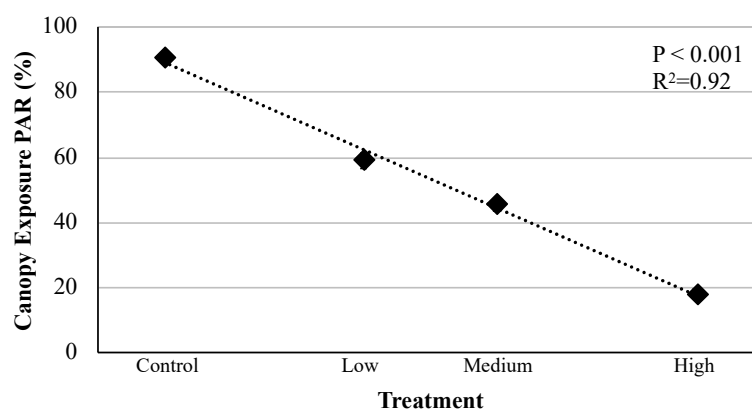


Supplemental Materials

Supplemental Figure



Supplementary Figure S1. Percentage of plant assimilable radiation (PAR) permeating the canopy and shadedcloth in Experiment 3 of 'Major', 'Ellis Bitter', and 'Harry Masters Jersey' apple trees grown in Lansing, NY. Branches on individual trees were subjected to different shading opacities from week four after full bloom until harvest. Values are means \pm standard error ($n = 8$ 'Major' 2016, 8 'Ellis Bitter' 2016, 8 'Major' 2017, and 8 'Harry Masters Jersey' 2017=32).

Supplemental Tables

Supplementary Table S1. Harvest dates of experiments in different cultivars and years within this study. ('HMJ'='Harry Masters Jersey', 'SRS'='Somerset Redstreak').

Experiment	Year	Cultivar	Harvest Date
Experiment 1: "Early Tree"	2018	'Dabinett'	10 October
Experiment 2: "Early Branch"	2018	'Ellis Bitter'	30 August
		'Major'	3 September
Experiment 3: "Late Branch"	2016	'Major'	1 September
		'Ellis Bitter'	31 August
	2017	'Major'	5 September
		'HMJ'	21 September
	2016	'GoldRush'	1 November
Experiment 4: "Fruit Location"	2016	'Major'	1 September
		'GoldRush'	1 November
	2017	'HMJ'	15 September
		'GoldRush'	30 October
	2018	'SRS'	18 September
Experiment 5: "Fruit Bagging"	2016	'GoldRush'	1 November
		'Ellis Bitter'	31 August
	2017	'GoldRush'	1 November
		'Major'	5 September
		'Ellis Bitter'	3 September

Supplementary Table S2. Percentage of plant assimilable radiation (PAR) permeating the canopy and shade cloth, and photosynthesis rate of Control leaves exposed to 1,500 $\mu\text{mol}/\text{m}^2/\text{s}$ of photons and Shade leaves exposed to 500 $\mu\text{mol}/\text{m}^2/\text{s}$ of photons in cv. 'Dabinett' apple trees grown in Lansing, NY. Treatment trees were shaded during weeks 1-5 after full bloom in Experiment 1. Values are means \pm standard error (n=6).

Treatment	Canopy Exposure PAR (%)	Photosynthesis Rate ($\mu\text{mol CO}_2/\text{m}^2/\text{s}$)
Control	47.9 \pm 3.9	20.9 \pm 0.5
Shade	13.8 \pm 1.1	12.9 \pm 0.5
<i>P-value</i>	<0.001	<0.001

Supplementary Table S3. Percentage of plant assimilable radiation (PAR) permeating the canopy and shade cloth two and four weeks after full bloom (WAFB) from cv 'Ellis Bitter' and 'Major' apple trees grown in Lansing, NY. Branches on individual trees were subjected to different shading treatments during weeks 1-5 after full bloom in Experiment 2. Values are means \pm standard error ('Ellis Bitter' n=7, 'Major' n=8). Different lowercase letters indicate a separation of treatments by the Tukey HSD method at a 5% significance level.

Cultivar	Treatment	Canopy Exposure PAR Availability (%)	
		Week 2	Week 4
'Ellis Bitter'	Control	59.1 \pm 3.7	65.6 \pm 2.5
'Major'		53.1 \pm 6.0 ^a	58.0 \pm 5.3 ^a
'Ellis Bitter'	1-3 WAFB	22.6 \pm 2.0	62.5 \pm 3.1
'Major'		20.3 \pm 1.4 ^b	54.5 \pm 4.7 ^a
'Ellis Bitter'	3-5 WAFB	51.7 \pm 4.1	20.7 \pm 1.7
'Major'		49.6 \pm 2.8 ^a	18.7 \pm 1.7 ^b
'Ellis Bitter'	1-5 WAFB	20.1 \pm 1.6	18.0 \pm 2.6
'Major'		17.6 \pm 2.1 ^b	18.3 \pm 1.3 ^b
<i>P-value</i>	Treatment	<0.001	<0.001
	Cultivar	0.677	0.077
	Treatment \times Cultivar	0.904	0.263

Supplementary Table S4. Mass of fruit at different stages of development from 'Dabinett' apple trees grown in Lansing, NY. Trees were either shaded or un-shaded during weeks 1-5 after full bloom in Experiment 1. Values are means \pm standard error (n=6).

