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Balchem® Plant Nutrition Research Paper

Advancing Ripening of Crimson Seedless using Albion® Potassium Metalosate®, deficit irrigation, and PGRs

by Bill Peacock and Joe Smilanick*

Color development is the limiting factor for Crimson Seedless, and it is not unusual that half the crop or more is not picked because of lack of color. Berry size, berry firmness, soft berries, and post harvest shatter are also concerns with this cultivar.

Research was conducted in a mature Crimson Seedless vineyard near Exeter to determine the efficacy of deficit irrigation, foliar potassium, and PGRs (ethephon, Protone®, both) on fruit color, production, and vine growth. The research was conducted in 2012 and then repeated in 2013.

The experiment was designed as a 3x factorial. Factor A compared two treatments: fully irrigated vines with vines deficit irrigated. Factor B compared four treatments: Albion foliar K applied either at 14˚brix, 16˚ brix or 18˚ brix along with a control. Factor C evaluated PGRs: ethephon, Protone®; both ethephon and Protone; untreated control. The PGR treatments were all applied at 14 obrix. Plot size consisted of four vines and there were 64 plots and two blocks.

Completely Randomized Split Split Plot Design

Factor A Irrigation	Factor B Foliar K	Factor C PGRs
1. Deficit	1. Control	1. Control
2. Full	2. K at 14° brix	2. Ethephon
	3. K at 16° brix	3. Protone®
	4. K at 18° brix	4. Both

The primary purpose of deficit irrigation during fruit ripening is to slow shoot growth. The shoot tip is a strong sink for photosynthates and slowing shoot growth during ripening enhances the flux of carbohydrates to fruit. The amount of stress to apply to maximize fruit maturity while minimizing negative impacts on fruit size and vine capacity is not entirely understood.

In this study, deficit irrigation consisted of applying full evapotranspiration (ET) from budbreak until the lag phase, fifty percent ET from the lag phase until September 18, and then full ET until dormancy. Daily irrigation amounts were based on the San Joaquin Valley Drip Irrigation Scheduler (Peacock, UCCE, Visalia CA) and then adjusted based on tensiometer and gypsum block measurements of soil matric potential. Water meters were used to record amounts applied to both deficit and full ET treatments. A pressure bomb was used to measure leaf water potential at mid-day and during an irrigation cycle.

During the period budbreak to June 28 both deficit and full irrigation treatments received 9.8 acre inches of water. Deficit irrigation was applied from June 28 to September 18 and the deficit and full irrigation treatments received 12.9 acre inches and 25.7 acre inches, respectively. After, September 18 to November 7 both treatments received full ET at about 3 acre inches for the period. The total seasonal application to the deficit and full irrigation treatments was 25.7 acre inches and 39.1 acre inches, respectively, Table 1.

Once deficit irrigation was initiated, the soil matric potential and leaf water potential were lowered, Tables 2 and 3. The consequence was that shoot growth slowed from 1.0 to 0.2 centimeters per day, Tables 4.

In 2013, harvest occurred on two dates: September 23 (first pick) and October 28 (final pick). The total amount of fruit on the vine was determined (total yield) along with the percent of the total yield harvested on the first and final pick. Culls were also measured. For this study, 90% of the berries on a cluster had to be 90% colored for fruit to be packed.

Deficit irrigation improved fruit color development and nearly doubled packable yield, Table 5. In 2012 results were even more pronounced with a total pack of 804 boxes per acre compared to 115 boxes for fully irrigated vines, Table 6.

In 2013, berries were sampled on August 11 and then again on September 13 to evaluate fruit characteristics. There was no difference in sugar maturity when sampled August 11 (thirty days into deficit irrigation) but by September 13 deficit irrigation had advanced maturity by 0.8˚ brix, Table 8. In 2012, berries were sampled on September 26 and October 15 and deficit irrigation increased sugar about one degree on both dates.

There were drawbacks associated with deficit irrigation. Berry weight was reduced by 7% in 2013 and 6% in 2012 and berries were less firm. Deficit irrigation slowed shoot growth the following spring. Shoot growth in the spring was measured by noting the number of shoots reaching the top foliage wire by April 19, 2013, Table 9. Trunk growth during the 2013 season was similar for deficit and full irrigation.

