz/A)	110, 137, 165	16.8 abc	0.9 ab
		ApF23002 (64fl oz/A) + DyneAmic (0.125% v/v)	127, 151, 180		
25	RC+R	Inspire Super (20 fl oz) + DyneAmic (6.4 fl oz)	110, 127, 137, 152, 172, 180	12.0 abc	0.9 ab
54	Pu+K	Luna Experience (8.6 fl oz/A)	110, 137, 165	10.4 abc	1.0 ab
		ApF23002 (32 fl oz/A) + DyneAmic (0.125% v/v)	127, 151, 180		
51	B+O	Inspire Super (16 fl oz)	110	14.4 abc	1.2 ab
		ApF23002 (64 fl oz/A) + DyneAmic (0.125% v/v)	127, 151, 180		
		Pristine (23 oz/A)	137		
		Quintec (6 fl oz/A)	165		
27	RKS	Cevya (4 fl oz) + DyneAmic 6.4 fl oz	110	20.0 abcd	1.3 ab
		Gatten (6.4 fl oz) + DyneAmic 6.4 fl oz	127		
		Inspire Super (20 fl oz) + DyneAmic 6.4 fl oz)	137		
		Prolivo (5 fl oz) + DyneAmic (6.4 fl oz)	152		
		Vivando (15.4 fl oz) + DyneAmic (6.4 fl oz)	172		
		Inspire Super (3 qt) + DyneAmic (6.4 fl oz)	180		
26	RKD	Cevya (4 fl oz) + DyneAmic (6.4 fl oz)	110	20.0 abcd	2.0 ab
		Gatten (6.4 fl oz) + DyneAmic (6.4 fl oz)	127		
		Scala DFO (17 fl oz) + DyneAmic (6.4 fl oz)	137, 179		
		Prolivo (5 fl oz) + DyneAmic 6.4 fl oz)	152		

		Vivando (15.4 fl oz) + DyneAmic 6.4 fl oz)	172				
49	B+Y	Mettle (5 fl oz/A) Luna Sensation (7.6 fl oz/A) Torino SC (3.4 oz/A) Quintec (6 oz/A)	110 127, 172 137, 180 152	20.8	abcd	2.8	ab
48	B+K	Ecoswing (32 fl oz/A) Luna Sensation (7.6 fl oz/A) Torino SC (3.4 oz/A)	110, 152 127, 172 137, 180	28.0	bcd	2.9	ab
39	BKD	Luna Experience (8.6 fl oz) + DyneAmic (0.125% v/v) Quintec (6.6 fl oz) SA-0130310 (18.5 fl oz/A) + NIS (6 fl oz)	110 127 137, 152, 165, 172, 180	33.6	bcd	3.0	ab
13	Y	Rhyme (5 fl oz)	110, 127, 136, 152, 165, 180	37.6	bcd	3.2	ab
53	B+W	Inspire Super (16 fl oz/A) ApF23002 (32 fl oz/A) + DyneAmic (0.125% v/v) Pristine (23 oz/A) Quintec (6 fl oz/A)	110 127, 151, 180 137 165	28.8	bcd	3.4	ab
37	BS	Luna Experience (8.6 fl oz) + DyneAmic (0.125% v/v) Quintec (6.6 fl oz) SA-0650004 (28 fl oz/A)	110 127 137, 152, 165, 180	52.8	de	6.6	abc
30	GD	Kenja (22 fl oz) + DyneAmic (0.125% v/v)	110, 127, 137, 151, 172, 179	47.2	de	9.5	abc
28	RKC	Prolivo (5 fl oz) + DyneAmic (0.125% v/v)	110, 127, 137, 152, 172, 180	28.0	bcd	9.7	abc
36	BD	Luna Experience (8.6 fl oz) + DyneAmic (0.125% v/v) Quintec (6.6 fl oz) Mevalone (55 fl oz/A) + OSS (6 fl oz/A)	110 127 137, 152, 165, 180	82.4	fgh	17.8	abcd
60	Y+G	Sulfur (5 lb/A) Elevate (1 lb/A) + Aviv (25 fl oz/A)	110, 127, 137 152, 165, 172, 180	84.8	fgh	19.1	abcd
1	W	Untreated control	-	100	h	89.2	f

[Z] ⁂ = Phytotoxicity observed on berries.
[Y] Products with a '+' sign in between indicate a tank mix.
[X] Means followed by the same letter within a column are not significantly different according to Fisher's LSD test ($p > 0.05$).