Treatment	Mass (g)						
	Week 1	Week 3	Week 5	Week 7	Week 9	Week 12	Week 20 (Harvest)
Control	0.29 \pm 0.02	4.94 \pm 0.22	12.70 \pm 0.19	15.83 \pm 0.55	29.19 \pm 0.90	42 \pm 0.94	63.46 \pm 2.25
Shade	0.30 \pm 0.02	3.47 \pm 0.24	7.78 \pm 0.23				56.84 \pm 1.65
<i>P-value</i>	0.457	0.001	<0.001	-	-	-	0.039

Supplementary Table S5. Mass of fruit at different stages of development from 'Ellis Bitter' and 'Major' apple trees grown in Lansing, NY. Branches on individual trees were subjected to different shading treatments during weeks 1-5 after full bloom in Experiment 2. Values are means \pm standard error ('Ellis Bitter' n=7, 'Major' n=8). Different lowercase letters indicate a separation of treatments by the Tukey HSD method at a 5% significance level.

Cultivar	Treatment	Mass (g)						
		Week 1	Week 3	Week 5	Week 7	Week 9	Week 12	Week 14 (Harvest)
'Ellis Bitter'	Control	0.30 \pm 0.03	6.21 \pm 0.55	16.73 \pm 0.62	19.66 \pm 0.69	33.32 \pm 1.2	48.81 \pm 1.85	93.25 \pm 3.16
'Major'		0.12 \pm 0.01	2.16 \pm 0.28 ^{ab}	9.58 \pm 0.45 ^a	14.07 \pm 0.32	21.78 \pm 1.07	46.78 \pm 1.04	76.27 \pm 2.95
'Ellis Bitter'	1-3	0.28 \pm 0.02	4.91 \pm 0.49	13.77 \pm 1.26	-	-	-	89.71 \pm 4.32
'Major'		0.12 \pm 0.01	2.04 \pm 0.19 ^b	8.18 \pm 0.53 ^b	-	-	-	75.2 \pm 2.39
'Ellis Bitter'	3-5	0.31 \pm 0.02	6.23 \pm 0.27	13.21 \pm 0.77	-	-	-	95.25 \pm 4.76
'Major'		1.30 \pm 0.01	2.54 \pm 0.25 ^a	7.33 \pm 0.42 ^b	-	-	-	65.6 \pm 3.52
'Ellis Bitter'	1-5	0.29 \pm 0.03	5.20 \pm 0.19	12.73 \pm 1.05	-	-	-	86.74 \pm 4.88
'Major'		0.13 \pm 0.01	2.03 \pm 0.23 ^{ab}	7.26 \pm 0.56 ^b	-	-	-	72.92 \pm 2.20
<i>P-value</i>	Treatment	0.551	0.001	<0.001	-	-	-	0.518
	Cultivar	<0.001	<0.001	<0.001	-	-	-	<0.001
	Treatment \times Cultivar	0.679	0.212	0.575	-	-	-	0.114

Supplementary Table S6. Diameter of fruit at different stages of development from 'Dabinett' apple trees grown in Lansing, NY. Trees were either shaded or un-shaded during weeks 1-5 after full bloom in Experiment 1. Values are means \pm standard error (n=6).

Treatment	Diameter (mm)						
	Week 1	Week 3	Week 5	Week 7	Week 9	Week 12	Week 20 (Harvest)
Control	6.02 \pm 0.15	20.33 \pm 0.34	29.47 \pm 0.19	31.66 \pm 0.38	39.67 \pm 0.45	45.96 \pm 0.39	51.24 \pm 0.73
Shade	6.20 \pm 0.21	17.92 \pm 0.43	24.54 \pm 0.29				49.66 \pm 0.50
<i>P-value</i>	0.516	0.001	<0.001	-	-	-	0.102

Supplementary Table S7. Diameter of fruit at different stages of development from 'Ellis Bitter' and 'Major' apple trees grown in Lansing, NY. Branches on individual trees were subjected to different shading treatments during the five weeks after full bloom (WAFB) in Experiment 2. Values are means \pm standard error ('Ellis Bitter' n=7, 'Major' n=8). Different lowercase letters indicate a separation of treatments by the Tukey HSD method at a 5% significance level.