Irrigation treatment impacted leaf blade and petiole mineral nutrition. Deficit irrigation reduced the potassium level in blades while increasing magnesium in petioles, Table 10. The mineral nutrition of fruit was also affected. Deficit irrigation reduced the level of potassium and boron in the pulp and reduced nitrogen, potassium, magnesium and boron in the skin, Table 11.

Albion potassium metalosate (one gallon per acre) was applied on July 11 (14˚ brix), July 29 (16˚ brix), and August 11 (18˚ brix). Foliar potassium applied July 11 improved packable yield (color) on the first pick by 30%, but there was no benefit associated with the second or total amount of packed fruit. The impact on packable fruit was much more pronounced in 2012.

When foliar K was applied early, the amount of fruit packed was increased on all picking dates, and the total amount of fruit packed for the season was 60% greater than the control. This research suggests than foliar K should be applied soon after veraison to maximize color development.

Foliar potassium enhanced sugar maturity. It is interesting to note that the maturity response occurred within 12 days of the July 29 application. All foliar K time of applications advanced maturity about 1˚ brix, Tables 7 and 8.

Foliar K reduced berry size (weight, length) when applied on July 11 but not at the later timings, Table 7. In 2012, foliar K did not affect berry size, no matter the timing.

The application of foliar potassium increased the concentration of K in fruit pulp but not fruit skin. Unexpected however, was that foliar K also increased the level of phosphorous and boron in the pulp of the fruit, Table 11. One of the biochemical roles of B in higher plants is to facilitate the transport of sugars through membranes.

PGR ethephon increased color and therefore packable yield both in 2012 and 2013. Protone did not significantly improve color or increase packable yield either year. Ethephon and Protone combination was no more efficacious the ethephon alone, Tables 5 and 6.

Conclusion: Deficit irrigation increased the amount of fruit that could be packed, meeting color requirements, and sugar maturity was also advanced. The enhancement of color and sugar maturity is contributed to a slowing of shoot growth and redirection of photosynthates to fruit rather than shoots. Deficit irrigation reduced berry size, berry firmness, spring growth, and nutrient status of vine and fruit. Vines were stressed for eight weeks during ripening in this study, but potentially a shorter period could improve color with less negative impact.

Albion potassium metalosate increased packable fruit (color) and advanced sugar maturity. For color development, foliar K was best applied soon after veraison. But, for sugar maturity, timings were similar, increasing sugar by about 1˚ brix. It took 12 days following foliar K application for the full impact on sugar maturity to occur.

Deficit irrigation impacted mineral nutrition by lowering levels of K in leaves, and K and B in fruit pulp, and N, K, Mg and B in fruit skin. Foliar K applied to foliage during ripening increased phosphorous, potassium and boron in fruit pulp and nitrogen in fruit skin. The fact that foliar potassium advances maturity while increasing boron in the pulp is interesting as boron is associated with the movement of sugars across membranes.

* Bill Peacock, UC Viticulturist, Emeritus. 559/260-6119; wlpeacock@ucdavis.edu

Joe Smilanick, USDA-ARS, Research Plant Pathologist

Table 1. Irrigation Amounts Applied to Full and Deficit Irrigation Treatments

Period	Full Irrigation (Gallons per Vine)	Deficit Irrigation (Gallons per Vine)	Full Irrigation (Acre inches)	Deficit Irrigation (Acre inches)
April 1 to June 28 (No Deficit Irrigation)	515	515	9.9	9.8
June 28 to Sept 18 (Deficit Irrigation Occurs)	1341	675	25.7	12.9
Sept 18 to November 7 (No Deficit Irrigation)	182	156	3.5	3.0
Total:	2038	1346	39.1	25.7

Table 2. Tensiometer soil matic measurements (-cbars) at 2' and 4' depth
Corrected for gravitational head

