EFFECTS OF DROP HEIGHTS AND FRUIT HARVESTING METHODS ON THE QUALITY OF 'HASS' AVOCADOS

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ABSTRACT

Mechanical damage to fruit is a major source of postharvest losses in many fruit including avocado. Although avocado fruit are harvested when green and hard, bruising can be a major cause of quality loss at the retailer. A study was conducted to determine the cumulative effects of handling at harvest on fruit quality after storage. A second study was carried out to characterise the relationship between drop height and fruit quality of freshly harvested fruit. Harvesting avocado fruit with an elevated work platform and passing the fruit across a commercial grader increased ripe rots after storage. Dropping freshly harvested avocado fruit from as little as 0.1m may increase the area of external bruising. This bruising may act as an infection pathway, increasing the incidence of brown patches. However, dropping from a height of up to 0.3m will lead to only minor increases in ripe rots. Empting avocado fruit from harvesting bags on elevated work platform into field bins may pose the greatest risk of exceeding the 0.3m drop height, so care is recommended to minimise the drop height when empting bags from elevated work platforms into field bins. The New Zealand class 1 export grade standard for bruising is 250mm^2 for the 2007/08 season. An otherwise unblemished fruit would exceed the grade standard if it received an impact equivalent to a drop of 0.276m. This fruit could also be expected to have a greater severity of brown patches. For best practice, fruit should be handled as carefully as possible and drop heights kept to a minimum, ideally less than 0.3m.

Keywords: *mechanical damage, handling damage, prochloraz*

INTRODUCTION

As a general rule, maximum fruit quality is determined at harvest (Hofman *et al.*, 2002). Post harvest handling can at best maintain fruit quality but cannot improve fruit quality. Mechanical damage to fruit is a major source of postharvest losses in many fruit (Kays and Paull, 2004) including avocados. Although avocado fruit are harvested when green and hard, bruising can be a major cause of quality loss at the retailer (Hofman *et al.*, 2002). Bruising can occur at any point from harvesting through to sale and can only be minimised with careful handling. The amount of bruising damage that occurs on a fruit depends on the ripeness of the fruit, the distance the fruit is dropped and the mass of an object hitting the fruit (Arpaia *et al.*, 1987). Hard green fruit when bruised can be damaged both internally and externally depending on the force of the impact. The mechanical damage to the skin caused by bruising can serve as an entry point for postharvest rots (Everett *et al.*, 2001) especially after rain (Pak *et al.*, 2003) and in most fruit the wound site serves as an ethylene source promoting premature ripening (Kays and Paull, 2004). Although it is recommended that New Zealand avocado fruit be handled gently it is not known how far the fruit can be dropped after harvest before damage occurs. It is also not well understood how the handling of the fruit at harvest and in the packhouse may be damaging the fruit leading to an increased expression of ripe rots. A study was conducted to determine the cumulative effects of handling at harvest on fruit quality after storage. A second study was carried out to characterise the relationship between drop height and fruit quality of freshly harvested fruit.

MATERIALS AND METHODS

1. Harvest method

Five hundred 'Hass' avocado fruit were harvested from one orchard in the Western Bay of Plenty, New Zealand (37°S, 176°E) on the 16th February 2004 and handled as described below:

Control: Fruit were carefully harvested by hand directly into single layer trays lined with cardboard fruit plixes.

Prochlroraz only treatment: Fruit were carefully harvested by hand then the fruit were stored in trays for 20hrs at 5°C ± 1°C fruit before being placed by hand onto conveyor directly before the inline sprayer. Fruit were sprayed to run off with prochloraz at label rate of 55ml per 100l and removed directly after the inline sprayer. The fruit were air dried at ambient and placed into single layer trays lined with cardboard fruit plixes.

Elevated work platform treatment: Fruit were harvested by a commercial operator using an elevated work platform (Hydralada®, Hastings, New Zealand), into a picking bag attached to the cage and carefully emptying the picking bag into a half full field bin. Fruit were stored in the field bin for 20hrs at 5°C ± 1°C before being placed into trays.