Cultivar	Treatment	Diameter (mm)						
		Week 1	Week 3	Week 5	Week 7	Week 9	Week 12	Week 14 (Harvest)
'Ellis Bitter'	Control	5.91 \pm 0.40	22.23 \pm 0.81 ^a	32.73 \pm 0.63	34.84 \pm 0.57	41.42 \pm 0.49	48.64 \pm 0.65	61.37 \pm 0.69
'Major'		3.68 \pm 0.25	14.52 \pm 0.72 ^b	26.53 \pm 0.46 ^a	30.78 \pm 0.27	36.09 \pm 0.67	47.85 \pm 0.44	56.54 \pm 0.76
'Ellis Bitter'	1-3 WAFB	5.76 \pm 0.27	20.09 \pm 1.02 ^b	30.21 \pm 1.16 ^b	-	-	-	61.31 \pm 1.17
'Major'		3.77 \pm 0.21	14.39 \pm 0.54 ^b	25.07 \pm 0.68 ^b	-	-	-	55.84 \pm 0.71
'Ellis Bitter'	3-5 WAFB	6.13 \pm 0.26	22.54 \pm 0.38 ^a	30.02 \pm 0.64 ^b	-	-	-	61.28 \pm 0.95
'Major'		3.80 \pm 0.22	15.82 \pm 0.52 ^a	24.00 \pm 0.48 ^b	-	-	-	53.00 \pm 0.94
'Ellis Bitter'	1-5 WAFB	5.96 \pm 0.37	5.96 \pm 0.37 ^b	29.51 \pm 0.88 ^b	-	-	-	60.31 \pm 1.58
'Major'		3.89 \pm 0.57	3.89 \pm 0.57 ^b	23.83 \pm 0.64 ^b	-	-	-	55.23 \pm 0.53
<i>P-value</i>	Treatment	0.541	0.009	<0.001	-	-	-	0.240
	Cultivar	<0.001	<0.001	<0.001	-	-	-	<0.001
	Treatment \times Cultivar	0.706	0.451	0.861	-	-	-	0.253

Supplementary Table S8. Total polyphenol concentrations (gallic acid equivalents) of dried fruit cortex tissue at different stages of development and juice from cv 'Dabinett' apple trees grown in Lansing, NY. Trees were either shaded or un-shaded during weeks 1-5 after full bloom in Experiment 1. Values are means \pm standard error (n=6).

Treatment	Cortex Tissue Total Polyphenols (mg/g)						Juice (g/L)	
	Week 1	Week 3	Week 5	Week 7	Week 9	Week 12	Week 20 (Harvest)	Week 20 (Harvest)
Control	60.90 \pm 1.92	113.30 \pm 2.82	96.28 \pm 2.02	51.44 \pm 3.75	39.54 \pm 0.71	27.41 \pm 0.94	11.02 \pm 0.3	1.28 \pm 0.1
Shade	66.3.0 \pm 2.17	93.00 \pm 2.62	83.71 \pm 1.63	-	-	-	8.36 \pm 0.45	0.99 \pm 0.07
<i>P-value</i>	0.150	0.002	0.003	-	-	-	0.005	0.047

Supplementary Table S9. Total polyphenol concentrations (gallic acid equivalents) of dried fruit cortex tissue at different stages of development and juice from cv 'Ellis Bitter' and 'Major' apple trees grown in Lansing, NY. Branches on individual trees were subjected to different shading treatments during in the five weeks after full bloom (WAFB) in Experiment 2. Values are means \pm standard error ('Ellis Bitter' n=7, 'Major' n=8). Different lowercase letters indicate a mean separation among treatments by the Tukey HSD method at a 5% significance level.

