Reduction of harvest losses in mango (*Mangifera indica* L.) fruit using improved harvesting methods

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ABSTRACT

An experiment was conducted in a private orchard, located along the Blue Nile bank at Hantoub, Gezira State during the seasons of 2007 and 2008, to investigate the effect of improved harvesting methods on reducing physical injury during harvesting of mango fruits of selected cultivars viz. Kitchener (Baladi), Alphonso, Timour, Abu Samaka and Gulbeltour. The experimental design was a split plot with three replications. Cultivars were assigned to the main plots and harvesting methods to the subplots. The harvesting methods consisted of a ladder, a modified picking pole (MPP), a straw mattress (SM) and the traditional picking pole (control). The ladder harvesting method resulted in the lowest percentage (4.4%) of physical injury followed by the modified picking pole (16.0%) and the straw mattress (29.5%), while the traditional picking pole resulted in the highest percentage (53.1%) of physical injury. The cultivar Gulbeltour and Abu Samaka showed the highest percentage of physical injury, while Timour showed the lowest. Both the ladder and the modified picking pole harvesting methods took the longest time (44 minutes) to harvest one hundred mango fruits followed by the straw mattress (19 minutes) and then the traditional method (10 minutes). The cultivars Alphonse, Kitchener and Timour required less time to harvest one hundred fruits, while Gulbeltour and Abu Samaka required more time.

INTRODUCTION

Mangoes are the leading Sudanese horticultural exports and constitute more than 50% of the total horticultural exports, with annual returns of more than five million dollars. The most important markets for Sudanese mangoes include Saudi Arabia, the other Gulf States and Western Europe (Elkashif *et al.*, 2003).

Although mangoes are successfully grown in many parts of the Sudan, yet the quality of mango fruits, whether exported or locally marketed, is very poor. This is mainly due to postharvest losses caused by physical injury, rotting and rapid deterioration in quality. Physical injuries, such as wounding, scratching and bruising are mainly caused by improper harvesting methods.

The traditional method used for harvesting mango fruits is by snapping the fruit by a hook attached to a long pole. Although this harvesting method is quick and easy, yet, it causes great losses of the crop. The hook causes injury to the shoulder of the fruits, and the drop of the fruit to the ground causes bruises and injuries to the fruit, making them unattractive, with a shorter shelf-life (Abu-Goukh and Mohamed, 2004). If the skin is broken, the mango fruit is very susceptible to decay and rot caused by micro-organisms (Barmore and Mitchell, 1975; Batagurki *et al.*, 1995). Hence, there is an urgent need to improve the harvest operation in order to reduce these harvesting losses. Therefore, the objective of this research was to reduce harvesting losses and improve postharvest quality of mango fruit using improved harvesting methods.

MATERIALS AND METHODS

An experiment was conducted in a private orchard along the Blue Nile bank at Hantoub area, Gezira State during the seasons 2007 and 2008. Cultivars used in this study were Kitchener, Alphonse, Timour, Abu Samaka and Gulbeltour. Three hundred fruits, from each cultivar, were harvested at the mature-green stage. Only the physical injury which occurred during mango harvesting was considered in this study.

Four methods were used for harvesting the mango fruits:

(i) The traditional method: A picking pole, 3-4 m long with a hooked wire attached to its end, locally called "Jabbada", was used to pick mango fruits (control).

(ii) Modified picking pole (MPP): The same picking pole mentioned in (i), but with a cutter blade and a cloth bag attached to a metal ring to receive fruits after they were picked.

(iii) Straw mattress (SM): Fruits were harvested as in (i) and were allowed to fall on jute sacks (1-1½ m) filled up with mango leaves, to make a pad 10 cm thick and was stretched under the tree to reduce physical injury to the fruits.

(vi) Ladder: A ladder of about three to four meters long with a support pole is used to reach the mango fruits and harvest them by hand.

Three trees from each cultivar were used. The experimental design was a split-plot design with three replications. The cultivars were assigned to the main plots and the harvesting methods to the sub-plots.

Physical injury was rated according to the following:

(i) Sound fruits: If no damage appears at all on fruits, even after seven days in storage at room temperature, then these fruits are considered sound fruits.

(ii) Latent injury: If injury appears on fruits surface in the form of brown areas or spongy tissue after 7 days in storage, then this is called latent injury, because it did not appear at the time of harvest.
(iii) Mild injury: Few scratches on the surface of fruits at harvest.
(iv) Medium injury: More elaborate scratches and blemishes on the surface of fruits at harvest.
(v) Severe injury: The appearance of significant wounds or cracks on the surface of fruits at harvest.