Elevated work platform and grading line treatment: Fruit were harvested as for the elevated work platform treatment but after 20hrs storage at 5°C ± 1°C the fruit were passed over a commercial grading system including dumping from the field bin onto the grading line. The fruit were not graded. Fruit were packed into single layer trays.

Elevated work platform, grading line and prochloraz treatment: Fruit were harvested as for elevated work platform and grading line treatment above, but fruit were sprayed to run off with 55ml per 100l of prochloraz with a commercial inline sprayer integrated into the grader line before being air dried at ambient. Fruit were not graded. Fruit were packed into single layer trays.

The fruit were stored for 28 days after treatment at 5°C ± 1°C, 85% ± 5% relative humidity (RH). After removal from storage all fruit was weighed and assessed for disorders according to the Avocado Industry Council Fruit Assessment Manual (Dixon, 2003). The fruit were ripened at 20°C ± 1°C, 60% ± 5% RH. The fruit were assessed daily for firmness by hand squeeze, equivalent to a firmness reading of at least 85 using a firmometer with a 300g weight. Disorders were rated by assessing the percentage of the skin surface or cut surface area affected by disorders.

2. Physical impacts

There were two experiments where in Experiment A fruit were dropped from 0 to 1.0m and stored for 14 or 28 days. In Experiment B fruit were dropped from 0 to 0.3m with delays prior to dropping of 2, 12 or 24 hours and storage after dropping totalling 28 days.

Experiment A

Three hundred 'Hass' avocado fruit were carefully harvested from one orchard in the Western Bay of Plenty on 1/3/2003. Ungraded fruit were dropped within 2 hours of harvest from 0, 0.1, 0.25, 0.5, 1.0m onto a smooth, hard surface. Fruit were stored for 28 days at 5°C ± 1°C. After removal from storage, fruit were ripened at 20°C ± 1°C, 60% ± 5% RH. Fruit were assessed for external and internal disorders according to the Avocado Industry Council Fruit Assessment Manual (Dixon, 2003) as described above. External bruise area was calculated by measuring the length of bruise and the widest point perpendicular to this measurement and calculated as if the bruise was a perfect ellipse shape using the formula: π x length x width. Each treatment was replicated with 3 trays of 20 fruit each.

Experiment B

One thousand and three hundred 'Hass' avocado fruit were carefully harvested from one orchard in the Western Bay of Plenty on 1/10/2003. Ungraded fruit were dropped within 2 hours of harvest or after 24 or 48 hours storage at 5°C ± 1°C. The fruit dropped after storage were cold when dropped. Fruit were dropped from 0, 0.025, 0.05, 0.1, 0.3m onto a smooth, hard surface. There was no 0m drop height after 24 or 48 hours storage. Fruit were stored for a total of 28 days at 5°C ± 1°C, 85% ± 5% RH. Fruit were ripened and assessed for external and internal disorders according to the Avocado Industry Council Fruit Assessment Manual (Dixon, 2003) as described above. External bruise area was calculated by measuring the length of bruise and the widest point perpendicular to this measurement and calculated as if the bruise was a perfect oval shape. Each treatment was replicated with 5 trays of 20 fruit each.

Results for all experiments were analysed by One-Way ANOVA using MINITAB version 13.31.

RESULTS

Harvest method

Picking with an elevated work platform increased the incidence of unsound fruit (at a 5% threshold) from 0% to11% compared to careful handling into trays. When picked with an elevated work platform and passed over a grading line, the incidence of unsound fruit increased to 15%, but this was reduced to 6% with the inline application of prochloraz (Table 1). Both stem end rot and brown patches followed a pattern of increasing incidence and severity of disorder with increasing handling. Applying prochloraz to fruit harvested with an elevated work platform and passed over a grading line reduced the severity of brown patches by about half (Table 1). The incidence of both stem end rot and brown patches tended to be reduced with application of prochloraz despite being increased by harvesting with an elevated work platform and passing over the grader. The incidence and severity of green fruit disorders was very low, but also followed the trend for increasing incidence and severity of disorder with increasing handling (data not shown).