Cortex Tissue Total Polyphenols (mg/g)									
Cultivar	Treatment	Week 1	Week 3	Week 5	Week 7	Week 9	Week 12	Week 14 (Harvest)	Juice (g/L) Week 14 (Harvest)
'Ellis Bitter'	Control	62.48 \pm 4.29	125.12 \pm 2.52	80.00 \pm 3.70	61.79 \pm 1.63	45.77 \pm 0.83	30.86 \pm 1.80	22.14 \pm 0.98	0.76 \pm 0.05
'Major'		45.90 \pm 2.80	136.38 \pm 1.73 ^a	102.29 \pm 1.44 ^a	55.36 \pm 1.19	39.51 \pm 0.6	25.24 \pm 0.57	19.75 \pm 0.88 ^a	1.07 \pm 0.09 ^a
'Ellis Bitter'	1-3 WAFB	63.89 \pm 4.67	115.09 \pm 3.46	73.8 \pm 1.42	-	-	-	22.57 \pm 0.73	0.66 \pm 0.04
'Major'		43.42 \pm 2.87	127.88 \pm 5.69 ^b	101.62 \pm 3.46 ^{ab}	-	-	-	19.25 \pm 0.55 ^{ab}	0.75 \pm 0.07 ^b
'Ellis Bitter'	3-5 WAFB	66.70 \pm 3.72	126.89 \pm 2.17	73.21 \pm 1.07	-	-	-	20.03 \pm 0.69	0.65 \pm 0.07
'Major'		39.74 \pm 3.13	138.72 \pm 2.67 ^a	100.30 \pm 2.14 ^{ab}	-	-	-	19.80 \pm 0.98 ^{ab}	0.82 \pm 0.06 ^b
'Ellis Bitter'	1-5 WAFB	56.63 \pm 4.73	114.01 \pm 1.99	71.72 \pm 2.80	-	-	-	20.29 \pm 0.54	0.59 \pm 0.08
'Major'		40.73 \pm 2.66	124.34 \pm 3.72 ^b	93.18 \pm 2.72 ^b	-	-	-	17.34 \pm 0.95 ^b	0.83 \pm 0.15 ^b
<i>P-value</i>	Treatment	0.126	<0.001	0.007	-	-	-	0.030	0.012
	Cultivar	0.004	0.004	<0.001	-	-	-	0.005	0.034
	Treatment \times Cultivar	0.124	0.974	0.423	-	-	-	0.214	0.470

Supplementary Table S10. Percentage of plant assimilable radiation (PAR) permeating the canopy and shade cloth in June, July, and August of 'Major', 'Ellis Bitter', and 'Harry Masters Jersey' ('HMJ') apple trees grown in Lansing, NY in 2016 and 2017. Branches on individual trees were subjected to different shading opacities from four weeks after full bloom until harvest in Experiment 3. Values are means \pm standard error (n= 8 'Major' 2016, 8 'Ellis Bitter' 2016, 8 'Major' 2017, and 8 'HMJ' 2017=32).

Year	Cultivar	Treatment	Canopy Exposure PAR (%)		
			June	July	August
2016	'Major'	Control	91.5±2.2	90.9±3.2	89.5±3.2
2016	'Ellis Bitter'		88.8±3.6	86.2±4.9	85.4±4.9
2017	'Major'		92.7±1.4	90.4±1.9	91±2.2
2017	'HMJ'		95.3±1.0	92.9±1.6	94.4±1.9
2016	'Major'	Low	52.9±3.9	53.5±4.7	53.6±6.4
2016	'Ellis Bitter'		48.8±4.1	51.8±6.8	43.3±5.9
2017	'Major'		50.8±1.3	52.2±4.8	58.9±6.3
2017	'HMJ'		52.2±3.2	60.3±4.4	52.6±2.3
2016	'Major'	Medium	35.3±3.5	38.5±5.5	35.7±4.8
2016	'Ellis Bitter'		36.9±3.8	42.7±3.2	33.2±4.7
2017	'Major'		39.7±1.5	33.8±3.2	30.0±2.9
2017	'HMJ'		38.6±1.8	38.4±4.1	36.5±1.9
2016	'Major'	High	15.5±2.2	13.4±2.5	11.3±2.5
2016	'Ellis Bitter'		18.1±1.6	16.6±2.5	12.4±3.8
2017	'Major'		15.4±1.8	9.7±2.1	11.8±1.6
2017	'HMJ'		17.6±2.1	15.6±2.6	13.8±2
<i>P-value</i>	Treatment		<0.001	<0.001	<0.001
	Cultivar		0.845	0.330	0.435
	Year		0.726	0.467	0.898
	Treatment × Cultivar		0.570	0.436	0.683
	Treatment × Year		0.952	0.578	0.658

Supplementary Table S11. Growing degree days base 10 °C inside shading enclosures of 'Major' and 'Harry Masters Jersey' ('HMJ') apple trees grown in Lansing, NY in 2017. Branches on individual trees were subjected to different shading opacities from four weeks after full bloom until harvest in Experiment 3. Values are means \pm standard error (n= 4 'Major' and 4 'HMJ'=8).