Conclusion Based on Numbered Product Programs in Trial Group 1: Synthetic Fungicides

The analysis of powdery mildew incidence and severity highlights key performance trends across the product programs, labeled by their respective numbers. These findings are summarized below:

Top-Performing Programs (Incidence < 5% and Severity < 5%)

- **Program 57 (Pu+O):** Sulfur (5 lb/A), Aprovia Top, Quintec, Miravis Prime, and Inspire Super achieved the lowest disease incidence (1.6%) and no severity (0.0%), demonstrating exceptional control for high disease pressure.
- **Program 29 (G):** Regev (8.5 oz/A) + DyneAmic effectively controlled disease with an incidence of 1.6% and severity of 0.1%.
- **Program 10 (OKD):** Wettable Sulfur (5 lb/A), V6M-5-14 (27.4 fl oz/A) + DyneAmic provided effective management, with a 2.0% incidence and 0.1% severity.
- **Program 24 (RS+R):** Scala DFO (17 fl oz) + DyneAmic showed strong efficacy, achieving a 3.2% incidence and 0.2% severity.
- **Program 9 (OC+O):** Luna Experience, Kitae, Pristine, Endura, Trojan, and Quintec performed well with a 4.0% incidence and 0.2% severity.
- **Program 59 (Pu+W):** Luna Experience, Pristine, Endura, Trojan, and Quintec controlled disease effectively with a 4.8% incidence and 0.2% severity.
- **Program 56 (Pu+G):** Sulfur (5 lb/A), Aprovia Top, Quintec, Miravis Prime, and Inspire Super maintained strong control with a 4.8% incidence and 0.2% severity.

Moderately Effective Programs (Incidence 5%–25% and Severity ≤ 25%)

- **Program 38 (BC):** Luna Experience, Quintec, Mevalone, and Miravis Prime resulted in an incidence of 5.6% and severity of 0.2%.
- **Program 43 (PWS):** OxiDate 5.0 and Luna Experience maintained control with an 8.0% incidence and 0.3% severity.
- **Program 12 (ONS):** UC-70 showed moderate effectiveness with a 7.2% incidence and 0.3% severity.
- **Program 42 (PWD):** Inspire Super, OxiDate 5.0, Luna Experience, Pristine, Miravis Prime, Quintec, and Aprovia Top achieved 8.0% incidence and 0.4% severity.
- **Program 2 (K):** Inspire Super, Luna Experience, Pristine, Miravis Prime, Quintec, and Aprovia Top resulted in 5.6% incidence and 0.4% severity.
- **Program 40 (BKC):** Luna Experience, Quintec, SA-0650004, and Miravis Prime had a 6.4% incidence and 0.4% severity.
- **Program 5 (KC):** ALD1901, Luna Experience, Miravis Prime, Quintec, and Aprovia Top controlled disease with a 7.2% incidence and 0.5% severity.
- **Program 4 (KS):** Luna Experience performed at 12.8% incidence and 0.6% severity.
- **Program 16 (YC):** Amara and Luna Experience achieved an incidence of 12.8% and severity of 0.7%.
- **Program 55 (Pu+Y):** Sulfur (5 lb/A), Inspire Super, Aprovia Top, Quintec, and Miravis Prime managed disease at 12.0% incidence and 0.8% severity.
- **Program 41 (Pu):** Luna Experience, Quintec, Inspire Super, Vivando, and Pristine controlled disease at 14.4% incidence and 0.8% severity.

