Evaluating Nutritional Effects on Fruit Quality and Storage Potential

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Peach, nectarine and plum fruit are highly perishable and may deteriorate quickly at room temperature. Low temperature during storage and/or shipping extends fruit market life. However, fruit from some cultivars develop lack of juiciness (flesh mealiness or woolliness), flesh browning, black pit cavity, flesh translucency (gel breakdown), red pigment accumulation (bleeding), failure to ripen and loss of flavor after prolonged cold storage and/or after ripening at room temperature. These symptoms are also reported as internal breakdown (IB) or chilling injury (CI). Since these symptoms mainly develop during fruit ripening after cold storage, this problem is usually not noticed until fruit reaches consumers. The onset of these symptoms determines the postharvest life because CI development reduces consumer acceptance. Susceptibility to CI varies according to genetic background, maturity, and orchard factors. Even though it is known that orchard factors play an important role in the onset and intensity of these chilling injury symptoms, there is a lack of specific information. This study was initiated to look at the specific role of plant nutrients on the onset of these chilling injury symptoms.

PLANS AND PROCEDURES

Fruit were collected from each cultivar and treatment as they ripened. This happened over an extended period as some of these treatments affect ripening dates (for example, low N advances fruit maturity). At least two pickings were taken from each tree. At each harvest, data were collected based on firmness, color, size, soluble solids and acidity. In at least one main harvest per treatment, fruit were stored for 3 to 6 weeks. After storage, fruit were evaluated for firmness, soluble solids, acidity, chilling injury symptoms and other disorders.

Postharvest Evaluations

Initial Quality Evaluations Fruit were picked at commercial maturity and the following fruit quality and physiological parameters were measured: flesh firmness, surface color, soluble solids content (SSC), titratable acidity (TA), pH, weight loss, and market life. Postharvest life was determined based on chilling injury and corking spot and/or pitting. Twenty-five fruit per treatment from each of the four to eight replications were collected for fruit quality determination at each harvest. Flesh firmness was measured using a FTA firmness tester with an 8 mm tip. Skin from opposite cheeks of each fruit was removed and flesh firmness calculated as an average of two measurements per fruit. A wedge from each fruit was removed and combined with wedges from each treatment within a replication to form a composite sample. From this composite sample, juice was extracted with a hand press, filtered through cheesecloth, and SSC by refractometer (Cambridge Instruments, Buffalo, NY), pH, TA at final pH 8.2 were determined.

Postharvest Life

Seventy-five fruit per treatment per each of the four to eight replications were stored in ethylene-free air, at 0°C and 90% RH (vapor pressure deficit = 0.061 kPa). Twenty-five fruit per treatment from each replication were removed following 2, 4, and 6 weeks of storage. After removal from storage, the samples were ripened at 20°C for 7-10 days prior to evaluation. Flesh firmness, SSC and TA were measured. Internal breakdown (chilling injury) symptoms were evaluated as flesh browning, texture (juiciness, mealiness), hardness, and bleeding according to our protocol (Crisosto et al., 1999). These observations were made on the mesocarp around the pit after the fruit was cut transversely along the plane of the suture. Specific observations looking for corking spots, pitting and other visual defects were conducted.

RESULTS

In general, nutrient alteration treatments significantly affected fruit weight, fruit load, and yield. Therefore, it is difficult to separate the direct role of nutrients from fruit load on quality attributes (Table 1).

Peaches

At harvest, all nutrient alteration treatments significantly reduced fruit weight, fruit load, and yield while red color percentage was not affected (Table 1). Nutrient alterations affected skin color, firmness, SSC, and TA measured at harvest without affecting fruit red color percentage. Fruit with low Zn and K had highest hue color (yellow-greenish) than fruit from other treatments. Fruit with low K had the lowest firmness and high SSC, maybe indicating a more advanced ripening stage. Fruit from the low P had the highest SSC (Table 2). By 3 weeks, fruit from the low P, K, and N had the lowest tip firmness while fruit from the low K and P still had the highest SSC. Fruit from low K had the lowest titratable acidity. A similar situation occurred at the 6 weeks cold storage evaluation. At this evaluation date, fruit firmness was affected, but still hard enough to tolerate physical postharvest handling. The differences of TA between treatments disappeared as TA in fruit from all treatments was reduced to a similar level.