Cultivar	Treatment	Growing Degree Days Base 10 °C	
		4-6 Weeks After Full Bloom	4 Weeks After Full Bloom Until Harvest
'Major'	Control	140.4 \pm 7.7	764.0 \pm 37.4
'HMJ'		136.5 \pm 5.0	826.4 \pm 30.3
'Major'	Low	128.0 \pm 2.4	700.7 \pm 13.4
'HMJ'		123.1 \pm 3.1	741.1 \pm 28.3
'Major'	Medium	124.6 \pm 3.1	699.4 \pm 21.3
'HMJ'		126.6 \pm 3.1	759.5 \pm 22.0
'Major'	High	122.2 \pm 5.0	697.2 \pm 30.8
'HMJ'		132.4 \pm 3.4	813.1 \pm 20.8
<i>P-value</i>	Treatment	0.024	0.026
	Cultivar	0.813	0.025
	Treatment \times Cultivar	0.101	0.453

Supplementary Table S12. Harvest and fruit characteristics of 'Major', 'Ellis Bitter', and 'Harry Masters Jersey' ('HMJ') apple trees grown in Lansing, NY in 2016 and 2017. Branches on individual trees were subjected to different shading opacities from four weeks after full bloom until harvest in Experiment 3. Values are means \pm standard error (n= 8 'Major' 2016, 8 'Ellis Bitter' 2016, 8 'Major' 2017, and 8 'HMJ' 2017=32).

Year	Cultivar	Treatment	Mass (g)	Yield (g)	Yield (g) / Leaf Count	Peel Blush (%)	Starch Pattern Index (1-8)	Firmness (N)	Chlorophyll a Index	
2016	'Major'	Control	59.8±4.0	437±64	7.3±1.3	48.6±5.4	4.5±0.5	63.6±4.0	-	
2016	'Ellis Bitter'		51.3±1.6	728±62	10.5±1.5	19.4±2.6	7.4±0.1	74.1±1.1	-	
2017	'Major'		66.2±5.1	785±103	10.3±1.6	50.0±6.2	5.5±0.3	73.2±3.5	1.05±0.09	
2017	'HMJ'		68.1±3.5	771±77	9.1±0.6	99.6±8.1	6.8±0.3	74.2±2.6	0.36±0.04	
2016	'Major'	Low	53.3±5.3	387±110	4.5±1.2	36.1±9.6	5.1±0.7	71.9±2.1	-	
2016	'Ellis Bitter'		53.6±3.3	766±125	7.5±1.1	29.1±4.8	7.1±0.3	74.4±1.8	-	
2017	'Major'		60.0±3.9	645±61	8.9±1.0	27.8±6.1	5.6±0.6	72.2±3.1	1.23±0.09	
2017	'HMJ'		58.5±2.2	692±63	8.8±1.3	92±10.9	6.7±0.2	77.1±2.9	0.42±0.05	
2016	'Major'	Medium	55.9±3.0	499±153	6.4±1.9	42.1±8.5	5.6±0.8	69.4±1.6	-	
2016	'Ellis Bitter'		51.1±2.4	673±78	12.2±2	38.5±3.5	7.2±0.1	74.1±1.9	-	
2017	'Major'		58.2±4.6	634±63	7.6±1.0	20.4±5.5	5.5±0.4	71.7±2.6	1.22±0.08	
2017	'HMJ'		55.1±2.2	461±71	6.1±0.7	53.8±3.7	6.4±0.4	71.8±3.1	0.57±0.11	
2016	'Major'	High	57.8±2.7	381±91	7.2±2.2	21.2±7.5	5.7±0.7	71.2±1.7	-	
2016	'Ellis Bitter'		58.0±2.3	738±157	11.5±1.8	8.7±2.6	6.8±0.1	71.6±1.2	-	
2017	'Major'		56.3±2.8	545±58	8.1±1.5	21.9±3.1	6.3±0.5	70.7±2.2	1.1±0.11	
2017	'HMJ'		56.1±3.4	485±32	6.9±0.5	71.1±4.4	6.6±0.3	69.2±2.4	0.48±0.08	
<i>P-value</i>			Treatment	0.022	0.009	0.485	<0.001	0.760	0.131	0.230
			Cultivar	0.310	0.004	0.018	<0.001	<0.001	0.226	<0.001
			Year	0.340	0.010	0.088	0.172	0.323	0.262	-
			Treatment × Cultivar	0.054	0.581	0.678	0.093	0.017	0.064	0.491
			Treatment × Year	0.304	0.443	0.310	0.130	0.442	0.298	-

Supplementary Table S13. Juice characteristics of 'Major', 'Ellis Bitter', and 'Harry Masters Jersey' ('HMJ') apple trees grown in Lansing, NY. Branches on individual trees were subjected to different shading opacities from four weeks after full bloom until harvest in Experiment 3. Values are means \pm standard error (n= 8 'Major' 2016, 8 'Ellis Bitter' 2016, 8 'Major' 2017, and 8 'HMJ' 2017=32).