- **Program 62 (Y+O):** Romeo, EMBRECE-EA, BAJA, SPARRA, and Fervent 475 SC resulted in an incidence of 12.8% and severity of 0.9%.
- **Program 52 (B+R):** Luna Experience, ApF23002 + DyneAmic achieved 16.8% incidence and 0.9% severity.
- **Program 25 (RC+R):** Inspire Super + DyneAmic performed at 12.0% incidence and 0.9% severity.
- **Program 54 (Pu+K):** Luna Experience, ApF23002 + DyneAmic maintained control at 10.4% incidence and 1.0% severity.
- **Program 51 (B+O):** Inspire Super, ApF23002 + DyneAmic, Pristine, and Quintec showed moderate efficacy with 14.4% incidence and 1.2% severity.
- **Program 27 (RKS):** Cevya + DyneAmic, Gatten + DyneAmic, Inspire Super + DyneAmic, Prolivo + DyneAmic, and Vivando + DyneAmic maintained control at 20.0% incidence and 1.3% severity.
- **Program 26 (RKD):** Cevya + DyneAmic, Gatten + DyneAmic, Scala DFO + DyneAmic, Prolivo + DyneAmic, and Vivando + DyneAmic performed at 20.0% incidence and 2.0% severity.
- **Program 49 (B+Y):** Mettle, Luna Sensation, Torino SC, and Quintec controlled disease at 20.8% incidence and 2.8% severity.

Programs with Limited Efficacy (Incidence > 25% or Severity > 25%)

- **Program 48 (B+K):** Ecoswing, Luna Sensation, and Torino SC had limited effectiveness with 28.0% incidence and 2.9% severity.
- **Program 39 (BKD):** Luna Experience, Quintec, SA-0130310 + NIS resulted in 33.6% incidence and 3.0% severity.
- **Program 13 (Y):** Rhyme had a higher incidence of 37.6% and severity of 3.2%.
- **Program 53 (B+W):** Inspire Super, ApF23002 + DyneAmic, Pristine, and Quintec performed at 28.8% incidence and 3.4% severity.
- **Program 37 (BS):** Luna Experience + DyneAmic, Quintec, SA-0650004 resulted in 52.8% incidence and 6.6% severity.
- **Program 30 (GD):** Kenja + DyneAmic was less effective, with 47.2% incidence and 9.5% severity.
- **Program 28 (RKC):** Prolivo + DyneAmic had an incidence of 28.0% and severity of 9.7%.
- **Program 36 (BD):** Luna Experience + DyneAmic, Quintec, Mevalone + OSS performed poorly, with 82.4% incidence and 17.8% severity.
- **Program 60 (Y+G):** Sulfur, Elevate, and Aviv were ineffective with 84.8% incidence and 19.1% severity.
- **Program 1 (W - Untreated Control):** Showed the highest disease pressure, with 100% incidence and 89.2% severity.

Summary of Recommendations

Programs such as 57 (Pu+O) and 29 (G), incorporating Sulfur or systemic fungicides like Luna Experience, Aprovia Top, and Quintec, demonstrated superior disease

management and should be prioritized in high-pressure scenarios. Including adjuvants such as DyneAmic improves fungicide efficacy by enhancing coverage and retention. Moderately effective programs, such as 10 (OKD) and 24 (RS+R), can complement rotations for resistance management and reduce chemical inputs under moderate disease pressure.

Lower-performing programs like 4 (KS) and 16 (YC) should be combined with more effective treatments to ensure comprehensive control.

This analysis reinforces the importance of selecting and tailoring fungicide programs to the specific pressures and conditions in the vineyard to achieve sustainable and effective powdery mildew management.

Trial Group II – Soft Chemistry Products

Disease incidence and severity of soft chemistry products, including biologicals, sulfur, nutrients, oils, and organic materials. Product names are followed by rate (per acre). Treatment means followed by the same letter are not significantly different according to Fisher's LSD test ($p > 0.05$).