	Deficit		Full ET	
Date	2 feet	4 feet	2 feet	4 feet
24-Apr	x	6	10	3
1-May	x	5	8	2
8-May	x	5	9	2
15-May	6	8	14	5
22-May	6	8	14	5
29-May	6	8	12	6
5-Jun	6	8	6	6
12-Jun	10	7	10	4
19-Jun	12	8	9	5
26-Jun	6	8	9	5
3-Jul	14	7	13	6
10-Jul	30	14	24	6
13-Jul	40	26	42	16
17-Jul	48	22	30	10
23-Jul	50	26	22	36
30-Jul	58	22	6	6
7-Aug	56	46	6	10
14-Aug	16	48	8	2
21-Aug	34	58	14	6
28-Aug	52	60	12	6
4-Sep	59	56	12	4
11-Sep	14	28	8	2
18-Sep	10	2	6	0
24-Sep	16	12	14	8
3-Oct	6	4	14	8
10-Oct	20	12	14	8
17-Oct	32	16	32	20
7-Nov	8	30	14	52

Note: Outlined area is deficit irrigation period.

Table 3. Effect of deficit and full irrigation on leaf water potential (Mpa)

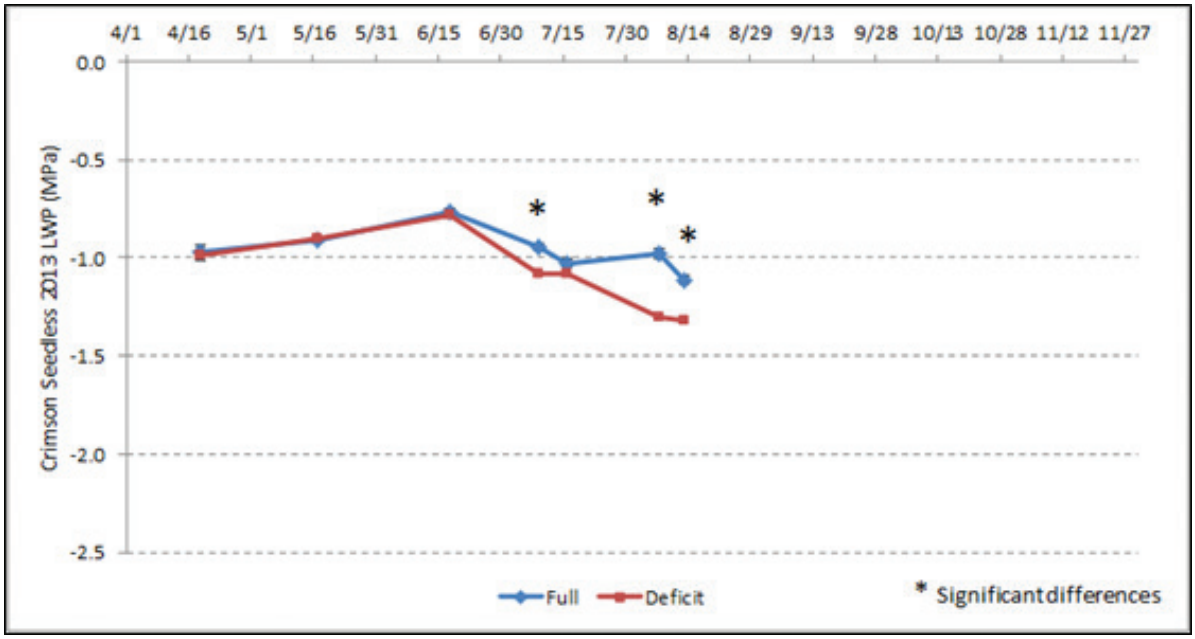

Table 4. Shoot growth comparing deficit and full irrigatin treatments (cm/day).

Irrigation	26-Jun	3-Jul	10-Jul	17-Jul	29-Jul	5-Aug	12-Aug
Deficit	1.9	2.0	0.6	0.6	0.5	0.2	0.2
Full	1.9	2.1	0.9	0.8	1.2	1	0.5
	n=64	n=64	n=64	n=64	n=128	n=128	n=128

n= total number of shoot measured.