Physical impacts

Experiment A

The incidence and severity of stem end rot was similar with increasing drop heights (Table 2). The incidence of brown patches increased from 46% to 70% and body rot severity more than doubled when fruit were dropped from a height of 0.1m

Table 1. Effect of harvest method and post harvest prochloraz application on incidence and severity of peel damage, stem end rot and brown patches and the incidence of unsound fruit.

Treatment	Peel Damage		Stem End Rot		Brown Patches		Unsound fruit[1]
	Sev[2] (%)	Inc %[3] (%)	Sev (%)	Inc (%)	Sev (%)	Inc (%)	Inc (%)
Control	0.07 a[4]	7.0	0.04 a	4.0 a	0.23 a	13.0 a	0.0 a
Prochloraz	0.12 a	15.0	0.05 a	4.0 a	0.31 a	11.0 a	2.0 ab
Elevated work platform	0.25 ab	22.0	0.40 ab	19.0 b	2.23 b	64.0 b	11.0 bc
Elevated work platform and grading line	0.47 ab	33.0	0.57 b	16.0 ab	2.22 b	53.0 b	15.0 c
Elevated work platform, grading line and prochloraz	0.54 b	40.0	0.29 ab	10.0 ab	1.09 a	47.0 b	6 abc

[1]Unsound fruit calculated using a disorder threshold at 5%, [2]Severity, [3]Incidence, [4]Means within a column followed by the same letter are not significantly different according to a One-Way analysis of variance using a Tukey's family error rate of 5%.

compared to undropped fruit. The incidence and severity of brown patches was similar for fruit dropped from 0.1, 0.25 and 0.5 meters. The incidence of brown patches increased to 95%, and severity to 5.8% when fruit were dropped from 1.0m. The percentage of unsound fruit tended to increase as drop height increased and was significaly greater at 1.0m than 0.5m and below drop heights.

The relationship between drop height and external bruise area was fitted with a Michaelis-Menton equation (Figure 1). External bruise area increased from a mean area of 105mm^2 when dropped from 0.1m to 429mm^2 when dropped from 1.0m (Figure 2).

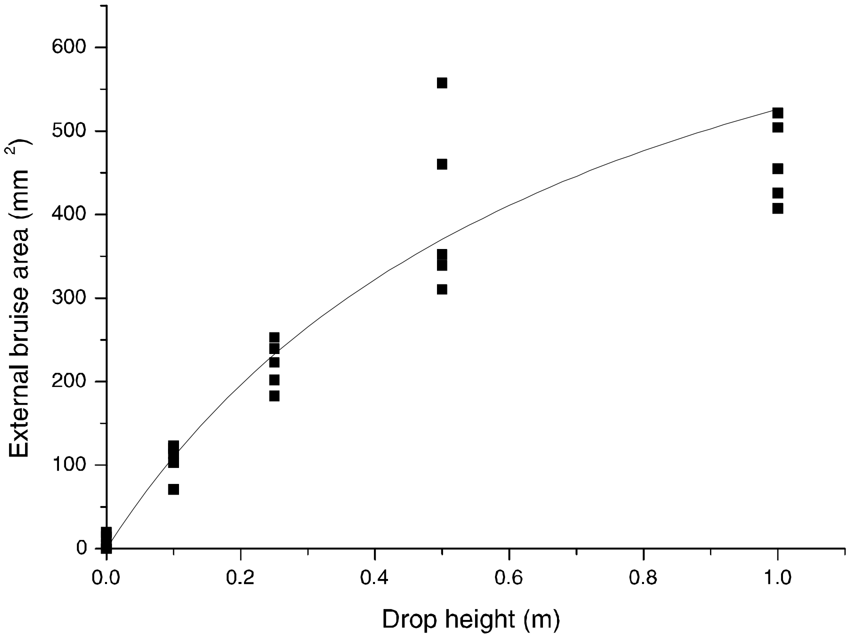

Figure 1. Relationship between external bruise area and drop height, after one week of storage at 5°C ± 1°C. Line fitted by Michaelis-Menton equation. Adjusted r^2 = 0.96, $p < 0.001$

Experiment B

In general the expression of ripe rots was similar to experiment A, with little difference in severity of ripe rots between fruit dropped from 0.1m to 0.3m. The exception being the severity of brown patches on fruit dropped after a 24 hour delay at 5°C ± 1°C (Table 3). Ripe fruit rots were similar between fruit that were not dropped and fruit that were dropped from 0.1m. Delaying drop treatments by storing fruit at 5°C ± 1°C had no effect on ripe rots. Fruit that were stored for 24 or 48 hours were cold when dropped, however this had no effect on ripe fruit quality. Drop height did not affect the incidence or severity of stem end rots (data not shown).