Treatment			Application date	Powdery mildew on the cluster[X]	
Nº	Flag[Z]	Rate/A[Y]	(Julian day)	Incidence (%)	Severity (%)
19	YKC	Shielder (4 lb/A) + Oroboost (16 fl oz/100 gal)	109,115,123,128,136,144,151,157,165,173,179	16.8 ab	1.0 ab
44	PWC	Sulfur DF (5 lb/A) OxiDate 5.0 (1.0% v/v)	109,123,136,151,165,179 115,128,144,157,173	7.0 abc	3.4 ab
7	O**	S10 5L/ha (2 L/A)+D0.9 2L/ha (0.8 L/A) S10 5 L/ha (0.8 L/A)+ID0.9 2L/ha (0.8 L/A) ID0.9 2L/ha (0.8 L/A)+MT0.9 2L/ha (0.8 L/A) S10 5,0L/ha (2 L/A)+MT0.9 2L/ha (0.8 L/A) S10 5L/ha (2 L/A)+ID0.9 2,5L/ha (1 L/A) +MT0.9 2,5L/ha (1 L/A) ID0.9 2,5L/ha (1 L/A) +MT0.9 2,5L/ha (1 L/A)	110 127 136 151 165 179	26.4 bcd	4.1 abc
20	YRD	Shielder (4 lb/A) + Oroboost (32 fl oz/100 gal)	109,115,123,128,136,144,151,157,165,173,179	35.2 bcd	4.3 abc
3	KD	Sulfur DF (5 lb)	109,115,123,128,136,144,151,157,165,173,179	32.0 bcd	4.9 abc
50	B+G	Sulfur DF (5 lb) ApF23002 (64 fl oz/A) + DyneAmic (0.125% v/v)	109,127,136,151,165,179 115,128,144,157,173	50.4 de	5.2 abc
31	GS	ApF23002 (64 fl oz) + DyneAmic (0.125% v/v)	109, 115, 123, 128, 136, 144, 151, 157, 165, 173, 179	39.2 cd	7.2 abc
18	YKS	Shielder (4 lb/A)	109,115,123,128,136,144,151,157,165,173,179	64.0 ef	10.7 abc

15	YS	AGS26 (14 fl oz) + Sulfur (5 lb/A) + Syl-Coat (4 fl oz/100 gal)	110,127,136,151,165,179	65.6	ef	13.7	abc
35	B	ProBlad (45 fl oz/A)	110,127,137,152,165,179	80.0	efgh	15.0	abc
8	OS+O	Kitae (12 fl oz) + DyneAmic (0.125% v/v)	109,115,123,128,136,144,151,157,165,173,179	69.6	ef	15.4	abc
tea	PKS⁂	Ecoswing (32 fl oz/A) Regalia (2 qt) Double Nickel 55 (16 fl oz) Kaligreen (5 lb)	109, 136, 165 115, 144, 173 123, 151, 179 128, 157,	62.4	ef	16.2	abcd
32	GKD	ApF23002 (32 fl oz) + DyneAmic (0.125% v/v)	109, 115, 123, 128, 136, 144, 151, 157, 165, 173, 179	84.0	fgh	20.6	abcd
33	GKS	ProBlad Verde (32 oz/A)	109, 115, 123, 128, 136, 144, 151, 157, 165, 173, 179	75.9	ef	21.7	abcd
47	PKC⁂	Ecoswing (32 fl oz/A) Kaligreen (5 lb) Double Nickel 55 (16 fl oz)	109, 136, 165 115, 128, 144, 157, 173 123, 151, 179	72.8	efg	23.5	abcd
58	Pu+R	Sulfur (5 lb/A) EMP Barrier (0.5% v/v)/50gal + Syl-Coat (4 fl oz/100gal) EMP Barrier (1% v/v)/100gal + Syl-Coat (4 fl oz/100gal) EMP Barrier 2% (v/v)/100gal + Syl-Coat 4 fl. oz per/100gal	110, 127 137 151, 157, 165, 179 173	85.6	fgh	24.0	abcd
34	GKC	Cinnerate (32 oz/100 gal)	109, 115, 123, 128, 136, 144, 151, 157, 165, 173, 179	82.4	fgh	32.3	bcd
45	PKD	Ecoswing (32 fl oz/A)	109, 115, 123, 128, 136, 144, 151, 157, 165, 173, 179	93.6	gh	38.3	bcd
6	BKS	ALD 1901 (0.23 lb/A)	110, 127, 136, 151, 165, 179,	92.8	fgh	38.7	bcd
17	YKD	Amara (2 qt) + DyneAmic	109, 115, 123, 128, 136, 144, 151, 157, 165, 173, 179	92.0	fgh	38.8	bcd
61	Y+R	Lime sulfur reduced rate (1 qt/100 gal)	110, 127, 137, 152, 172, 180	98.4	h	54.6	bcde
14	YD	AGS26 (14 fl oz/A) + Syl-Coat (4 fl oz /100gal)	110, 127, 136, 151, 165, 179	98.4	h	55.8	cde
23	RD	Kaligreen (3 lb) + Silwet (2 oz/100 gal)	173, 179	98.4	h	60.0	cdef
1	W	Untreated Control	-	100	h	89.2	f

[Z] ⁂ = Phytotoxicity observed on berries.
[Y] Products with a '+' sign in between indicate a tank mix.
[X] Means followed by the same letter within a column are not significantly different according to Fisher's LSD test ($p > 0.05$).

