The skin colouring problem of 'Hass' avocado fruit during ripening

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Abstract
'Hass' avocado fruits are characterised by a change in skin colour from green to purple/black after harvesting as indicative of ripening. Recently, markets importing South African 'Hass' avocado fruits have been complaining about skin colour not changing to purple/black during ripening. Therefore, the aim of this research was to investigate pre- and postharvest factors (orchard block slope [temperature differential], harvest maturity and ripening temperature) leading to 'Hass' skin colour being de-synchronised with softening during ripening. The results indicated that 'Hass' fruits harvested early from lower (cooler) parts of the slope showed significantly higher de-synchronised colouring. Furthermore, lower ripening temperature (16 and 21°C) significantly affected colouring of 'Hass' avocado fruit when compared with higher ripening temperature (25°C). In addition, colour de-synchronisation was further associated with higher external cold/chilling damage, especially with fruits harvested from lower (cooler) parts of orchard blocks.

INTRODUCTION

The skin colour of 'Hass' avocado fruit changing from green to purple after harvest has been established as a ripening parameter by growers and consumers. However, markets importing 'Hass' avocado fruits from South Africa have found such a ripening guide not to hold in some consignments, resulting in external quality challenges or variability. Therefore, the reliability of colour changes as a ripening or softening indicator has been questioned by consumers, especially lucrative overseas markets.

The South African Avocado Growers' Association (SAAGA) commissioned the Postharvest Technologies Division of the Agricultural Research Council's Institute for Tropical and Subtropical Crops (ARC-ITSC) and Lowveld Postharvest Services to investigate pre- and postharvest factors causing such a phenomenon. Previous studies have indicated that 'Hass' skin colour change is affected by ripening temperatures (Cox *et al*., 2004; Donetti & Terry, 2012). A study was therefore designed to verify ripening and maturity as causing factors; and further, investigate pre-harvest factors also causing the problem.

The aim of this study was to investigate the role of orchard block slope, harvest maturity and ripening temperature on variable colour change of 'Hass' avocado fruits.

MATERIALS AND METHODS

'Hass' avocado fruits were harvested at early- (May 2014), mid- (June 2014) and late-season (July 2014) from two blocks with a slope (upper or lower slope) at Kiepersol area, afterwards transported to the ARC–ITSC postharvest laboratory. At the laboratory, fruits were sorted and graded, and afterwards stored at 5.5°C for up to 28 days. After withdrawal from cold storage, fruit samples were ripened at 16, 21 and 25°C respectively. During ripening, fruits were evaluated at 0, 2, 4, 6 and 8 days for firmness, skin eye colour (Plate 1, score: 1-5), chromatic skin colour (L-Lightness, C-Chroma and H-hue angle), external and internal damage (chilling damage).

RESULTS AND DISCUSSION

Effect of ripening temperature, harvest time, orchard block and slope on 'Hass' skin colour change during ripening.

Ripening temperature

In general, 'Hass' avocado fruit ripened after 4, 6 and 8 days at 25, 21 and 16°C, respectively (Plate 2). There seems to be no significant difference (P=0.065) in fruit ripening over ripening time, harvest time and orchard slope (Table 1 and 2). As expected, fruit firmness decreased faster at higher ripening tem-

peratures (25 and 21°C) and lowest at lower ripening temperature (16°C), irrespective of harvest time, orchard blocks and slope (Table 1 and 2).

Harvest time

Variable colouring of 'Hass' avocado fruit was mostly prevalent on early-season fruits as compared with mid- and late-season fruit, irrespective of ripening temperature, orchard block and slope (Table 1 and 2). According to subjective colour parameter (eye colour), fruit colouring only increase to 3 (olive green) for early harvested fruit, while colouring improved at mid-harvest (score: 4; purple) and reached maximum (score: 4-5; purple and black) with late-season fruit. The same trend was observed with all objective colour parameters (L, C and hue angle). However, the observed trend was affected by orchard block and slope severity.

