

POTENTIAL OF CA FOR POSTHARVEST ARTHROPOD CONTROL IN FRESH HORTICULTURAL PERISHABLES: AN UPDATE OF SUMMARY TABLES COMPILED BY KE AND KADER, 1992a.

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Time required to kill certain arthropods in some fresh horticultural perishables by controlled atmospheres.

Arthropod Species	Arthropod		Temperature (°C)	CA Composition		Time for		References
	Commodity	Stage		O ₂ kPa	CO ₂ kPa	100% mortality	LT ₉₉	
Hemiptera								
Aphids								
General Aphids	asparagus	adult	2	7	7	14 d		Batchelor <i>et al.</i> (1985a)
	asparagus, broccoli, carnation, lettuce, rose	adult	0	0.02	-	14-21 d		Zheng <i>et al.</i> (1993)
			0	0.5	-	>21 d		
			5	0.5	-	14-21 d		
			0	~10	50	4 d		
			5	~10	50	6 d		
			0	0.02	-	14-21 d		
Green peach aphid <i>Myzus persicae</i> (Sulzer)	cut flowers, leafy vegetables	adult	10	8	60	2 d		Cantwell <i>et al.</i> (1996)
		adult	20	8	60	1.5 d		
True Bugs								
New Zealand wheat bug <i>Nysius huttoni</i> (White)	apple	adult	0.5	3	3	2 mo.		Waddell <i>et al.</i> (1988)
		fifth instar	20/40	>1.2/1.2	<1/1		6/10.6 h ^y	Lay-Yee <i>et al.</i> (1997)
Mealybugs								
Tuber mealybug <i>Pseudococcus viburni</i> (Signoret) [formerly Obscure mealybug <i>Pseudococcus affinis</i> (Maskell)]	apple	first instar	35	0.4	0		12.9 h	Whiting and Hoy (1997a)
		second/third instars	35	0.4	0		12.4 h	
		adult (female)	35	0.4	0		14.8 h	

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Tuber mealybug (continued)	apple	first instar	40	0.4	0		9.7 h	
		second/third instars	40	0.4	0		8.3 h	
		adult (female)	40	0.4	0		8.7 h	
		first instar	40	1-2	0		11-13 h	
		second/third instars	40	1-2	0		13-16 h	
		adult (female)	40	1-2	0		14-17 h	
Longtailed mealy bug <i>Pseudococcus longispinus</i> (Targioni & Tozzetti)	persimmon	larvae/adult	20	0.5	5	7 d		Dentener et al. (1990,1992)
Scales								
San Jose scale <i>Quadraspidiotus perniciosus</i> (Comst.)	apple	cap/adult	2	3	3	3.7 mo.		Dickler (1975)
		cap/nymph	12	1	90	2 d		Morgan and Gaunce (1975)
			1 or 3	1.5-1.7	1.0-1.1	7.2-7.9 mo.		Chu (1992)
Thysanoptera								
Thrips								
General thrips	asparagus	adult	2	7	7	14 d		Batchelor <i>et al.</i> (1985a)
Western flower thrips <i>Frankliniella occidentalis</i> (Pergande)	cut flowers and leafy vegetables	adult	20	8	60	1.5 d		Cantwell et al. (1996)
	grape	egg	0	11.5	45		4.8 d	Mitcham et al. (1997b)
		first instar	0	11.5	45		5.3 d	
		second Instar	0	11.5	45		6.2 d	
		pseudopupae	0	11.5	45		4.1 d	
		adult	0	11.5	45		4.8 d	
	strawberry	adult/pupae	2.5	1	50-90	1-2 d		Aharoni et al. (1979,1981)