Year	Cultivar	Treatment	Soluble Solid Concentration (°Brix)	pH	Titrateable Acidity (g malic acid/L)	Total Polyphenols (g GAE/L ²)
2016	'Major'	Control	14.1±0.6	4.53±0.04	2.5±0.1	1.58±0.21
2016	'Ellis Bitter'		11.9±0.3	4.57±0.02	2±0.1	1.04±0.11
2017	'Major'		11.2±0.3	4.48±0.02	2±0.1	1.26±0.08
2017	'HMJ'		12.5±0.2	4.73±0.03	1.6±0.1	2.24±0.06
2016	'Major'	Low	12.6±0.5	4.56±0.03	2.5±0.1	1.24±0.13
2016	'Ellis Bitter'		11.1±0.2	4.63±0.02	2.1±0	1.01±0.11
2017	'Major'		10.6±0.2	4.53±0.03	2.1±0	1.18±0.06
2017	'HMJ'		12±0.1	4.8±0.03	1.6±0	2.17±0.11
2016	'Major'	Medium	13.1±0.5	4.57±0.03	2.5±0.1	1.18±0.14
2016	'Ellis Bitter'		10.6±0.3	4.64±0.01	2±0.1	0.92±0.09
2017	'Major'		10.7±0.3	4.54±0.03	2±0	1.21±0.09
2017	'HMJ'		11.5±0.1	4.79±0.02	1.6±0	2.19±0.09
2016	'Major'	High	11.8±0.3	4.75±0.04	2.2±0.1	0.99±0.05
2016	'Ellis Bitter'		10.3±0.3	4.7±0.01	1.9±0.1	0.89±0.04
2017	'Major'		10.5±0.2	4.58±0.03	2±0	1.29±0.05
2017	'HMJ'		11.3±0.1	4.83±0.02	1.6±0.1	2.07±0.08
<i>P-value</i>						
		Treatment	<0.001	<0.001	0.021	0.003
		Cultivar	<0.001	<0.001	<0.001	<0.001
		Year	<0.001	0.010	<0.001	0.862
		Treatment × Cultivar	0.348	0.132	0.126	0.032
		Treatment × Year	0.010	0.010	0.009	<0.001

²GAE=gallic acid equivalents

Supplementary Table S14. Percentage of plant assimilable radiation (PAR) permeating the canopy in different regions of 'GoldRush', 'Major', 'Harry Masters Jersey' ('HMJ'), and 'Somerset Redstreak' ('SRS') apple trees in Experiment 4. The study was conducted in Lansing, NY in 2016, 2017, and 2018. Values are means \pm standard error ($n=8 \times 3$ years in 'GoldRush', 8 'Major' in 2016, 8 'HMJ' in 2017, and 8 'SRS' in 2018=32). Different lowercase letters indicate a separation of treatments by the Tukey HSD method at a 5% significance level.

Cultivar	Treatment	Canopy Exposure PAR (%)				
		June	July	August	September	October
'GoldRush'	East	38.1 \pm 2.5	57.3 \pm 2.1	50.3 \pm 2.7	60.7 \pm 3.2	56.6 \pm 2.1
'Major'		61.8 \pm 4.2	55.0 \pm 6.6	52.5 \pm 3.5	-	-
'HMJ'		49.0 \pm 6.4 ^b	66.8 \pm 4.0 ^b	65.5 \pm 2.9 ^b	48.5 \pm 2.3 ^b	- ^b
'SRS'		53.0 \pm 3.3	53.7 \pm 3.3	73.7 \pm 2.2	69.4 \pm 1.9	-
'GoldRush'	West	27.5 \pm 4.3	40.9 \pm 5.7	41.4 \pm 6.0	46.8 \pm 6.3	41.1 \pm 5.8
'Major'		58.0 \pm 5.5	49.9 \pm 4.3	63.5 \pm 2.7	-	-
'HMJ'		47.1 \pm 3.2 ^b	62.2 \pm 2.2 ^b	65.1 \pm 4.6 ^b	56.4 \pm 3.3 ^b	- ^b
'SRS'		60.1 \pm 3.2	51.9 \pm 2.9	73.1 \pm 3.9	67.3 \pm 7.3	-
'GoldRush'	Interior	4.0 \pm 0.9	3.6 \pm 0.5	4.5 \pm 0.6	9.6 \pm 1.8	8.9 \pm 2.4
'Major'		11.7 \pm 3.8	8.6 \pm 4.2	12.3 \pm 3.0	-	-
'HMJ'		9.0 \pm 1.8.0 ^c	11.4 \pm 3.1 ^c	6.5 \pm 1.6 ^c	5.4 \pm 1.0 ^c	- ^c
'SRS'		16.1 \pm 1.1	12.4 \pm 2.2	23.0 \pm 3.1	19.7 \pm 1.5	-
'GoldRush'	Top	71.5 \pm 2.1	76.7 \pm 1.8	77.2 \pm 2.2	83.8 \pm 2.0	80.7 \pm 2.2
'Major'		76.8 \pm 4.3	65.8 \pm 4.1	76.0 \pm 4.4	-	-
'HMJ'		71.6 \pm 2.4 ^a	82.8 \pm 1.9 ^a	84.5 \pm 2.6 ^a	82.5 \pm 2.6 ^a	- ^a
'SRS'		87.6 \pm 4.3	72.8 \pm 2.7	87.8 \pm 2.2	84.7 \pm 0.9	-
<i>P-value</i>	Treatment	<0.001	<0.001	<0.001	<0.001	<0.001
	Cultivar	<0.001	0.053	<0.001	0.533	-
	Year	0.151	0.003	<0.001	<0.001	<0.001
	Treatment \times Cultivar	0.111	0.050	<0.001	0.127	-
	Treatment \times Year	0.158	0.002	<0.001	0.003	0.266