Orchard block and slope

'Hass' colouring problem was found mainly in orchard blocks with slopes, and lower parts of slopes were severely affected by variable colouring. In this study, orchard block HL12 had a severe slope effect compared with HL8, and therefore, variable colouring being mainly found in HL12 lower part of the slope (Table 2). The fruits harvested from lower and upper slope of the orchard blocks showed no significant

Plate 1. 'Hass' avocado skin colour change rating used during ripening in the study.

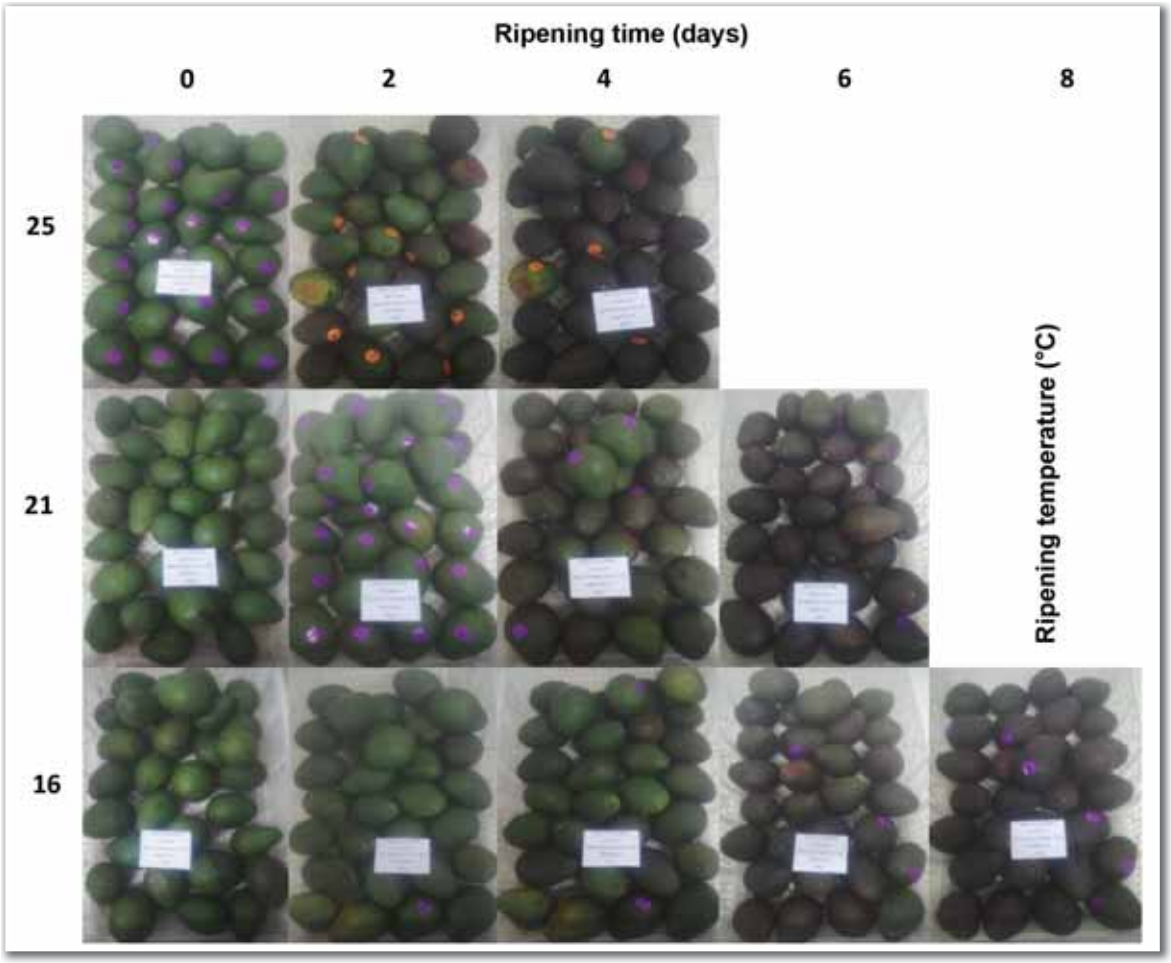

Plate 2. Effect of ripening temperature on skin colour of 'Hass' avocado fruits harvested from upper slopes.