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New Zealand flower thrips <i>Thrips obscuratus</i> (Crawford)	fruits and vegetables	adult	0	2	18	8 d	Potter <i>et al</i> (1994)	
		adult	7	2	18	8 d		
		adult	13	2	18	6 d		
		adult	20	2	18	6 d		
		adult	12	0.25	60	1 d		Carpenter <i>et al</i> (1996)
		adult	24	0, 8, 20	60	1 d		
		adult	36	0-20	40	1 d		
		adult	48	0-20	40	1 h		
			stone fruits	all	0-1	2 or 6		40-60
Coleoptera								
Beetles								
Flour beetle <i>Tribolium confusum</i> Koch	Cut flowers	adult	1	8-11	45-60	7 d	Seaton and Joyce (1993)	
Nitidulid or sap beetle <i>Carpophilus</i> spp.	dates, dried fruit		22-28	4-7	60-85	(prevented insect development in cold storage)	Navarro et al. (1998)	
Weevils								
Sweet potato weevil <i>Cylas formicarius</i> <i>elegantulus</i> (Summers)	sweet potato	adult	25	2-4	40-60	2-7 d	Delate et al. (1990)	
		adult	30	8	40-60	4-8 d		
Diptera								
Fruit Flies								
Apple Maggot <i>Rhagoletis pomonella</i>	apple	egg	0	0		24 d	Ali Niazee et al. (1989) Kosittrakun (1989)	
		egg	20	0		7 d		
Caribbean fruit fly <i>Anastrepha suspensa</i> (Loew)	citrus	egg	15.6	0.5-2	30	10 d	Benschoter (1987)	
		pupa	15.6	0.5-2	30	10 d		
	grapefruit	larva	22	0	0	2.5 d	Benschoter et al. (1981)	
		larva	22	0-12	40-100	3 d		
		egg	10	0-12	40-100	3 d		

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Mexican fruit fly <i>Anastrepha ludens</i> (Loew)	grapefruit	third instar	44	1	0	3.5 h		Shellie et al. (1997b)
		mango	third instar	42	0	50	160 min	Yahia et al. (1999)
	mango	egg	48	0	50	160 min		Yahia and Ortega-Zaleta (2000)
		egg	55	0	50	80 min		
		third instar	48	0	50	80 min		
		third instar	48	21	0	220 min		
West Indian fruit fly <i>Anastrepha obliqua</i> (Macquart)	mango	third instar	35	0	50	160 min		Yahia et al. (1999)
		egg	55	0	50	80 min		Yahia and Ortega-Zaleta (2000)
		egg	52	21	0	240 min		
		third instar	55	0	50	80 min		
		third instar	48	21	0	220 min		
<i>Anastrepha serpentina</i>	mango	eggs	25	0-0.25	70-100	4 d		Rojas Villegas et al. (1995)

Lepidoptera

Leafrollers

Greenheaded leafroller <i>Planotortrix excessana</i> (Walker)	apple	first/third instars	0.5	3	3	2 mo.		Batchelor <i>et al.</i> (1985b)
		egg, first/third/fifth instars	40	1.2	5		1.5-4.1 h	Whiting <i>et al.</i> (1995)
		egg, first/third/fifth instars	40	4.2	5		1.8-4.9 h	
	persimmon	third instar	20	0.5	5	4 d		Dentener <i>et al.</i> (1990, 1992)

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	Commodity	Stage		O ₂ kPa	CO ₂ kPa	100% mortality	LT ₉₉	
Brownheaded leafroller <i>Ctenopseustis obliquana</i> (Walker)	apple	first/fifth instars	0.5	3	3	1-2 mo.	2-4 d	Waddell et al. (1990) Whiting et al. (1992a)
		fifth instar	20	0.4	5			
			30	0.4	5			
			eggs, first and third instars	20/40	>1.2/1.2	<1/1	6/15 h ^y	Whiting and van den Heuvel (1998)
			egg, first/third/fifth instars	40	1.2	5	1.5-4.1 h	Whiting <i>et al.</i> (1995)
			egg, first/third/fifth instars	40	4.2	5	1.8-4.9 h	
		first instar	20	0.4	5	18.8 h	Whiting <i>et al.</i> (1996)	
		first instar	20	0.4	5	31.5 h		
		first instar	20	0.4	5	31.6 h		
		first instar	30	0.4	5	6 h		
		first instar	40	0.4-3.8	5	2.5-4.2 h		
		kiwifruit	egg (3 d old)	40	2	5	3.47 h	Hoy and Whiting (1998)
			first instar	40	2	5	3.85 h	
			third instar	40	2	5	3.83 h	
	fifth instar		40	2	5	5.58 h		
Black lyre leafroller <i>Cnephasia jactatana</i> (Walker)	kiwifruit	egg (3 d old)	40	2	5	4.19 h	Hoy and Whiting (1998)	
		first instar	40	2	5	3.86 h		
		third instar	40	2	5	4.69 h		
		fifth instar	40	2	5	5.55 h		
	apple	egg, first/third/fifth instars	40	1.2	5	1.5-4.1 h	Whiting <i>et al.</i> (1995)	
		egg, first/third/fifth instars	40	4.2	5	1.8-4.9 h		
		first instar	20	0.4	5	18.8 h	Whiting <i>et al.</i> (1996)	
		first instar	20	0.4	5	31.5 h		
		first instar	20	0.4	5	31.6 h		
		first instar	30	0.4	5	6 h		
	first instar	40	0.4-3.8	5	2.5-4.2 h			