Physical injury (%) in each category was calculated as percentage of total number of fruits harvested by each method.

The time required to harvest one hundred mango fruits by each harvesting method in each cultivar was determined.

Statistical analysis

Analysis of variance procedure followed by Duncan's Multiple Range Test (DMRT) were performed on the data.

RESULTS AND DISCUSSION

Results presented in Table1 showed highly significant effects of harvest-ing methods on all types of physical injury in both seasons. The least percentage of physical injury was obtained when using the ladder as a harvesting method, followed by the modified picking pole and the straw mattress. The traditional picking pole resulted in the highest physical injury. The ladder harvesting method resulted in the lowest physical injury because the picker reached the fruit, picked it up and put it in his basket, hence, the fruit was not subjected to falling impact on the ground and, therefore, was not liable to any kind of physical injury. The modified picking pole was provided with a cutter blade and a cloth bag which resulted in significantly low percentages of physical injury as compared to the straw mattress, because the fruits were collected in the bag and were not allowed to fall down on the ground.

Table1. Main effects of harvesting methods on types of physical injury of mango fruits.

Harvesting methods	Types of physical injury (%)				Total injured fruits (%)	Total sound fruits (%)
	Latent	Mild	Medium	Severe		
			Season 2007			
Ladder	4.40c	0.00 c	0.00 d	0.00 d	4.40 d	95.60 a
MPP	9.47 b	2.40 b	1.07 c	3.07 c	16.01 c	83.99 b
SM	11.87 a	8.07 a	5.80 b	3.73 b	29.47 b	70.53 c
Control	11.87 a	8.73 a	11.07 a	21.67 a	53.34 a	46.66 d
Sig. level	***	***	***	***	***	***
C.V. (%)	29.78	24.52	16.58	22.69	14.94	6.71
			Season 2008			
Ladder	5.07 d	0.00 c	0.00 d	0.00 d	5.07 d	94.93 a
MPP	8.47 c	4.00 b	3.20 c	0.87 c	16.54 c	83.46 b
SM	11.67 b	10.00 a	7.80 b	4.13 b	33.60 b	66.40 c
Control	15.60 a	9.00 a	11.00 a	17.47 a	53.07 a	46.93 d
Sig. level	***	***	***	***	***	***
C.V. (%)	28.78	17.09	16.17	20.83	6.31	6.11

*** Indicate significance at 0.1% probability level.

MPP and SM indicate modified picking pole and straw mattress, respectively.

Means in the same column having different letters are significantly different according to DMRT.

These results indicated that the ladder and modified picking pole methods of harvest are more appropriate for mango fruits intended for export and the local market because they resulted in the highest percentages of sound fruits. In the straw mattress harvesting method, the fruits were picked using the traditional picking pole, but the fruits were allowed to fall on a straw mattress which made a cushion to the fruits and hence resulted in significa-ntly lower percentages of physical injury as compared to the control, where the fruits fell directly on the ground. These results are in agreement with those reported by Abu Goukh and Mohamed (2004), who showed that improved mango harvesting methods resulted in a significant reduction in the percentage of unmarketable fruits and improved the quality of fruits. They also reported that fruits harvested using the improved method reached the ripe stage three days later than those harvested using the traditional method. By using the traditional method of harvesting mango fruits, physical injury is increased because the fruit hit the branches while they were falling down and at last they dropped on the hard ground, which caused bruises and injuries to fruits making them unattractive with a shorter shelf life. Elshiekh and Abu-Goukh (2008) reported that improved harvesting methods of grapefruits significantly decreased respiration rate and water loss, delayed total soluble solids accumulation, reduced titratable acidity, improved fruit quality, reduced postharvest losses and extended shelf-life during storage.