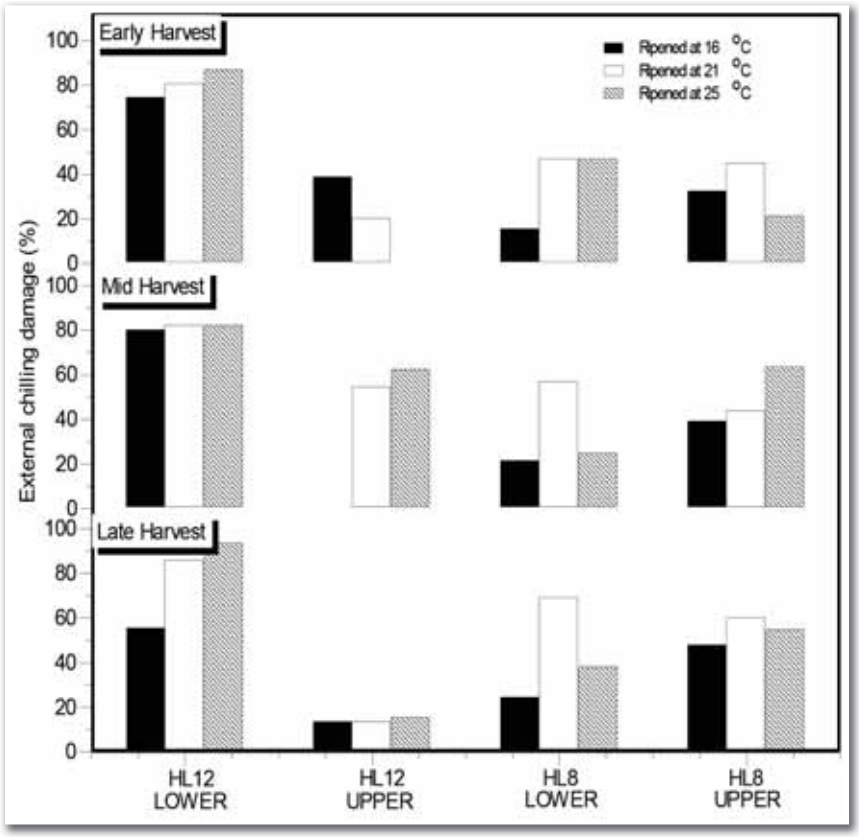

Figure 1. Effect of harvest time, ripening temperature and orchard block slope (HL8 and HL12) on external chilling damage of 'Hass' avocado fruits.