Supplementary Table S15. Growing degree days base 10 °C in different regions of 'GoldRush', and 'Harry Masters Jersey' ('HMJ') apple trees grown in Experiment 4 in Lansing, NY in 2017. Values are means \pm standard error (n = 4 'GoldRush' and n = 8 'HMJ'). Different lowercase letters indicate a separation of treatments by the Tukey HSD method at a 5% significance level.

Cultivar	Treatment	Growing Degree Days base 10°C		
		1-6 Weeks After Full Bloom		1 Week After Full Bloom Until Harvest
'GoldRush'	East	328.8±2.3	ab	1334.4±9.2
'HMJ'		333.7±8.2		976.0±20.0
'GoldRush'	West	337.9±5.7	a	1400.8±22.7
'HMJ'		353.5±7.9		1075.7±30.0
'GoldRush'	Interior	323.3±6.8	b	1287.1±17.8
'HMJ'		322.6±4.4		939.7±13.2
'GoldRush'	Top	330.8±5.0	a	1362.0±22.5
'HMJ'		359.3±3.0		1096.2±21.0
<i>P-value</i>	Treatment	0.004		<0.001
	Cultivar	0.009		<0.001
	Treatment × Cultivar	0.124		0.182

Supplementary Table S16. Fruit characteristics of apples from different regions of 'GoldRush', 'Major', 'Harry Masters Jersey' ('HMJ'), and 'Somerset Redstreak' ('SRS') apple tree canopies grown in Experiment 4. The study was conducted in Lansing, NY in 2016, 2017, and 2018. Values are means \pm standard error ($n=8 \times 3$ years in 'GoldRush', 8 'Major' in 2016, 8 'HMJ' in 2017, and 8 'SRS' in 2018=32). Different lowercase letters indicate a separation of treatments by the Tukey HSD method at a 5% significance level.

Cultivar	Treatment	Mass (g)	Peel Blush (%)	Green Scale (1-5)	Chlorophyll a Index	Starch Pattern Index (1-8)	Firmness (N)
'GoldRush'	East	186.9 \pm 9.5	-	2.6 \pm 0.1	0.41 \pm 0.07	4.3 \pm 0.2	71.7 \pm 3.8
'Major'		63.3 \pm 3.4	46.6 \pm 3.3	-	-	3.3 \pm 0.2	77.6 \pm 2.0
'HMJ'		68.6 \pm 2.6 ^a	68.1 \pm 11.5 ^a	- ^b	1.37 \pm 0.15 ^a	3.0 \pm 0.2 ^a	101.8 \pm 1.6
'SRS'		67.5 \pm 3.4	64.3 \pm 3.6	-	1.14 \pm 0.05	4.9 \pm 0.3	74.8 \pm 2.0
'GoldRush'	West	187.4 \pm 10.5	-	2.7 \pm 0.1	0.33 \pm 0.06	4.8 \pm 0.2	69.4 \pm 3.4
'Major'		63.7 \pm 2.5	33.8 \pm 2.5	-	-	3.3 \pm 0.3	76 \pm 1.4
'HMJ'		70.1 \pm 2.2 ^a	72.8 \pm 4.5 ^a	- ^{bc}	1.28 \pm 0.08 ^a	3.1 \pm 0.2 ^a	96.1 \pm 2.0
'SRS'		62.9 \pm 3.4	61.3 \pm 2.3	-	1.15 \pm 0.05	5.1 \pm 0.2	76.7 \pm 0.8
'GoldRush'	Interior	175.9 \pm 7.5	-	3.2 \pm 0.1	0.54 \pm 0.09	4.3 \pm 0.3	70.5 \pm 3.7
'Major'		59.0 \pm 1.9	5.8 \pm 1.4 ^b	-	-	2.7 \pm 0.2	67.7 \pm 9.9
'HMJ'		69.0 \pm 3.7 ^b	68.4 \pm 9.1 ^b	- ^a	1.41 \pm 0.09 ^b	2.8 \pm 0.2 ^b	101.4 \pm 0.8
'SRS'		58.4 \pm 2.1	37.9 \pm 5.3	-	1.49 \pm 0.03	4.0 \pm 0.3	78.7 \pm 1.2
'GoldRush'	Top	190.9 \pm 11.2	-	2.3 \pm 0.2	0.34 \pm 0.06	4.4 \pm 0.2	71.4 \pm 3.7
'Major'		62.1 \pm 2.0	58.4 \pm 4.3	-	-	3.2 \pm 0.3	77.0 \pm 1.3
'HMJ'		70.3 \pm 2.0 ^a	70.1 \pm 4.5 ^a	- ^c	1.37 \pm 0.09 ^a	3.0 \pm 0.2 ^a	101.0 \pm 1.8
'SRS'		62.8 \pm 2.6	63.5 \pm 5.3	-	1.14 \pm 0.05	5.2 \pm 0.3	76.7 \pm 1.3
<i>P-value</i>	Treatment	0.013	<0.001	<0.001	<0.001	<0.001	0.072
	Cultivar	<0.001	<0.001	-	<0.001	<0.001	<0.001
	Year	<0.001	<0.001	<0.001	0.277	<0.001	<0.001
	Treatment \times Cultivar	<0.001	0.001	-	0.027	<0.001	<0.001
	Treatment \times Year	<0.001	0.001	0.120	0.015	0.008	0.026

