

Article

Heat Stress and Irrigation Management Effects on the Fruit Color and Fruit Quality in ‘Hongro’ Apples

Van Giap Do[†], Youngsuk Lee[†], Juhyeon Park, Nay Myo Win, Soon-Il Kwon, Sangjin Yang, Seonae Kim*

Apple Research Center, National Institute of Horticultural and Herbal Science, Rural Development Administration, Daegu, 43100, Republic of Korea

Supplementary Table:

- Table S1. qRT-PCR primer list used for analysis the expression levels of anthocyanin biosynthesis genes
- Table S2. qRT-PCR primer list used for analysis the expression levels of carotenoid biosynthesis genes
- Table S3. The growth characteristics of apple tree grown under different orchard-based managements

Supplementary Figure:

- Figure S1. Meteorological data collected at the experimental site of the Apple Research Center (Gunwi-gun, Daegu, South Korea) in 2022.
- Figure S2. Apparent differences in the coloration pattern of on-tree fruits among the three groups were subjected to different orchard-based management.
- Figure S3. Variant coloration patterns of ‘Hongro’ fruit at different treatments among three groups based on orchard management practices at harvest.
- Figure S4. The emergence of new shoots was observed in ‘Hongro’ apple trees grown inside the vinyl house during fruit maturing.

Table S1. qRT-PCR primer list used for analysis the expression levels of anthocyanin biosynthesis genes

Gene	Encoded protein		Primer sequence (5'-3')	GenBank ID
<i>MdPAL</i>	Phenylalanine Ammonialyase	F	TTCCTTGGCAACCCTGTCAC	AF494403
		R	ATGTCGACCGCCTCAAAGG	
<i>MdCHS</i>	Chalcone Synthase	F	GGACTGGAACTCACTCTTC	AB074485.1
		R	GCCGTAATCTGACAACAC	
<i>MdCHI</i>	Chalcone Isomerase	F	AGGATCACTAACGATCAGCTTCTCT	XM_029100826.1
		R	TGGCCAAACTTTGCTTTGCTG	
<i>MdC4H</i>	Cinnamate- 4-hydroxylase	F	ACTTGACACACCCACAGAGG	DR998024.1
		R	ATACGGGTACGGGTATGGGA	
<i>Md4CL</i>	4-coumarate: CoA ligase	F	TTCTGTGACCTGTGCCTCTC	MG334585.1
		R	GAGAATGGAATCGTTTCTGCCT	
<i>MdF3H</i>	Flavanone 3-hydroxylase	F	CCAAGCAGTGGTGAAGTC	AB074486
		R	CTTCTCTCCCTCCCTCAC	
<i>MdDFR</i>	Dihydro Xavonol 4-reductase	F	AAGCCTCATCACTGGACT	AF117268
		R	ATGTGAGAAAGGCAGAGG	
<i>MdANS</i>	Anthocyanin Synthase	F	GCTGGAGAAAGAAGTTGG	AB074487
		R	GGAGGATGAAGGTGAGTG	
<i>MdUFGluT</i>	UDP-glucose: flavonoid-3-O- glucosyltransferase	F	CAACATCCAAGGTCTCTC	AF117267
		R	GTCCCATCTGAAGTAGCA	
<i>MdMYB10</i>	R3R3 myb-type Transcript Factor	F	TCATCTCTCTACTGCAGTGCCTA	XM_029107483.1
		R	CCAGAAAGACACCTTAGACCTTCG	

Table S2. qRT-PCR primer list used for analysis the expression levels of carotenoid biosynthesis genes