Among the physiological disorders, only flesh mealiness (texture) and flesh browning developed approximately 3 weeks earlier during cold storage on fruit with low P. By 6 weeks, fruit from low P and K had a high incidence of flesh mealiness. It appears that fruit from low K treatment had a trend towards high flesh bleeding. Low Zn treatment did not affect flesh mealiness, but induced high flesh browning and moderate flesh bleeding by 6 weeks. Thus, it looks like fruit from the low P treatment had approximately 3 weeks shorter market life compared with fruit from other treatments because of high incidence of flesh mealiness, flesh browning, and flesh bleeding. Weight loss reached a level of ~ 7.0% and it was not affected by any treatment (Table 3).

Nectarine

At harvest, only fruit from the low K, P and Zn treatments significantly reduced fruit weight, fruit load, and yield while red color percentage was not affected (Table 1). Fruit weight was only reduced on fruit from the low P. Fruit load was reduced on fruit from the low K, P and Zn treatments.

During 6 weeks cold storage, there were not significant differences in quality attributes between treatments, except for hue color on low Zn treated fruit. In this case fruit had higher hue values (yellow-greenish) than fruit from other treatments (Table 4).

During cold storage at 34°F, in this cultivar flesh mealiness and flesh browning were not a problem (Table 5). However, flesh bleeding incidence was higher on fruit that had low K, N, and Zn within this cold storage period. Weight loss reached approximately 10% by 6 weeks cold storage. Despite this there was not a significant difference in weight loss, although fruit from low N treatment showed a lower weight loss compared to fruit from the other treatments.

Plum

At harvest, all nutrient alteration treatments reduced fruit weight (including high CA), but fruit from the low Zn treatment had the lowest fruit weight (Table 1). Fruit load was also reduced by all of the nutrient alteration treatments, except on trees with low P treatment.

Fruit from the low Zn treatments had the lowest fruit load. Fruit weight was higher on fruit with all nutrients and low Zn treatments while fruit from the other treatments were always smaller. Fruit red color was not affected by any treatment. At harvest, only fruit firmness was affected on fruit from the low Zn and high CA treatments. A similar situation remained during the 6 weeks of cold storage when quality attributes were not affected by any of the nutrient alteration treatments (Table 6). Only fruit firmness from the low Zn treatments was lower than fruit from the other treatments by 6 weeks of cold storage.

In this cultivar flesh bleeding was not a problem but flesh browning and flesh mealiness were high (Table 7). By 3 weeks of cold storage, flesh browning was higher on fruit from low N. By 6 weeks, flesh browning was very high (~60%) in most of the treatments

while only ~30% on fruit from the low P and low Zn treatments. Flesh mealiness was high on fruit from the high CA and low N. Weight loss reached a level of ~ 2.5% and it was not affected by any treatment.

FINAL COMMENTS

Based on the interesting information revealed by this season's study, we encourage continuation of the work. Next season's work should be focused on a few of the nutrient treatments that are showing an important impact on postharvest quality.

Table 1. Fruit size and yield.

Treatment	Fruit Weight (g)	Fruit Load (No of fruit Per tree)	Fruit Weight Per Tree (lbs)	Red Color (%)
Peach				
All Nutrients	176.0	305.1	118.4	63.6
High Ca	118.4	241.4	63.0	66.5
Low K	119.2	142.7	37.5	77.6
Low N	142.0	207.3	64.9	67.3
Low P	138.7	175.3	53.6	65.1
Low Zn	143.9	158.2	50.2	64.8
P-Value	0.015	--	0.0002	0.17
$LSD_{0.05}$	32.9		30.0	NS
Nectarine				
All Nutrients	133.9	297.8	87.9	83.2
High Ca	136.0	289.5	86.8	77.5
Low K	116.3	186.8	47.9	83.6
Low N	140.7	235.7	73.1	89.1
Low P	88.4	176.0	34.3	79.2
Low Zn	142.0	161.3	50.5	73.2
P-Value	<0.0001	--	<0.0001	0.28
$LSD_{0.05}$	20.7	--	22.5	NS
Plum				
All Nutrients	123.1	252	61.3	80.9
High Ca	99.9	149	29.0	89.5
Low K	95.5	162	30.5	90.0
Low N	83.5	139	24.1	87.3
Low P	69.9	252	34.5	89.5
Low Zn	104.0	66	16.2	90.7
P-Value	0.0004	0.0078	0.0072	0.22
$LSD_{0.05}$	20.7	106.3	22.0	NS

Table 2. Peach quality attributes measured at harvest and after 3 and 6 weeks storage at 34ºF.