Table 5. Harvest averages for irrigation, foliar K, and PGRs treatments 2013

Factorial Averages	1st Pick 23-Sep (% Total)	2nd Pick 28-Oct (% Total)	Total Sept + Oct (% Total)	Cull 15-Oct (% Total)	Total Yield (lbs/vine)
Deficit Irrigation	32	47	80	19	43.0
Full Irrigation	15	31	46	53	42.0
L.S.D.$_{.05}$ =	6	4	6	6	n.s.
No foliar K	24	46	70	30	45.0
Applied: 14˚ brix	31	28	60	39	42.0
Applied: 16˚ brix	17	41	58	41	40.0
Applied: 18˚ brix	23	41	64	35	42.0
L.S.D..05 =	5	4	n.s.	n.s.	n.s.
No PGR	20	32	53	46	41.0
Ethrel	31	43	74	25	44.0
Protone	15	44	60	39	41.0
Both	29	36	66	33	44.0
L.S.D..05 =	8	6	8	8	n.s.

n.s. = not significant

Table 6. Harvest averages for irrigation, foliar K, and PGRs treatments, 2012

Factorial Averages	1st Pick 27-Aug (box/ac.)	2nd Pick 26-Sep (box/ac.)	3rd Pick 15-Oct (box/ac.)	Total (box/ac.)
Deficit Irrigation	371	191	243	804
Full Irrigation	46	25	44	115
	***	***	*	***
No foliar K	172	76	123	371
Applied: 14˚ brix	248	142	202	592
Applied: 16˚ brix	117	74	120	311
Applied: 18˚ brix	297	5	128	430
	**	ns	*	***
No PGR	112	85	117	314
Ethrel	333	158	164	654
Protone	150	65	93	308
Both	240	120	199	559
	**	ns	**	***

L.S.D.: 1% = ***; 5%= **;1 0%= * & not significant = ns

Table 7. Crimson Seedless Fruit Characteristics Sample August 11, 2013

Treatment Factorial Average	Sugar (Brix)	TartaricAcid (g/L)	Acid (pH)	Berry Wt. (g)	B. Length (cm)	B. Width (cm)
Factor A: Irrigation						
Deficit	18.8	2.64	3.5	5.3	2.7	1.7
Full	18.8	2.76	3.5	5.7	2.8	1.7
	ns	*	ns	***	*	ns
Factor B: Potassium						
Control	18.2 a	2.74 bc	3.5	5.6 a	2.7a	1.8 a
14˚ Brix (July 11)	19.4 b	2.60 a	3.5	5.1 b	2.6 b	1.6 b
16˚ Brix (July 29)	19.4 b	2.78 c	3.5	5.5 a	2.7 a	1.8 a
18˚ Brix (Aug 11)	18.5 a	2.68 b	3.5	5.6 a	2.7 a	1.8 a
Factor C: PGR						
Control	18.8	2.8	3.5	5.3	2.7 a	1.8
Ethephon	18.9	2.7	3.5	5.7	2.8 b	1.8
Protone	18.7	2.7	3.5	5.6	2.7 a	1.7
Both	18.8	2.7	3.5	5.4	2.7 a	1.7
	n.s.	n.s.	ns	n.s.	*	ns

L.S.D..10 = *; L.S.D .05 = **; L.S.d. .01 = *** 1 inch = 2.5 centimeters (cm)

n.s. = not significant

Table 8. Crimson Seedless Fruit Characteristics Sample September 13, 2013

Treatment Factorial Average	Sugar (Brix)	Acid (g/L)	Sugar/Acid ratio	Berry Wt. (g)	Berry Dia (cm)	Firmness (g)
Factor A: Irrigation						
Deficit	20.6	3.40	60	5.3	1.30	397
Full	19.8	3.70	54	5.8	1.26	459
	***	***	***	***		***
Factor B: Potassium						
Control	19.4	3.60	55	5.7 a	1.26	443
14˚ Brix (July 11)	20.4	3.50	59	5.3 b	1.29	432
16˚ brix (July 29)	20.4	3.70	56	5.6 ab	1.28	414
18˚ brix (Aug 11)	20.5	3.60	59	5.5 ab	1.28	425
	***	n.s.	n.s.	**		n.s.
Factor C: PGR						
Control	20.0	3.6	56	5.5	1.28	443
Ethephon	20.4	3.5	58	5.7	1.26	417
Protone	19.9	3.7	55	5.5	1.28	436
Both	20.4	3.5	59	5.5	1.28	417
	n.s.	n.s.	n.s.	n.s.		n.s.