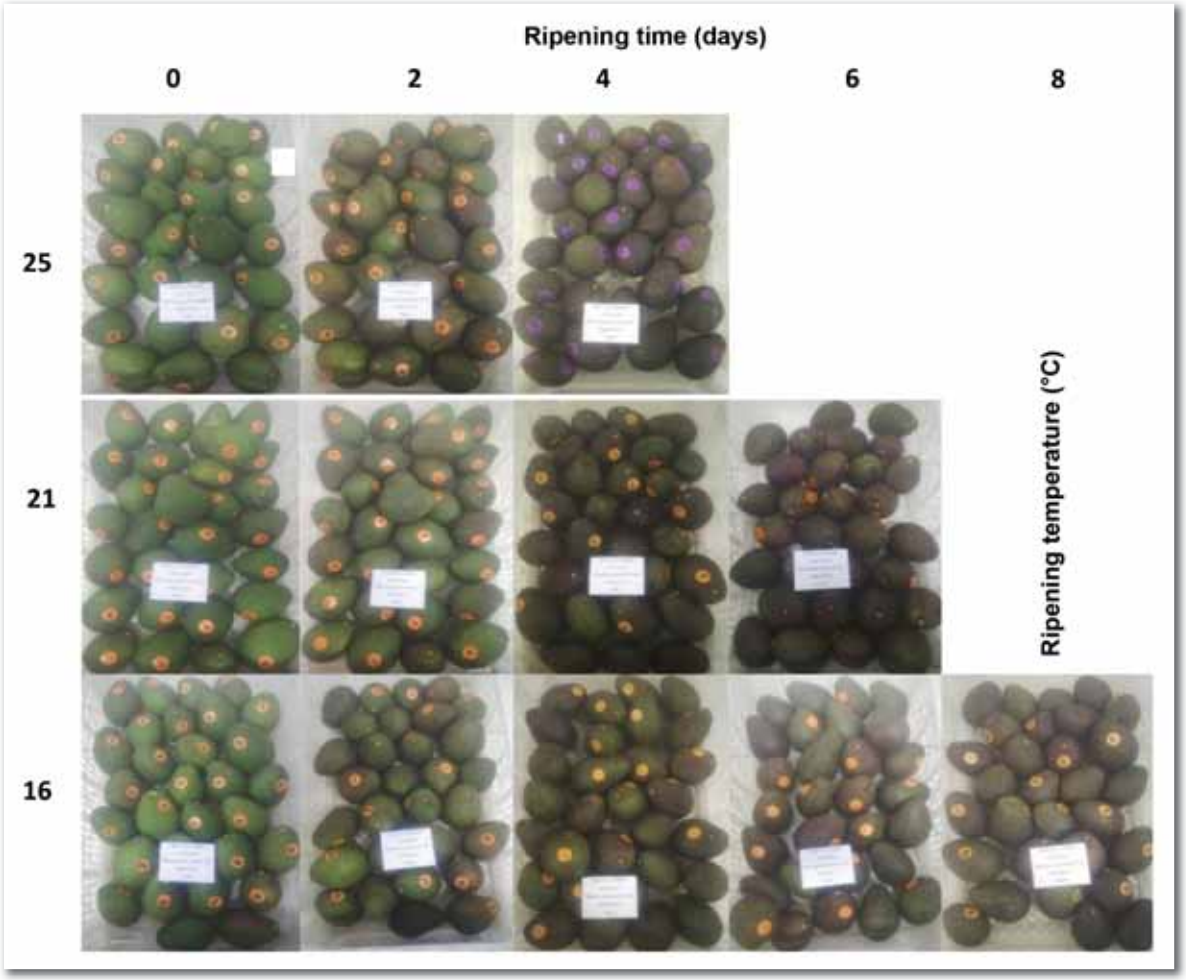

Plate 3. Effect of ripening temperature on colouring of 'Hass' avocado fruits harvested from lower slopes.

Table 1. Effect of harvest time, ripening temperature and orchard block slope (HL 8) on ripening and skin colouring of 'Hass' avocado fruits.