Supplementary Table S17. Juice characteristics of apples from different regions of 'GoldRush', 'Major', 'Harry Masters Jersey' ('HMJ'), and 'Somerset Redstreak' ('SRS') apple tree canopies grown in Experiment 4. The study was conducted in Lansing, NY in 2016, 2017, and 2018. Values are means \pm standard error (n= 8 \times 3 years in 'GoldRush', 8 'Major' in 2016, 8 'HMJ' in 2017, and 8 'SRS' in 2018=32). Different lowercase letters indicate a separation of treatments by the Tukey HSD method at a 5% significance level.

Cultivar	Treatment	Soluble Solid Concentration ($^{\circ}$ Brix)	pH	Titrateable Acidity (g malic acid/L)	Total Polyphenols (g GAE/L ²)
'GoldRush'	East	13.8 \pm 0.2	3.4 \pm 0.0	9.0 \pm 0.2	0.5 \pm 0.0
'Major'		15.1 \pm 0.3	4.4 \pm 0.0	2.7 \pm 0.2	1.8 \pm 0.1
'HMJ'		11.3 \pm 0.2 ^{ab}	4.6 \pm 0.0 ^b	1.8 \pm 0.0	1.6 \pm 0.1
'SRS'		10.5 \pm 0.2	4.4 \pm 0.0	1.7 \pm 0.0	1.5 \pm 0.1
'GoldRush'	West	13.3 \pm 0.2	3.4 \pm 0.0	8.4 \pm 0.2	0.4 \pm 0.0
'Major'		14.3 \pm 0.4	4.4 \pm 0.0	3.0 \pm 0.1	1.6 \pm 0.1
'HMJ'		11.5 \pm 0.3 ^b	4.5 \pm 0.0 ^b	2.0 \pm 0.1	1.8 \pm 0.1
'SRS'		10.8 \pm 0.2	4.4 \pm 0.0	1.6 \pm 0.0	1.5 \pm 0.1
'GoldRush'	Interior	12.8 \pm 0.2	3.5 \pm 0.0	8.3 \pm 0.2	0.4 \pm 0
'Major'		12.9 \pm 0.4	4.4 \pm 0.0	2.9 \pm 0.1	1.2 \pm 0.1
'HMJ'		10.2 \pm 0.3 ^c	4.6 \pm 0.0 ^a	2.1 \pm 0.0	1.4 \pm 0.1
'SRS'		9.7 \pm 0.1	4.4 \pm 0.0	1.9 \pm 0.0	1.6 \pm 0.1
'GoldRush'	Top	14.3 \pm 0.2	3.4 \pm 0.0	8.9 \pm 0.2	0.5 \pm 0.0
'Major'		15.1 \pm 0.5	4.4 \pm 0.0	2.8 \pm 0.1	1.9 \pm 0.1
'HMJ'		11.5 \pm 0.3 ^a	4.5 \pm 0.0 ^b	1.9 \pm 0.0	1.9 \pm 0.1
'SRS'		10.9 \pm 0.2	4.4 \pm 0.0	1.6 \pm 0.0	1.8 \pm 0.1
<i>P-value</i>	Treatment	<0.001	<0.001	0.828	<0.001
	Cultivar	<0.001	<0.001	<0.001	<0.001
	Year	<0.001	0.006	<0.001	0.132
	Treatment \times Cultivar	0.058	0.100	<0.001	<0.001
	Treatment \times Year	<0.001	0.165	<0.001	0.876

²GAE=gallic acid equivalent