Table 2. Effect of drop heights on external bruise area, incidence and severity of stem end rot and brown patches and the incidence of unsound fruit.

Drop height (m) (%)	External bruise area (mm^2)	Incidence of stem end rot (%)	Severity of stem end rot (%)	Incidence of brown patches (%)	Severity of brown patches (%)	Incidence of unsound fruit[1] (%)
0	11 a[2]	15.0	0.19	46.0 a	1.3 a	8.3 a
0.1	106 a	23.0	0.40	70.0 b	3.5 ab	16.7 a
0.25	220 b	16.0	0.16	66.0 b	3.9 ab	18.3 a
0.5	361 c	10.0	0.18	71.0 b	3.5 ab	21.7 a
1.0	462 c	21.0	0.71	95.0 c	5.8 b	46.7 b

[1]Unsound fruit calculated using a disorder threshold at 5%. [2]Means within a column followed by the same letter are not significantly different according to a One-Way analysis of variance using a Tukey's family error rate of 5%.

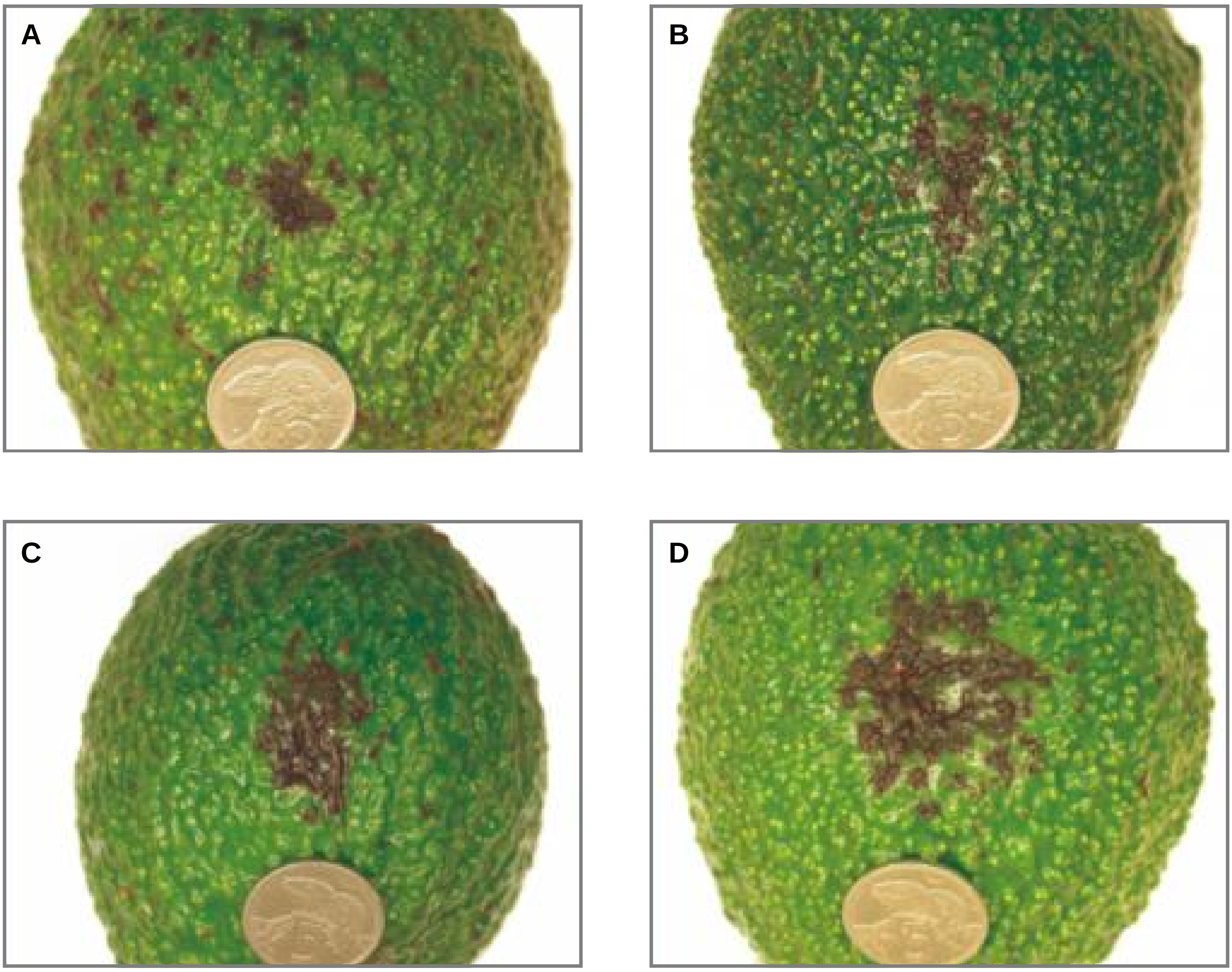

Figure 2. Typical bruise area on green fruit after 1 week storage at 5°C ± 1°C. Values in parenthesis are mean bruise areas for each treatment ± standard error of the mean.

- **A.** 0.10 meters (106 ± 9 mm^2)
- **B.** 0.25 meters (220 ± 11 mm^2)
- **C.** 0.50 meters (361 ± 13 mm^2)
- **D.** 1.00 meters (462 ± 14 mm^2)

DISCUSSION

The more the fruit are handled after harvest the greater the increase in ripe fruit rots after storage. The effect of handling was cumulative, where fruit harvested using an elevated work platform and commercial grader lines combined had a greater negative impact on fruit quality compared to fruit harvested carefully into trays. Post harvest application of prochloraz could partially mitigate the increase in ripe rots. This trend for prochloraz to reduce the severity of stem end rots confirmed previous findings (Le Roux *et al.,* 1985). The increase in ripe fruit rots with increasing handling is most likely to be due to physical damage of the fruit surface, allowing latent fungal infections to develop more readily and to provide a wound site for fungal spores to infect the fruit.