Gene	Encoded protein		Primer sequence (5'-3')	GenBank ID
<i>MdGGPPS</i>	Geranylgeranyl Pyrophosphate Synthase	F	CCGTGACCCGATTACGATCC	XM_008356445.3
		R	ATGGATTCCGACCCACCAAC	
<i>MdPSY</i>	Phytoene Synthase	F	GGGGATATGCCCAGAATCAAGC	NM_001294092.1
		R	CTCTTCTCTCTCTAGCATCTTCTCC	
<i>MdPDS</i>	Phytoene Desaturase	F	ACATTCCGGTTTCTGACCCG	XM_008356843.3
		R	ACCAAAGCCTTATCGGGTGG	
<i>MdZISO</i>	Zeta-carotene Isomerase	F	AGCCCTGAGGTTGTGATGTTG	XM_008339306.3
		R	GTCCCCGCAAACAAAACACG	
<i>MdZDS</i>	Zeta-carotene Desaturase	F	TTTGCCACTAAGACCGAGGC	XM_029100719.1
		R	CTGAGATGAAACCTGCCCCC	
<i>MdCRTISO</i>	Carotenoid Prolycopene Isomerase	F	CCAAAGACACACAGGCGGTA	NM_001329029.1
		R	AGACCATCTATGGCGGTGGT	
<i>MdLCYϵ</i>	Epsilon Lycopene Cyclase	F	CTGGCCGCAAGAAAGGAAAC	XM_008389970.3
		R	CCACATCCAGGTGGGTAAGC	
<i>MdLCYβ</i>	Beta Lycopene Cyclase	F	ACCCACATGAGCTTGTCGTC	XM_008394165.3
		R	GACACAACAAGTTCCGAAGAGC	
<i>MdCRHβ</i>	Beta-carotene Hydroxylase 2	F	CGGTGTTTGGGATGGCGTAT	XM_029106190.1
		R	CTTCGAGTTCTGATGAGCCG	
<i>MdZEP</i>	Zeaxanthin Epoxidase	F	AGGGCCTTCCCCTCACTATC	XM_029099177.1
		R	GCTGTAACCTTGCTTGGGTCT	

Table S3. The growth characteristics of apple tree grown under different orchard-based managements

Treatment	Tree No	Tree height (cm)	Stem diameter (cm)	Total new shoot growth length (cm)	The primary shoot growth length (cm)	Number of Fruits/Trre
Water spray	1	200.5	76.7	19.0	11.3	105
	2	177.0	39.1	17.4	9.0	58
	3	118.5	49.7	11.3	0.0	40
	4	204.0	42.6	17.6	0.0	68
	5	209.0	87.9	9.2	0.0	60
Average		181.8 ± 37.5	59.2 ± 21.8	14.9 ± 4.4	4.1 ± 5.6	66.2 ± 24.0
Vinyl house	1	183.0	42.3	10.3	5.6	66
	2	196.5	76.1	9.4	7.3	117
	3	201.0	84.6	16.8	19.0	133
	4	200.5	84.0	10.7	12.5	95
	5	244.0	91.6	19.6	15.9	136
Average		205.0 ± 23.0	75.7 ± 19.5	13.4 ± 4.5	12.1 ± 5.6	109.4 ± 29.2
Control	1	136.5	36.7	12.0	6.0	71
	2	156.5	36.7	17.1	10.8	66
	3	149.5	45.2	15.5	3.0	120
	4	209.0	61.3	14.6	10.4	97
	5	195.0	58.7	18.7	10.5	65
Average		169.3 ± 31.1	47.7 ± 11.8	15.6 ± 2.5	8.1 ± 3.5	83.8 ± 24.1

All values are shown as mean ± SD of data measured from the 5 individual trees of each group.