Treatment	Hue^{o}	Flesh Firmness (lbf)				SSC (%)	TA (% malic)	SSC:TA
		Cheek	Tip	Suture	Shoulder			
Week 0								
All Nutrients	49.75	13.6	12.6	10.8	9.1	11.6	0.67	17.6
High Ca	52.11	15.8	13.7	11.4	9.6	11.5	0.58	20.0
Low K	47.89	12.4	9.1	8.7	7.3	12.9	0.49	26.7
Low N	52.56	13.9	10.5	9.3	8.6	11.7	0.59	19.8
Low P	55.13	13.1	10.9	10.6	8.7	13.4	0.68	19.9
Low Zn	55.11	13.4	11.9	10.0	9.3	11.5	0.59	19.9
P-Value	0.022	0.21	0.056	0.15	0.30	0.012	0.0014	0.0005
$LSD_{0.05}$	4.8	NS	3.0	NS	NS	1.3	0.09	3.5
Week 3								
All Nutrients	46.87	14.6	13.5	11.2	9.5	12.5	0.50	25.1
High Ca	47.74	13.7	10.3	9.3	9.1	11.6	0.46	25.6
Low K	44.35	12.9	10.2	8.8	8.3	14.4	0.41	35.5
Low N	48.71	14.1	11.5	9.0	9.1	11.5	0.47	24.3
Low P	47.92	13.5	10.7	10.2	8.5	14.1	0.46	31.1
Low Zn	49.26	12.8	13.1	10.2	8.8	11.8	0.49	24.3
P-Value	0.44	0.36	0.022	0.039	0.72	<0.0001	0.046	0.0002
$LSD_{0.05}$	NS	NS	2.3	1.5	NS	1.2	0.06	4.9
Week 6								
All Nutrients	49.94	13.3	11.3	10.8	8.3	12.2	0.35	34.9
High Ca	52.59	13.8	10.3	9.1	7.8	12.1	0.36	34.6
Low K	45.60	9.5	6.9	6.2	5.4	13.3	0.32	42.2
Low N	47.11	11.7	9.0	8.2	7.5	11.9	0.40	30.1
Low P	50.30	10.2	7.2	7.4	6.2	13.8	0.33	42.7
Low Zn	51.57	12.3	10.3	9.1	8.0	12.8	0.36	35.6
P-Value	0.11	0.076	0.035	0.023	0.030	0.014	0.13	0.040
$LSD_{0.05}$	NS	3.3	3.2	2.6	2.0	1.2	NS	8.5

Table 3. Peach storage disorders and weight loss measured during cold storage at 34ºF.

Treatment	Texture	Bleeding Score (1-3)	Bleeding (%)	Browning Score (1-6)	Browning (%)	Weight Loss (%)
Week 3						
All Nutrients	4.0	1.1	6.0	1.1	2.0	3.56
High Ca	0.0	1.1	6.0	1.1	2.0	3.97
Low K	0.0	1.2	25.0	1.4	0.0	4.00
Low N	0.0	1.2	15.0	1.0	0.0	3.16
Low P	20.0	1.1	6.7	1.5	13.3	3.40
Low Zn	5.0	1.3	15.7	1.2	7.1	4.22
P-Value	0.015	0.72	0.79	0.40	0.35	0.46
$LSD_{0.05}$	13.2	NS	NS	NS	NS	NS
Week 6						
All Nutrients	6.0	1.0	4.0	2.1	13.7	7.09
High Ca	14.0	1.1	6.0	2.0	4.0	7.21
Low K	22.0	1.4	31.0	2.0	4.0	7.34
Low N	5.0	1.1	12.5	2.0	2.5	6.38
Low P	25.3	1.4	34.4	2.6	46.0	6.56
Low Zn	0.0	1.2	17.2	2.5	27.1	7.66
P-Value	0.21	0.091	0.091	0.0049	0.0059	0.59
$LSD_{0.05}$	NS	0.3	26.1	0.4	25.4	NS

Table 4. Nectarine quality attributes measured at harvest and after 3 and 6 weeks cold storage at 34ºF.