L.S.D..10 = *; L.S.D .05 = **; L.S.d. .01 = *** n.s. = not sig. 1 inch = 2.5 centimeters (cm)

Table 9. Trunk growth, shoot growth, and fruitfulness comparing deficit and full irrgation treatments

Treatment Factorial Average	19-Mar Trunk Circumference [1] (cm)	10-Oct Trunk Circumference [1] (cm)	19-Apr Shoot growth [2] (# above wire)	19-Apr Flowers (#/vine)
Factor A: Irrigation				
Deficit	50.3	57.7	14.9	30
Full	50.3	58.0	21.1	32
	n.s.	n.s.	***	***
Factor B: Potassium				
Control	50.8	57.3	17.1	32 a
14˚ Brix (July 11)	48.7	57.2	17.5	31 a
16˚ brix (July 29)	51.8	58.6	19.5	33 b
18˚ brix (Aug 11)	49.9	58.2	17.8	29 a
	n.s.	n.s.	n.s.	***
Factor C: PGR				
Control	51.0	58.5	17.4	31
Ethephon	49.4	56.2	18.5	31
Protone	50.4	58.5	16.8	32
Both	50.4	58.2	19.3	31
	n.s.	n.s.	n.s.	n.s.

L.S.D..10 = *; L.S.D .05 = **; L.S.d. .01 = *** n.s. = not significant

1. Trunk circumference measured 18 inches above floor.

2. Number of shoots reaching foliar wire 2 feet above cordon.

Table 10. Nutrients in leaves sampled July 2013 - after two years of full and deficit irrigation.

	Nitrogen		Phosphorous		Potassium		Magnesium		Boron	
	Petiole	Blade	Petiole	Blade	Petiole	Blade	Petiole	Blade	Petiole	Blade
Irrigation	(%)		(%)		(%)		(%)		(%)	
Deficit	0.06	2.8	0.06	0.15	0.6	0.8	0.98	0.43	32	36
Full	0.07	2.8	0.07	0.15	0.7	1.0	0.88	0.42	33	35
Sig.	n.s.	n.s.	n.s.	n.s.	n.s.	***	**	n.s.	n.s.	n.s.

Significance: * 10%; ** 5%; *** 1% n.s. = not significant

Table 11. The impact of foliar K and deficit irrigation on fruit mineral nutrition.

	Nitrogen		Phosphorous		Potassium		Calcium	
	Pulp	Skin	Pulp	Skin	Pulp	Skin	Pulp	Skin
Treatments	(%)		(%)		(%)		(ppm)	
Deficit Irrigation	0.41	1.05	0.07	0.07	7.23	1.37	0.06	0.15
Full Irrigation	0.42	1.20	0.07	0.08	8.13	1.83	0.05	0.16
L.S.D.$_{.05}$ =	n.s.	*	n.s.	n.s.	***	*	n.s.	n.s.
No foliar K	0.39	1.12	0.060	0.07	0.70	1.75	0.06	0.17
Applied: 14˚ brix	0.44	1.10	0.072	0.08	0.78	1.2	0.06	0.16
Applied: 16˚ brix	0.42	1.11	0.067	0.07	0.76	1.57	0.05	0.14
Applied: 18˚ brix	0.42	1.16	0.070	0.07	0.82	1.86	0.06	0.15
L.S.D..05 =	n.s.	**	0.004	0.01	0.05	n.s.	n.s.	n.s.

	Magnesium		Boron		zinc		Manganese	
	Pulp	Skin	Pulp	Skin	Pulp	Skin	Pulp	Skin
Treatments	(ppm)		(ppm)		(ppm)		(ppm)	
Deficit Irrigation	0.04	0.05	16	57	6	10	< 5	7
Full Irrigation	0.05	0.08	18	66	4	10	< 5	8
L.S.D.$_{.05}$ =	n.s.	*	**	***	n.s.	n.s.	< 5	
No foliar K	0.05	0.06	16	66	4	11	< 5	7
Applied: 14˚ brix	0.05	0.05	18	63	6	11	< 5	8
Applied: 16˚ brix	0.04	0.05	18	57	5	10	< 5	7
Applied: 18˚ brix	0.05	0.06	18	59	5	8	< 5	8
L.S.D..05 =	n.s.	n.s.	*	n.s.	n.s.	n.s.		n.s.

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