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<i>Ctenopseustis herana</i> (Felder and Rogenhoffer)	apple	egg, first/third/fifth instars	40	1.2	5		1.5-4.1 h	Whiting <i>et al.</i> (1995)		
		egg, first/third/fifth instars	40	4.2	5		1.8-4.9 h			
Greenheaded leafroller <i>Planotortrix octo</i> Dugdale	apple	egg, first/third/fifth instars	40	1.2	5		1.5-4.1 h	Whiting <i>et al.</i> (1995)		
		egg, first/third/fifth instars	40	4.2	5		1.8-4.9 h			
		egg, first/third/ fifth instars	20	0.4	5		1.5-4 d	Whiting <i>et al.</i> (1992a)		
		egg, first/third/fifth instars	30	0.4	5		7-15 h			
		first instar	20	0.4	5		18.8 h	Whiting <i>et al.</i> (1996)		
		first instar	20	0.4	5		31.5 h			
		first instar	20	0.4	5		31.6 h			
		first instar	30	0.4	5		6 h			
		first instar	40	0.4-3.8	5		2.5-4.2 h			
				egg, fifth instar	20/40	>1.2/1.2	<1/1		6/13 h ^y	Whiting and van den Heuvel (1998)
		first/third instars	20/40	>1.2/1.2	<1/1		6/15 h ^y			
Omnivorous leafroller <i>Platynota stultana</i> Wlsm.	grape	egg	0	11.5	45		1.3 d	Mitcham <i>et al.</i> (1997b)		
		third instar	0	11.5	45		4.3 d			
		fifth instar	0	11.5	45		2.9 d			
		pupa	0	11.5	45		3.6 d			
		adult	0	11.5	45		2.5 d			
				pupa	10	21	20		15.8 d	Zhou <i>et al.</i> (2000)
					10	21	40		7.6 d	
					10	21	79		4.5 d	
					20	21	20		5.3 d	
					20	21	40		5.9 d	
			20	21	79		4.3 d			

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	Commodity	Stage		O ₂ kPa	CO ₂ kPa	100% mortality	LT ₉₉	
Moths								
Codling moth <i>Cydia pomonella</i> (L.)	apple	Larvae	0	1.5-2	<1	3 mo.		Toba and Moffitt (1990, 1991)
		Larvae	27	1	95	2 d		Whiting <i>et al.</i> (1992a,b)
		fifth instar	20	0.4	5	15 d		
			30	0.4	5	3.6 d		Whiting <i>et al.</i> (1992b)
	apple, pear	fifth instar (ND ^z)	28; 0.5	2	5	14.4 h		
							3 d; 158 d ^y (probit 9)	Chervin <i>et al.</i> (1999)
	apple	egg, first/third/ fifth instars	20	0.4	5		1.5-14 d	Whiting <i>et al.</i> (1992a)
			30	0.4	5		1-4 d h	
	cherry	fifth instar	45	1	15		64 min.	Neven and Mitcham (1996)
			47	1	15		44 min.	
	pear	fifth instar	30; 0	0.3; 21	4.6; 0	30 h; 1 mo. ^y		Chervin <i>et al.</i> (1997) Mitcham <i>et al.</i> (1999)
			46	1	15	2.5 h (fast heating rate)		
46			1	15	3.0 h (slow heating rate)			
Light brown apple moth <i>Epiphyas postvittana</i> (Walker)	apple	fifth instar	40	1.2	5		8.5 h	Whiting <i>et al.</i> (1995)
		fifth instar	40	4.2	5		15.5 h	
		first/fifth instars	0.5	3	3	1-2 mo.		Waddell <i>et al.</i> (1990)
		first/third instars	2	3	3	3 mo.		
		fifth instar	20	0.4	5	4 d		Batchelor <i>et al.</i> (1985b)
		fifth instar	30	0.4	5	1 d		
		fifth instar	40	0.4	5	4.8 h		Whiting <i>et al.</i> (1991 and 1992a,b)
		first instar	20	0.4	1-20	1-1.7 d		
		first instar	20	2	5	13 d		
		first instar	40	1	1		7.9-13.4 h ^x	Whiting and Hoy (1998)
		third instar	40	1	1		8.1-14.8 h ^x	
		fifth instar	40	1	1		7.8-16.2 h ^x	
		fifth instar	20/40	>1.2/1.2	<1/1		6/8.2 h ^y	Lay-Yee <i>et al.</i> (1997)
		egg	20/40	>1.2/1.2	<1/1		6/18 h ^y	
		first instar	20/40	>1.2/1.2	<1/1		6/21 h ^y	Whiting and van den Heuvel (1998)
		third instar	20/40	>1.2/1.2	<1/1		6/33 h ^y	
fifth instar	20/40	>1.2/1.2	<1/1		6/31 h ^y			