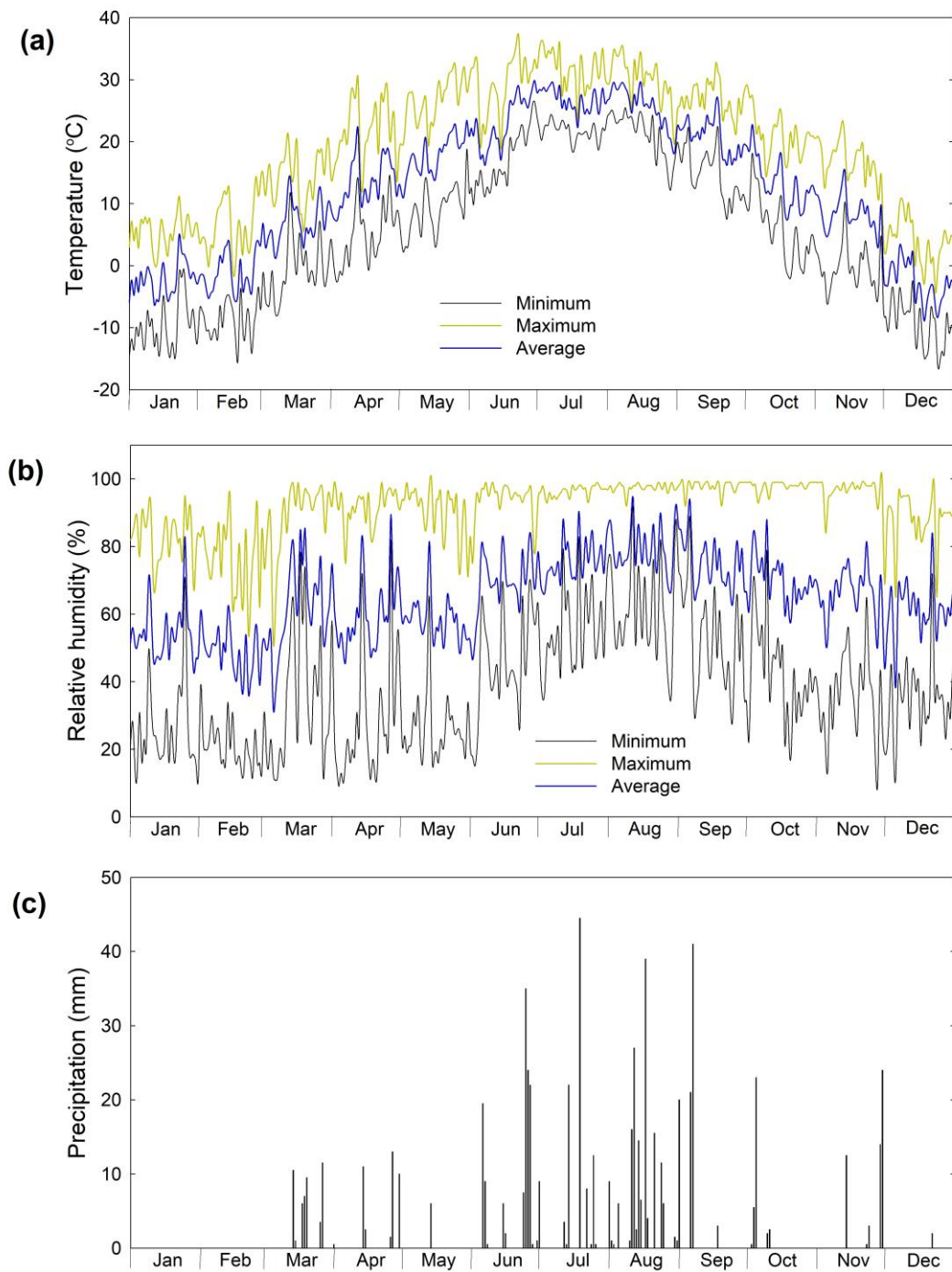


Figure S1. Meteorological data collected at the experimental site of the Apple Research Center (Gunwi-gun, Daegu, South Korea) in 2022. Meteorological data were downloaded from the Korean Meteorological Administration (<http://www.kma.go.kr>). Data included daily mean, minimum, and maximum temperatures (a), relative humidity (rainfall) (b), and precipitation (c).



Figure S2. Apparent differences in the coloration pattern of on-tree fruits among the three groups were subjected to different orchard-based management. Picture representative for fruit of each groups were captured at ripening stage (1 week before harvesting). Scale bars = 20 mm.