Conclusion Based on Numbered Product Programs in Trial Group 2: Soft Chemistry Products:

The analysis of powdery mildew incidence and severity for Group 2 treatments highlights the following trends in product program efficacy:

Top-Performing Programs (Incidence < 20% and Severity < 20%)

- **Program 19 (YKC):** Shielder (4 lb/A) + Oroboost (16 fl oz/100 gal) achieved an incidence of 16.8% and severity of 1.0%, demonstrating strong control for a soft chemistry treatment.
- **Program 44 (PWC):** Sulfur DF (5 lb/A) + OxiDate 5.0 (1.0% v/v) performed well, with a 7.0% incidence and 3.4% severity.

Moderately Effective Programs (Incidence 20%–40% and Severity ≤ 40%)

- **Program 7 (O):** S10 5L/ha (2 L/A) + D0.9 2L/ha (0.8 L/A) resulted in a 26.4% incidence and 4.1% severity.
- **Program 20 (YRD):** Shielder (4 lb/A) + Oroboost (32 fl oz/100 gal) showed moderate control with a 35.2% incidence and 4.3% severity.
- **Program 3 (KD):** Sulfur DF (5 lb) provided moderate protection with a 32.0% incidence and 4.9% severity.
- **Program 31 (GS):** ApF23002 (64 fl oz) + DyneAmic (0.125% v/v) had an incidence of 39.2% and severity of 7.2%.

Programs with Limited Efficacy (Incidence > 40% or Severity > 40%)

- **Program 50 (B+G):** Sulfur DF (5 lb) + ApF23002 (64 fl oz/A) + DyneAmic (0.125% v/v) resulted in 50.4% incidence and 5.2% severity.
- **Program 18 (YKS):** Shielder (4 lb/A) showed a high incidence of 64.0% and severity of 10.7%.
- **Program 15 (YS):** AGS26 (14 fl oz) + Sulfur (5 lb/A) + Syl-Coat (4 fl oz/100 gal) had 65.6% incidence and 13.7% severity.
- **Program 35 (B):** ProBlad (45 fl oz/A) resulted in an incidence of 80.0% and severity of 15.0%.
- **Program 8 (OS+O):** Kitae (12 fl oz) + DyneAmic (0.125% v/v) had a high incidence of 69.6% and severity of 15.4%.

- **Program 32 (GKD):** ApF23002 (32 fl oz) + DyneAmic (0.125% v/v) performed poorly, with an 84.0% incidence and 20.6% severity.
- **Program 33 (GKS):** ProBlad Verde (32 oz/A) had an incidence of 75.9% and severity of 21.7%.
- **Program 47 (PKC):** Ecoswing (32 fl oz/A), Kaligreen (5 lb), and Double Nickel 55 (16 fl oz) resulted in 72.8% incidence and 23.5% severity.
- **Program 58 (Pu+R):** Sulfur (5 lb/A) + EMP Barrier + Syl-Coat had 85.6% incidence and 24.0% severity.
- **Program 34 (GKC):** Cinnerate (32 oz/100 gal) resulted in 82.4% incidence and 32.3% severity.
- **Program 45 (PKD):** Ecoswing (32 fl oz/A) was less effective, with an incidence of 93.6% and severity of 38.3%.
- **Program 6 (BKS):** ALD 1901 (0.23 lb/A) had an incidence of 92.8% and severity of 38.7%.
- **Program 17 (YKD):** Amara (2 qt) + DyneAmic resulted in 92.0% incidence and 38.8% severity.
- **Program 61 (Y+R):** Lime sulfur reduced rate (1 qt/100 gal) performed poorly, with an incidence of 98.4% and severity of 54.6%.
- **Program 14 (YD):** AGS26 (14 fl oz/A) + Syl-Coat (4 fl oz /100 gal) showed an incidence of 98.4% and severity of 55.8%.
- **Program 23 (RD):** Kaligreen (3 lb) + Silwet (2 oz/100 gal) had an incidence of 98.4% and severity of 60.0%.
- **Program 1 (W - Untreated Control):** Expectedly showed the highest disease pressure, with 100% incidence and 89.2% severity.