Freshly harvested avocado fruit dropped from as little as 0.1m can cause an increase in external bruising. This small amount of bruising may act as an infection pathway for fungal spores on the fruit and lead to an increase in the incidence of brown

Table 3. Effect of drop height and delay prior to drop treatment on incidence and severity of brown patches and the incidence of unsound fruit.

	No Delay	24 hour delay	48 hour delay	Mean
Severity of brown patches (%)				
0	0.7			
0.025	1.4	0.7 a[1]	0.8	1.0
0.05	1.3	0.7 a	0.7	0.9
0.1	1.0	0.8 a	0.9	0.9
0.3	0.8	2.2 b	1.7	1.6
Incidence of brown patches (%)				
0	27			
0.025	40	26	38	35
0.05	30	28	32	30
0.1	27	30	31	29
0.3	21	49	42	37
Incidence of unsound fruit at a 5% threshold (%)				
0	11			
0.025	13	17	7	12
0.05	6	11	12	10
0.1	13	12	15	13
0.3	6	24	21	17

[1]*Means within a column followed by the same letter are not significantly different according to a One-Way analysis of variance using a Tukey's family error rate of 5%.*

patches (Everett, 2001). However, dropping fruit from a height of up to 0.3m only leads to a small increase in ripe rots. Our observations are that most fruit packing systems used in New Zealand currently have drop heights less than 0.3m. Empting avocado fruit from harvesting bags on elevated work platform into field bins may pose the greatest risk of exceeding the 0.3m drop height, so care is recommended to minimise the drop height when empting bags from elevated work platforms into field bins.

Stem end rots were less affected by bruising fruit on their sides, as the main infection pathway is through the cut stem (Everett, 2002). The incidence and severity of stem end rot was increased when the fruit were harvested with an elevated work platform and passed over a grading line. This could possibly be due to physical damage to the stem end or fruit surface adjacent to the stem end. Increased handling may also spread fungal spores on to the cut stem end, allowing for stem end infection.