Treatment	Hue^{o}	Flesh Firmness (lbf)				SSC (%)	TA (% malic)	SSC:TA
		Cheek	Tip	Suture	Shoulder			
Week 0								
All Nutrients	44.37	13.5	13.6	11.2	11.0	15.5	0.32	49.0
High Ca	45.25	14.3	14.1	11.5	11.3	16.1	0.30	54.2
Low K	38.61	14.3	14.5	11.8	11.3	16.7	0.31	56.0
Low N	38.52	12.6	12.6	10.5	9.9	16.1	0.28	49.7
Low P	43.51	14.2	14.4	12.2	11.6	18.5	0.34	54.4
Low Zn	46.80	13.2	14.0	11.0	10.5	16.8	0.34	49.2
P-Value	0.18	0.47	0.42	0.18	0.22	0.07	0.18	0.32
$LSD_{0.05}$	NS	NS	NS	NS	NS	2.8	NS	NS
Week 3								
All Nutrients	42.93	13.2	12.8	11.1	10.9	16.3	0.34	48.0
High Ca	42.95	13.5	13.9	11.7	10.9	15.2	0.35	43.5
Low K	36.40	13.0	13.4	11.0	11.0	15.7	0.30	54.9
Low N	38.76	12.5	13.2	10.9	10.6	15.5	0.32	48.0
Low P	48.35	13.7	13.9	12.2	11.3	16.7	0.32	52.6
Low Zn	50.15	12.2	13.1	10.0	10.9	14.8	0.36	41.2
P-Value	0.0068	0.36	0.71	0.14	0.96	0.55	0.063	0.043
$LSD_{0.05}$	7.2	NS	NS	NS	NS	NS	0.04	8.9
Week 6								
All Nutrients	33.18	11.3	11.6	9.5	9.3	18.0	0.38	47.3
High Ca	34.60	11.8	12.1	10.1	9.6	16.6	0.38	43.7
Low K	27.40	11.8	12.7	10.6	9.6	18.2	0.34	53.5
Low N	26.90	11.5	11.6	9.5	9.0	17.2	0.37	46.5
Low P	33.01	11.6	11.0	10.1	9.3	19.5	0.35	55.7
Low Zn	39.79	11.5	13.4	9.7	10.3	17.1	0.46	37.2
P-Value	0.0011	0.81	0.031	0.49	0.58	0.23	0.0007	0.0013
$LSD_{0.05}$	5.4	NS	1.5	NS	NS	NS	0.21	1.7

Table 5. Nectarine storage disorders and weight loss measured during cold storage at 34ºF.

Treatment	Texture	Bleeding Score (1-3)	Bleeding (%)	Browning Score (1-6)	Browning (%)	Weight Loss (%)
Week 3						
All Nutrients	0.0	1.1	6.7	1.0	0.0	5.30
High Ca	0.0	1.1	12.0	1.0	0.0	5.08
Low K	0.0	1.4	40.2	1.0	0.0	4.99
Low N	0.0	1.3	27.4	1.0	0.0	4.71
Low P	0.0	1.0	3.6	1.0	0.0	5.38
Low Zn	0.0	1.3	26.7	1.0	0.0	4.37
P-Value	NS	0.015	0.0075	NS	NS	0.78
$LSD_{0.05}$	NS	0.2	19.9	NS	NS	NS
Week 6						
All Nutrients	0.0	1.3	26.7	1.1	0.0	10.43
High Ca	0.0	1.3	26.0	1.0	0.0	10.71
Low K	0.0	1.9	65.0	1.3	0.0	10.78
Low N	0.0	1.8	66.1	1.2	0.0	9.90
Low P	0.0	1.5	38.3	1.0	0.0	12.83
Low Zn	0.0	2.3	75.0	1.2	2.8	9.54
P-Value	NS	0.021	0.073	0.12	0.38	0.028
$LSD_{0.05}$	NS	0.6	42.0	NS	NS	2.05

Table 6. Plum quality attributes measured at harvest and after 3 and 6 weeks storage at 34ºC.