Summary and Recommendations

- **Top-Performing Programs** (YKC, PWC) provided the most effective control for a soft chemistry approach, though their efficacy is lower than synthetic fungicides.
- **Moderately Effective Programs** (O, YRD, KD, GS) offered partial control and can be integrated into disease management strategies to reduce reliance on synthetic fungicides.
- **Programs with Limited Efficacy** (B+G, YKS, YS, etc.) were less effective under high disease pressure and may need to be used in combination with stronger treatments.

Note on Soft Chemistry Products:

Soft chemistry treatments generally show **lower efficacy** compared to synthetic fungicides but offer a **more sustainable approach** to disease management. These products contribute to resistance management, reduce chemical load, and align with organic production practices. They should be integrated **strategically** within an IPM (Integrated Pest Management) program to optimize their benefits while minimizing disease impact.

The results demonstrate the importance of selecting the right combination of treatments based on disease pressure, environmental conditions, and program limitations. Rotational use of effective treatments alongside integrated pest management (IPM) strategies can improve long-term powdery mildew control while mitigating resistance risks.

H. Appendix: Treatments

Product	Active ingredient(s)	Manufacturer or distributor	Chemical class (FRAC Code)
A9180A	Proprietary	Syngenta	N/A
AGS26	Proprietary	Agrosphere	N/A
ALD 1901	Proprietary	Agrauxine	N/A
Amara	Proprietary	Nichino America	N/A
ApF23002	Proprietary	Meese	N/A
Aprovia Top	Difenoconazole (10.95%) + benzovindiflupyr (7.30%)	Syngenta	DMI (3), SDHI (7)
Aviv	N/A	N/A	N/A
BAJA	Proprietary	Willbur Ellis	N/A
Bio Project lD0.9	Proprietary	FP Invest	N/A
Bio Project MT0.9	Proprietary	FP Invest	N/A
Bio Project S10	Proprietary	FP Invest	N/A
Cevya	Mefentrifluconazole	BASF	DMI (3)
Cinnerate	Proprietary	SymAgro	N/A
Double Nickel	*Bacillus amyloliquefaciens* strain D747	Nichino America	Microbial (44)
DyneAmic	Methyl esters of C16-C18 fatty acids	Helena Chemical Company	N/A
Ecoswing	Extract of *Swinglea glutinosa*	Gowan	N/A
Elevate	Fenhexamid	Arysta	Hydroxyanilide (17)
EMBRECE-EA	Proprietary	Willbur Ellis	N/A
EMP Barrier	Cinnamon oil 1.5%	GemmaProducts	N/A
Endura	Boscalid	BASF	SDHI (7)
Fervent	Proprietary	Willbur Ellis	N/A
Gatten	Flutianil, 4.7%	Nichino America	Thiazolidine (U-13)
Inspire Super	Difenoconazole + cyprodinil	Syngenta	DMI (3), AP (9)
Kaligreen	Potassium bicarbonate	Brandt	Not classified (NC)
Kenja	Isofetamid	SummitAgro	SDHI (7)
Kitae	Chitosan hydrochloride	Green Impulse	N/A
Lime Sulfur	Calcium polysulfide and thiosulfate	Brandt	Inorganic (M-02)
Luna Experience	Fluopyram (17.54%) + tebuconazole (17.54%)	Bayer	SDHI (7), DMI (3)