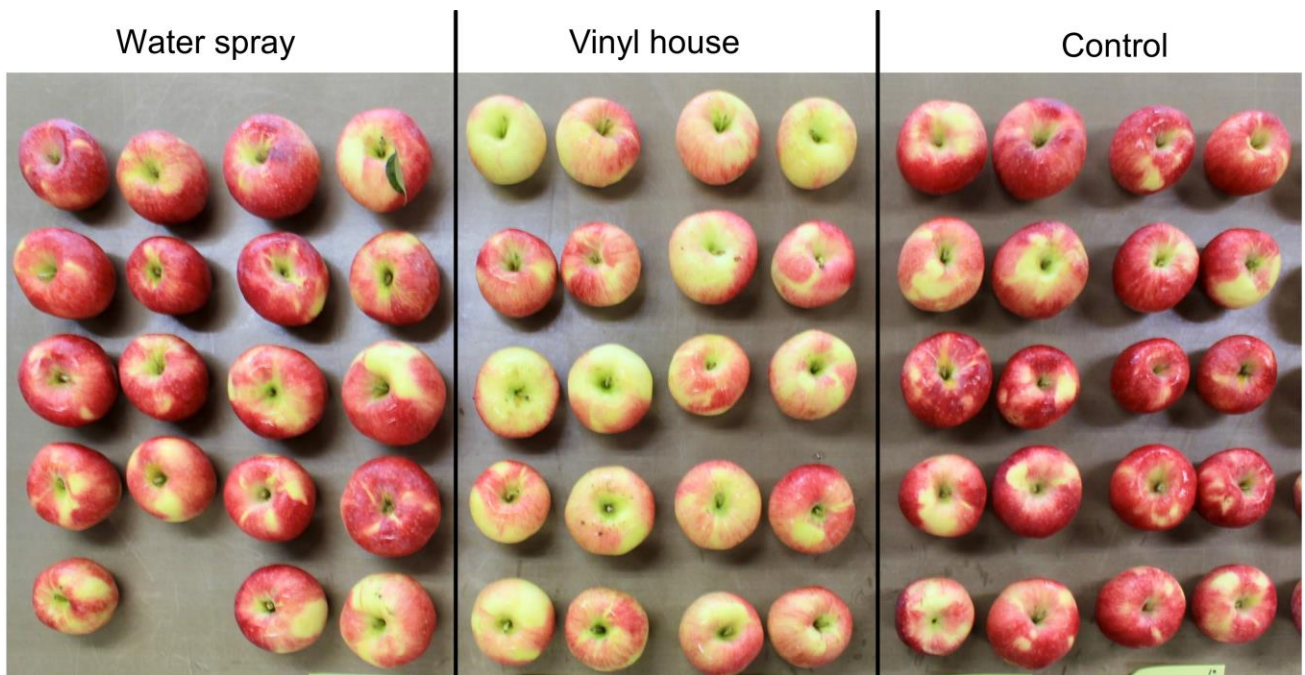


Figure S3. Variant coloration patterns of 'Hongro' fruit at different treatments among three groups based on orchard management practices at harvest.

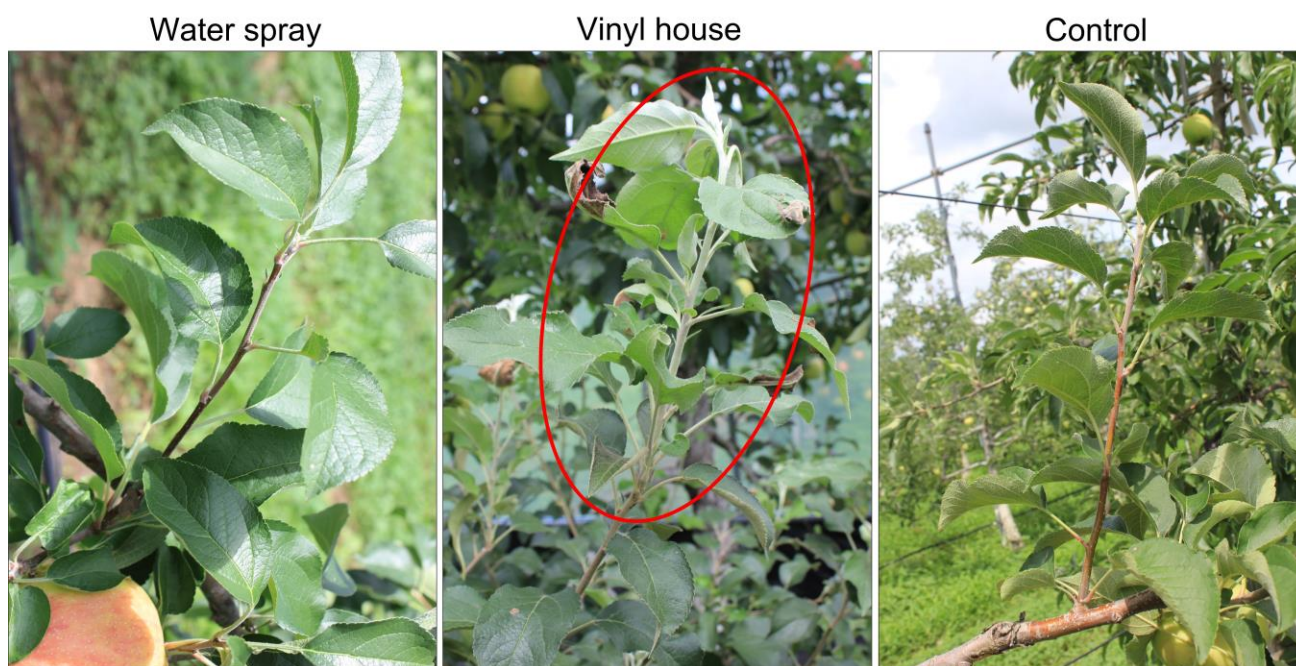


Figure S4. The emergence of new shoots was observed in 'Hongro' apple trees grown inside the vinyl house during fruit maturing.