Treatment	Hue^{o}	Flesh Firmness (lbf)				SSC (%)	TA (% malic)	SSC:TA
		Cheek	Tip	Suture	Shoulder			
Week 0								
All Nutrients	50.76	8.2	9.4	8.2	7.8	13.9	0.75	18.8
High Ca	40.56	7.2	8.6	8.0	7.2	13.3	0.60	22.4
Low K	39.37	7.6	8.8	8.1	6.8	14.0	0.58	24.1
Low N	39.81	8.3	8.9	8.8	8.2	13.6	0.62	22.0
Low P	40.23	8.5	8.5	8.6	7.8	15.4	0.73	21.3
Low Zn	34.97	7.0	7.7	7.2	6.3	14.2	0.62	24.0
P-Value	0.16	0.010	0.11	0.014	0.022	0.070	0.32	0.17
$LSD_{0.05}$	NS	0.9	NS	0.8	1.1	N.S.	N.S.	NS
Week 3								
All Nutrients	41.51	8.4	9.6	9.1	8.6	14.1	0.69	21.1
High Ca	26.40	7.3	8.2	7.7	7.4	14.2	0.75	19.3
Low K	29.91	8.0	9.4	8.9	8.3	14.5	0.72	20.5
Low N	34.42	8.7	9.1	9.1	9.2	14.5	0.69	22.1
Low P	30.85	8.6	9.2	9.0	8.9	15.3	0.74	22.0
Low Zn	32.71	7.3	7.4	7.8	7.4	15.3	0.66	23.2
P-Value	0.14	0.031	0.0022	0.010	0.22	0.20	0.90	0.86
$LSD_{0.05}$	NS	1.1	1.1	1.0	NS	NS	NS	NS
Week 6								
All Nutrients	31.30	6.9	7.7	7.2	5.8	14.1	0.70	20.1
High Ca	25.95	6.9	7.4	6.8	5.7	14.8	0.68	22.1
Low K	25.16	6.5	7.7	7.1	5.9	14.3	0.76	19.0
Low N	26.50	7.4	7.9	7.4	6.5	14.0	0.73	19.2
Low P	27.40	7.8	7.7	8.0	6.9	15.0	0.74	21.0
Low Zn	23.97	6.3	6.5	6.6	4.8	14.5	0.73	19.9
P-Value	0.37	0.11	0.15	0.084	0.044	0.12	0.67	0.61
$LSD_{0.05}$	NS	NS	NS	1.1	1.3	NS	NS	NS

Table 7. Plum storage disorders and weight loss measured during cold storage at 34ºF.

Treatment	Texture	Bleeding Score (1-3)	Bleeding (%)	Browning Score (1-6)	Browning (%)	Weight Loss (%)
Week 3						
All Nutrients	0.0	--	0.0	1.9	4.0	1.18
High Ca	0.0	--	0.0	2.3	36.3	1.10
Low K	0.0	--	0.0	2.5	32.5	1.13
Low N	2.5	--	0.0	3.0	67.5	1.04
Low P	0.0	--	0.0	1.9	11.7	1.08
Low Zn	0.0	--	0.0	1.8	16.3	1.53
P-Value	0.32	--	NS	0.0019	0.0002	0.023
$LSD_{0.05}$	NS	--	NS	0.5	23.3	0.29
Week 6						
All Nutrients	2.0	--	0.0	2.6	62.0	2.00
High Ca	23.7	--	0.0	2.9	64.6	1.94
Low K	4.0	--	0.0	2.6	42.0	1.94
Low N	15.0	--	0.0	3.1	67.5	1.75
Low P	3.3	--	0.0	2.2	26.7	1.79
Low Zn	0.0	--	0.0	2.1	29.3	2.62
P-Value	0.022	--	NS	0.014	0.086	0.018
$LSD_{0.05}$	15.0	--	NS	0.6	36.5	0.51

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