Luna Sensation	Fluopyram (21.4%) + trifloxystrobin (21.4)	Bayer	SDHI (7), QoI (11)
Mettle	Tetraconazole	Gowan	DMI (3)
Mevalone	Eugenol 3.2% + geraniol 6.4% + thymol 6.4%	Sipcam Agro	Terpene (BM01)
Miravis Prime	Fludioxonil (21.4%) + pydiflumetofen (12.8%)	Syngenta	PP (12), SDHI (7)
NIS	Adjuvant	N/A	N/A
Oroboost	adjuvant with Secondary Alcohol Ethoxylate	Oro-Agri	N/A
Shielder	Bacillus subtilis and sodium bicarbonate	Oro-Agri	N/A
OSS	Adjuvant	N/A	N/A
OxiDate 5.0	Hydrogen peroxide + peroxyacetic acid	BioSafe	N/A
Pristine	Pyraclostrobin + boscalid	BASF	QoI (11), SDHI (7)
ProBlad Verde	Banda de Lupinus albus doce (BLAD)	SymAgro	N/A
Prolivo	Pyriofenone	Summit Agro	(50)
Quintec	Quinoxyfen	Corteva	Aryloxyquinoline (13)
Rally	Myclobutanil	Corteva	DMI (3)
Regalia	Extract of *Reynoutria sachalinensis*	Marrone Bio Innovations	Plant extract (P-05)
Regev	Tea tree oil (40.6%) + difenoconazole (20.3%)	Summit Agro	Terpene (BM02)
Rhyme	Flutriafol (22.7%)	FMC Corporation	DMI (3)
Romeo	Proprietary	Willbur Ellis	N/A
SA-0130310	Proprietary	Sipcam Agro	N/A
SA-0650004	Proprietary	Sipcam Agro	N/A
Scala DFO	pyrimethanil + difenconazole	Bayer	AP (9)
Serenade ASO	*Bacillus subtilis* strain QST 713	Bayer	Microbial (44)
Silwet	Surfactant	Helena Chemical Company	N/A
SPARRA	Proprietary	Willbur Ellis	N/A
Sulfur DF	Sulfur (80%)	Willbur Ellis	Inorganic (M-02)
Switch	Cyprodinil + fludioxonil	Syngenta	AP (9), PP (12)
Syl-Coat	Copolymer, polyether (100%)	Willbur Ellis	N/A
Toledo	Tebuconazole	Rotam Agrochemical	DMI (3)
Torino	Cyflufenamid	Gowan	U-06
Trojan	Tetraconazole (13.8%)	FMC	DMI (3)
UC-70	Proprietary	BASF	SDHI (7)
V6M-5-14	Proprietary	Corteva	N/A
Vivando	Metrafenone	BASF	(50)

I. Appendix: Julian Date Calendar for Year 2024

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1	32	61	92	122	153	183	214	245	275	306	336
2	2	33	62	93	123	154	184	215	246	276	307	337
3	3	34	63	94	124	155	185	216	247	277	308	338
4	4	35	64	95	125	156	186	217	248	278	309	339
5	5	36	65	96	126	157	187	218	249	279	310	340
6	6	37	66	97	127	158	188	219	250	280	311	341
7	7	38	67	98	128	159	189	220	251	281	312	342
8	8	39	68	99	129	160	190	221	252	282	313	343
9	9	40	69	100	130	161	191	222	253	283	314	344
10	10	41	70	101	131	162	192	223	254	284	315	345
11	11	42	71	102	132	163	193	224	255	285	316	346
12	12	43	72	103	133	164	194	225	256	286	317	347
13	13	44	73	104	134	165	195	226	257	287	318	348
14	14	45	74	105	135	166	196	227	258	288	319	349
15	15	46	75	106	136	167	197	228	259	289	320	350
16	16	47	76	107	137	168	198	229	260	290	321	351
17	17	48	77	108	138	169	199	230	261	291	322	352
18	18	49	78	109	139	170	200	231	262	292	323	353
19	19	50	79	110	140	171	201	232	263	293	324	354
20	20	51	80	111	141	172	202	233	264	294	325	355
21	21	52	81	112	142	173	203	234	265	295	326	356
22	22	53	82	113	143	174	204	235	266	296	327	357
23	23	54	83	114	144	175	205	236	267	297	328	358
24	24	55	84	115	145	176	206	237	268	298	329	359
25	25	56	85	116	146	177	207	238	269	299	330	360
26	26	57	86	117	147	178	208	239	270	300	331	361
27	27	58	87	118	148	179	209	240	271	301	332	362
28	28	59	88	119	149	180	210	241	272	302	333	363
29	29	60	89	120	150	181	211	242	273	303	334	364
30	30		90	121	151	182	212	243	174	304	335	365
31	31		91		152		213	244		305		366