	Orchard block							
	HL8 UPPER							
Harvest time	Ripening temperature (°C)	Ripening duration (days)	Ripening (%)	Firmness	Eye colour (1-5)	L	C	Hue angle
Early-harvest	25	0	0.0	69.5	1.0	37.69	20.1	146.2
		2	4.3	48.9	1.9	36.96	17.7	112.8
		4	83.3	40.8	2.4	35.83	14.5	118.7
		6	*	*	*	*	*	*
		8	*	*	*	*	*	*
	21	0	0.0	72.3	1.0	37.35	19.7	145.6
		2	0.0	58.9	1.7	36.68	18.7	117.0
		4	1.0	40.8	1.7	38.23	12.8	140.6
		6	82.0	23.7	3.5	34.93	9.6	85.3
		8	*	*	*	*	*	*
	16	0	0.0	71.6	1.0	37.84	20.4	145.0
		2	0.0	65.2	1.3	37.35	19.4	134.6
		4	0.0	51.3	2.6	36.16	17.4	110.0
		6	2.3	34.2	2.6	37.31	17.7	112.1
		8	88.0	23.3	2.8	36.44	15.2	103.7
Mid-harvest	25	0	0.0	66.2	1.0	37.57	20.5	148.0
		2	24.3	40.0	2.1	36.84	18.1	107.1
		4	85.7	23.6	3.1	32.45	13.1	87.9
		6	*	*	*	*	*	*
		8	*	*	*	*	*	*
	21	0	0.0	61.0	1.0	37.23	19.9	147.5
		2	0.0	46.3	1.8	36.56	18.5	117.5
		4	7.7	32.7	2.8	33.89	14.4	82.8
		6	87.7	22.9	3.1	32.25	7.1	103.8
		8	*	*	*	*	*	*
	16	0	0.0	65.5	1.0	37.72	20.8	146.8
		2	0.0	56.2	1.4	37.23	19.8	133.4
		4	0.0	41.8	2.1	36.04	17.9	108.9
		6	20.0	29.7	3.2	32.79	12.5	84.7
		8	100.0	21.1	3.9	30.33	10.5	72.2
Late-harvest	25	0	0.0	59.3	1.0	36.26	21.2	152.8
		2	0.0	27.8	2.1	34.89	17.3	114.3
		4	83.3	22.5	4.1	28.43	9.1	84.3
		6	*	*	*	*	*	*
		8	*	*	*	*	*	*
	21	0	0.0	61.3	1.0	34.94	19.7	151.1
		2	0.0	49.4	1.8	35.01	18.7	120.8
		4	3.3	32.0	2.7	31.93	12.7	120.2
		6	81.0	21.7	3.9	28.97	9.6	89.6
		8	*	*	*	*	*	*
	16	0	0.0	65.5	1.0	35.37	20.2	147.9
		2	0.0	52.3	1.3	34.74	18.9	134.9
		4	0.0	38.3	1.9	33.3	15.9	116.9
		6	29.0	28.5	3.2	29.91	10.3	105.7
		8	79.0	23.9	4.7	27.66	8.6	73.37

Orchard block						
	HL8 LOWER					
	Ripening (%)	Firmness	Eye colour (1-5)	L	C	Hue angle
	0	73.1	1.0	37.2	19.2	145.2
	3.3	54.8	1.0	36.94	18.4	151.1
	88.0	28.5	1.9	35.76	15.3	142.5
	*	*	*	*	*	*
	*	*	*	*	*	*
	0	71.8	1.0	37.7	20.2	146.2
	0	58.1	1.0	37.37	19.2	148.2
	3.3	39.2	1.2	38.37	20.2	155.9
	86.7	71.8	1.2	35.18	14.3	102.8
	*	*	*	*	*	*
	0	79.9	1.0	37.91	20.3	144.8
	0	68.2	1.1	37.23	19.0	148.6
	0	53.6	1.0	36.98	17.2	154.1
	3.3	35.8	1.3	38.9	19.8	156.3
	81.3	23.9	2.3	36.2	14.8	126.7
	0	63.8	1.0	37.64	20.3	145.2
	0	47.4	1.0	37.81	19.6	130.1
	78.7	24.5	2.3	35.45	15.9	98.1
	*	*	*	*	*	*
	*	*	*	*	*	*
	0.0	64.0	1.0	38.14	19.4	146.2
	0.0	51.7	1.3	37.67	17.6	135.1
	1.0	36.6	1.9	37.42	13.7	110.5
	70.0	25.5	3.1	35.6	11.1	95.6
	*	*	*	*	*	*
	0.0	64.0	1.0	38.35	20.7	144.8
	0.0	56.6	1.6	38.76	19.3	123.5
	0.0	44.3	1.7	36.6	17.4	112.9
	9.0	32.4	3.9	35.87	14.5	99.6
	72.7	24.9		30.09	10.5	80.6
	0.0	64.2	1.0	36.81	21.5	150.4
	0.0	39.7	2.2	34.73	16.8	110.9
	71.0	23.6	4.2	28.52	9.1	85.9
	*	*	*	*	*	*
	*	*	*	*	*	*
	0.0	70.2	1.0	37.3	22.6	151.5
	0.0	48.9	1.6	34.88	19.8	130.3
	16.7	29.9	2.9	31.94	12.9	101.2
	84.7	20.1	4.3	28.54	22.6	88.2
	*	*	*	*	*	*
	0.0	64.0	1.0	37.66	23.6	153.4
	0.0	53.0	1.1	36.04	21.7	152.6
	0.0	37.7	2.2	34.36	16.0	114.9
	43.3	25.3	2.9	32.47	13.8	102.8
	91.3	19.4	3.3	31.03	12.5	107.4