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Oriental fruit moth <i>Grapholita molesta</i> (Busck.)	apple	egg, first/third/ fifth instars	20	0.4	5		1-4 d	Whiting et al. (1992a)
		egg, first/third/fifth instars	30	0.4	5		0.5-1.5 d	
	apple, pear	egg sixth instar pupae	28	2		3 d	3 d:42 d ^y	Chervin et al. (1999) Tabatabai et al. (2000)
			28: 0.5	2				
			29: 0	1.2		3 d: 2 wks ^y		
	apricot	first instar	0	1.5	3		19.9 d	Whiting and Hoy (1997b)
		fifth instar	0	1.5	3		22.4 d	
	kiwifruit	egg (3 d old) first instar third instar fifth instar	40	2	5		4.80 h	Hoy and Whiting (1998)
			40	2	5		7.53 h	
			40	2	5		9.56 h	
40			2	5		13.39 h		
pear	egg, larva, adult pupa	20; 0	0.3; 21	4.6; 0		16 h; 1 mo ^y	Chervin <i>et al</i> (1997)	
		30; 0	0.3; 21	4.6; 0		30 h; 1 mo ^y		
pear	fifth instar	30; 0	0.3; 21	4.6; 0		30 h; 1 mo ^y	Chervin et al. (1997)	
Navel orangeworm <i>Amyelois transitella</i> (Walker)	walnut	later larvae to early pupae	25	0.4	0		6 d	Johnson et al. (1998)
Acarina								
Mites								
Apple rust mite <i>Aculus schlechtendali</i> (Nal.)	apple	egg	2.8	1	1		5.3 mo.	Lidster <i>et al.</i> (1981)
European red mite or Fruit tree red spider mite <i>Panonychus ulmi</i> (Koch)	apple	egg	2.8	1	1		5.3 mo.	Lidster <i>et al.</i> (1981, 1984)
		egg	7.5	1	1.5		14 d	

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Pacific spider mite <i>etranychus pacificus</i> McGregor	grape	egg	0	11.5	45		4.7 d	Mitcham et al. (1997b)
		larva	0	11.5	45		7.6 d	
		protonymph	0	11.5	45		8.1 d	
		adult	0	11.5	45		7.9 d	
		larva, protonymph, deutonymph, adult	0; 0	1; 21	95; 0.03	3 d; 18 d ^y		Zhou and Mitcham (1998)
		larva, protonymph, deutonymph, adult	0; 0	4; 19	80; 8	2 d; 18 d ^y		
		larva, protonymph, deutonymph, adult	0; 0	1; 19	95; 8	2 d; 18 d ^y		
		larva, protonymph, deutonymph, adult	0; 0	7; 19	65; 8	3 d; 18 d ^y		
		larva, protonymph, deutonymph, adult	0; 0	7; 5	65; 20	2 d; 18 d ^y		
		adults, deutonymphs	0; 0	4; 5	80; 20	1 d; 18 d ^y		
		adults, deutonymphs	0; 0	4; 5	95; 20	1 d; 18 d ^y		
Two-spotted spider mite <i>Tetranychus urticae</i> Koch	kiwifruit	adult	40	0.4	20	7 h		Lay-Yee and Whiting (1996)
		adult (D ^z)	40	0.4	20	15.1 h		Whiting and van den Heuvel (1995)
		adult (D ^z)	38	0.4	20	19.3 h		
		adult (D ^z)	35	0.4	20	1.2 d		
		adult (D ^z)	20	0.4	20	4.7 d		
		adult (D ^z)	20	0.4	10	7.4 d		

^xTime to LT₉₉ varies with time to establish target temperature ranging from 5 to 12 hours, respectively

^ySequential CA treatments

^zD – diapausing; ND - nondiapausing

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