There was a marked variation in susceptibility to rots from physical impacts between fruit drop experiments A and B. The variation in susceptibility to rots from physical impacts may be due to pre-harvest conditions including fruit maturity, water status and rot inoculum level in the orchard. The fruit maturity is likely to have differed between the fruit used in the two physical impacts experiments. Fruit in experiment A was harvested on 1/03/2003, late in the New Zealand season. These fruit could be expected to have more ripe rots than fruit in experiment B, harvested on 1/10/03 (Dixon *et al.*, 2004), accounting for some of the variation in fruit quality between experiments.

The New Zealand class 1 export grade standard for bruising is 250mm^2 for the 2007/08 season (AIC, 2007). An otherwise unblemished fruit would exceed the grade standard if it received an impact equivalent to a drop of 0.276m. This fruit could also be expected to have a greater severity of brown patches. The current grade standard for bruising is reasonable with respect to minimising handling damage effects on fruit quality.

CONCLUSIONS

Harvesting avocado fruit with elevated work platform and commercial grader lines both have a significant negative effect on fruit quality. Dropping green avocado fruit from as little as 0.1m can increase the area of external bruising. This bruising may act as an infection pathway, increasing the incidence of brown patches. However, dropping from a height less than 0.3m is likely lead to only minor decreases if fruit quality. For best practice, fruit should be handled as carefully as possible and drop heights kept to a minimum, ideally less than 0.3m.

REFERENCES

Arpaia, M.L., Mitchell, F.G., Katz, P.M. and Mayer, G. (1987). Susceptibility of avocado fruit to mechanical damage as influenced by variety, maturity and stage of ripeness. *South African Avocado Growers' Association Yearbook* **10**: 149-151.

Avocado Industry Council (2007). *Quality Manual 2007/2008*. Avocado Industry Council Ltd.

Dixon, J. (2003). *Avocado Assessment Manual 2003.* Version 3.0 Avocado Industry Council Ltd.

Dixon, J., Smith, D.B. and Elmsly, T.A (2004). Fruit age, storage temperature and maturity effects on Hass avocado fruit quality and ripening. *New Zealand Avocado Growers' Association Annual Research Report* **4**: 47-53.

Everett, K.R. (2001). Stem-end rots:infection of ripening fruit. *New Zealand Avocado Growers' Association Annual Research Report* **1**: 44-46.

Everett, K.R., Hallett, I., Yeasley, C., Lallu, N., Rees-George, J. and Pak, H.A. (2001). Morphological changes in lenticel structure resulting from imbibition and susceptibility to handling damage. *New Zealand Avocado Growers' Association Annual Research Report* **1**: 47-53.

Everett, K.R., Rees-George J., Parkes, S.L. and Johnson, P.R (2003). Predicting avocado fruit rots by quantifying inoculum potential in the orchard before harvest. *New Zealand Avocado Growers' Association Annual Research Report* **3**: 93-98.

Hofman, P.J., Fuchs, Y. and Milne, D.L. (2002). Harvesting, packing, postharvest technology, transport and processing. In: *The avocado: Botany, Production and Uses*. (Eds: A.W. Whiley, Bschaffer and B.N. Wolstenholme). CABI Publishing, Oxon, UK.

Kays, S.J. and Paull, R.E. (2004). *Postharvest biology*. Exon press, Athens, GA, USA.

Le Roux, A.W.G., Wentzel, R.C. and Roose, C. (1985). Efficacy of prochloraz treatments for post harvest disease control in avocados. *South African Growers' Association Yearbook* **8**: 44-45

Pak, H.A., Dixon, J. and Cutting, J.G.M. (2003). Impact of rainfall prior to harvest on ripe fruit quality of 'Hass' avocados in New Zealand. *New Zealand Avocado Growers' Association Annual Research Report* **3**: 22-31.

ACKNOWLEDGEMENTS

Thanks to New Zealand Kiwifruit Ltd, Katikati, for their assistance with handling, treating and storing fruit for all three trials.

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