variability in ripening percentages and firmness. However, there was an insignificant decrease in fruit lightness (L), hue angle (H) and chroma (C) (Table 2). Therefore, the problem with variable colouring is mainly with fruits harvest from lower slopes of orchard blocks with a slope (Plate 3).

External chilling damage on colouring problem

'Hass' avocado fruit from HL12 lower had higher external chilling damage compared with HL12 upper slope and HL8 (upper and lower slope) fruit (Fig. 1). Interestingly, higher external chilling damage was strongly associated with fruit skin colour not changing from green to purple during ripening (Plate 3). Furthermore, the high external chilling damage in HL12 lower was observed irrespective of harvest time (early-, mid- and late-harvest) and ripening temperature (Fig. 1). Fruits harvested from lower slope showed an insignificant decrease in objective colour parameters (L, C and hue angle) when compared with upper slope fruits and HL8 fruit (both lower and upper slope), especially, early season fruit (Table 1 and 2).

CONCLUSION

The incidence of variable colouring in 'Hass' avocado fruit during ripening is prevalent mainly in early harvested fruits, irrespective of ripening temperatures. Furthermore, fruit harvested from orchard blocks with slopes have been found to be the major contributor of 'Hass' avocado variable colouring during ripening. In addition, variable colouring of 'Hass' avocado fruit is escalated by external chilling damage, and external chilling damage is associated with fruits harvest from lower slopes. Therefore, the major findings of variable colouring of 'Hass' avocado fruit are

1) to a lesser extent caused by lower ripening temperatures,
2) to a greater extent caused by harvest time i.e. early harvested fruit, and
3) caused by external chilling damage and pre-harvest stress (irrigation and other forms of stress).

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Table 2. Effect of harvest time, ripening temperature and orchard block slope (HL 12) of ripening and skin colouring on 'Hass' avocado fruits.

Orchard block								
	HL12 UPPER							
Harvest time	Ripening temperature (°C)	Ripening duration (days)	Ripening (%)	Firmness	Eye colour (1-5)	L	C	Hue angle
Early-harvest	25	0	0.0	72.2	1.0	37.66	19.5	144.5
		2	0.0	56.2	1.8	36.25	16.4	119.7
		4	71.0	34.0	1.6	37.36	18.6	143.1
		6	*	*	*	*	*	*
		8	*	*	*	*	*	*
	21	0	0.0	73.0	1.0	38.72	22.1	145.5
		2	0.0	61.1	1.7	37.32	21.5	117.3
		4	0.0	40.2	1.0	39.17	18.4	154.2
		6	71.0	28.3	2.0	35.6	14.4	134.9
		8	*	*	*	*	*	*
	16	0	0.0	72.5	1.0	37.26	24.4	144.3
		2	0.0	67.9	1.0	37.16	19.7	145.1
		4	0.0	55.1	1.0	40.06	19.3	150.6
		6	21.0	37.7	1.2	37.88	19.1	154.6
		8	84.7	25.9	1.7	37.73	17.8	142.9
Mid-harvest	25	0	0.0	62.9	1.0	37.77	19.1	146.9
		2	1.0	36.8	2.0	36.36	16.2	113.7
		4	84.3	20.1	2.7	30.95	10.4	99.5
		6	*	*	*	*	*	*
		8	*	*	*	*	*	*
	21	0	0.0	67.4	1.0	38.83	21.1	147.6
		2	0.0	50.2	2.0	37.43	18.1	109.5
		4	31.0	33.0	2.4	34.62	14.3	103.3
		6	89.0	24.1	2.8	34.08	4.7	95.1
		8	*	*	*	*	*	*
	16	0	0.0	69.7	1.0	37.37	19.3	146.7
		2	0.0	59.5	1.5	37.27	18.7	126.5
		4	0.0	49.9	1.8	36.47	17.9	116.2
		6	11.0	35.8	2.6	33.86	16.7	97.4
		8	71.2	24.7	3.2	31.62	12.6	103.6
Late-harvest	25	0	0.0	64.2	1.0	37.36	22.5	162.3
		2	1.0	41.2	3.6	30.88	15.9	101.1
		4	100.0	19.3	3.9	27.25	7.5	95.4
		6	*	*	*	*	*	*
		8	*	*	*	*	*	*
	21	0	0.0	62.9	1.0	36.61	22.7	147.8
		2	0.0	59.3	1.4	35.71	19.9	135.9
		4	17.7	37.9	2.5	32.94	14.8	109.4
		6	96.7	22.7	4.7	28.67	9.8	74.1
		8	*	*	*	*	*	*
	16	0	0.0	69.7	1.0	35.37	20.2	147.9
		2	0.0	61.8	1.3	34.74	18.9	133.5
		4	10.0	47.6	1.8	33.3	15.9	119.9
		6	53.3	34.4	3.2	29.91	10.3	100.5
		8	89.0	22.4	4.5	27.66	8.6	80.2

Orchard block						
	HL12 LOWER					
	Ripening (%)	Firmness	Eye colour (1-5)	L	C	Hue angle
	0	66.2	1.0	38.95	21.3	147.7
	3.3	45.4	1.7	37.04	18.3	134.9
	88.0	25.6	1.8	36.66	16.9	155.0
	*	*	*	*	*	*
	*	*	*	*	*	*
	0	69.6	1.0	37.91	20.6	142.7
	0	56.4	1.7	37.06	18.8	118.6
	3.3	33.7	1.9	33.92	14.3	122.2
	86.7	26.6	1.5	37.19	17.3	152.9
	*	*	*	*	*	*
	0	65.3	1.0	37.97	21.2	140.5
	0	54.9	1.0	38.03	20.6	148.0
	0	40.8	1.2	40.24	22.9	151.5
	3.3	29.2	1.5	38.63	20.4	151.4
	81.0	22.5	1.8	37.09	17.0	144.8
	0	56.4	1.0	38.95	22.1	149.0
	4.3	32.9	1.8	37.04	19.2	119.7
	86.3	22.7	2.8	33.34	14.8	86.7
	*	*	*	*	*	*
	*	*	*	*	*	*
	0	67.9	1	37.91	21.4	144.4
	0	52.1	1.5	37.06	19.7	129.1
	3.3	34.8	2.5	33.92	15.3	96.5
	88.7	23.2	2.4	32.76	3.1	120.3
	*	*	*	*	*	*
	0.0	63.0	1.0	37.97	22.0	147.9
	0.0	51.7	1.1	38.03	21.4	144.9
	1.0	36.7	2.0	35.77	17.7	112.9
	12.0	29.3	2.5	32.87	14.4	118.3
	86.7	23.8		30.98	3.5	89.0
	0	63.6	1.0	37.02	21.8	156.5
	27.7	27.9	2.8	34.19	14.4	107.8
	93.3	21.3	3.9	28.69	8.4	89.1
	*	*	*	*	*	*
	*	*	*	*	*	*
	0.0	65.4	1.0	39.82	27.5	153.7
	0.0	45.3	1.9	38.22	22.8	120.9
	24.3	31.5	2.5	34.16	15.1	110.8
	70.0	25.9		30.58	11.2	97.8
	*	*	*	*	*	*
	0	63.0	1.0	38.74	25.3	155.0
	0	42.4	1.9	35.43	21.9	122.5
	16.7	30.5	2.9	34.09	16.3	106.2
	50.0	25.7	3.5	32.62	13.7	88.7
	90.0	21.8	3.6	32.54	13.8	85.2