This was also confirmed by Johnson *et al.* (1993) who reported that the use of the traditional picking pole and the subsequent fall of fruit on the ground resulted in considerable damage and led to the appearance of soft, darkened areas and bruises on the fruits. Also, Sargent and Sidahmed (1987) showed that mechanical damage speeded up the rate of water loss, provided sites of entry for decay micro-organisms such as fungi and bacteria which caused rotting of fruits, increased the rate of heat production at injury sites and caused the development of off-flavours. Similar reports (FAO, 1983) showed that mechanical injury increased the rates of respiration and ethylene production which led to quick deterioration of fruits. This was in agreement with Santos *et al.* (2004) who reported that ethylene production in mango was anticipated when fruits were dropped instead of being carefully picked. Fruits harvested by the traditional method were less firm at the end of storage than fruits harvested by the ladder and modified picking pole. This effect was also reported by Abu Goukh and Mohamed (2004) who found that a rapid decrease in flesh firmness during ripening was observed on fruits harvested by the traditional picking pole. Cutting fruits with a piece of pedicel attached to the fruit, as done by improved methods (ladder and modified picking pole), prevented the oozing of sap from fruits to flow on the surface of other fruits and hence stain them. Similarly, Bagshaw and Brown (1989) showed that the sap had a low pH and high oil content and it stained the surface of fruits and caused sap-burn damage which was estimated by Holmes *et al.* (1993) to be 9-16% of fruits.

Table 2 showed significant effect of cultivar on all types of physical injury in both seasons. The cultivar Gulbeltour showed the highest percentage of all types of physical injury in both seasons, followed by Abu Samaka. This was because these two cultivars had large-sized fruits as compared to the other cultivars and hence resulted in higher percentages of physical injury due to their heavy weight. This is in line with the findings of Abu-Goukh and Mohamed (2004) who reported that physical injury was more in 'Abu-Samaka' (420 g fruits) than in 'Dr.Knight' (230 g fruits). The small-sized fruits of the cultivars Alphonse, Kitchener and Timour showed the lowest percentages of physical injury because of their light weight. Needless to say that small-sized light fruits are not subject to physical injury when

they hit the ground to the same extent as large-sized heavy fruits. These results were supported by the results Wills *et al.* (1996) who found that there was a direct relationship between physical injury and fruit size.

Table 2. Main effects of cultivar on types of physical injury of mango fruits.

Cultivar	Types of physical injury (%)				Total injured fruits (%)	Total sound fruits (%)
	Latent	Mild	Medium	Severe		
			Season 2007			
Kitchener	8.17 cd	3.92 c	2.58 d	7.58 b	22.25 d	77.75 a
Alphonse	8.75 c	4.67 b	4.58 b	6.00 c	24.00 bc	76.00 b
Timour	7.67 d	3.67 c	5.17 b	4.50 d	21.01 d	78.99 a
Abu Samaka	10.67 a	5.58 a	4.00 c	8.92 a	29.17 b	70.83 c
Gulbeltour	11.75 a	6.17 a	6.08 a	8.58 a	32.58 a	67.42 d
Sig. level	*	***	**	*	***	*
C.V. (%)	29.78	27.60	16.58	22.69	14.94	6.17
			Season 2008			
Kitchener	10.25 a	3.67 d	3.42 c	7.25 a	24.59 d	75.41 b
Alphonse	10.50 a	5.92 b	5.42 b	5.50 b	27.34 c	72.66 c
Timour	8.83 b	4.50 c	4.92 b	4.50 c	22.75 e	77.25 a
Abu Samaka	10.75 a	7.50 a	6.75 a	5.17 b	28.17 b	71.83 c
Gulbeltour	10.67 a	8.00 a	7.00 a	5.67 b	31.34 a	68.66 d
Sig.level	*	***	**	*	***	*
C.V. (%)	28.78	17.09	16.17	20.83	6.13	5.95

*,** and *** indicate significance at 5%, 1% and 0.1% probability levels, respectively.
Means in the same column having different letters are significantly different according to DMRT.

Tables 3 and 4 showed significant interaction effects of cultivar and harvesting methods on all types of physical injury in both seasons. The ladder and modified picking pole harvesting methods resulted in the lowest percentages of injured fruits and highest percentages of sound fruits in all cultivars.

Table 3. Interaction effect of cultivar and harvesting methods on types of physical injury of mango fruits (season 2007).

Cultivar	Harvest method	Types of physical injury (%)				Total injured fruits (%)	Total sound fruits (%)
		Latent	Mild	Medium	Severe		
Kitchener	Ladder	3.3 g	0.0 f	0.0 f	0.0 i	3.3 l	96.7 a
	MPP	6.7 f	2.0 ef	0.0 f	1.7 hi	10.4 ij	89.6 c
	SM	9.3 bc	6.7 b	4.3 de	2.7 gh	23.0 f	77.0 g
	Control	13.3 b	7.0 b	6.0 cd	26.6 b	52.3 d	47.7 i
Alphonse	Ladder	4.0 g	0.0 f	0.0 f	0.0 i	4.0 l	96.0 a
	MPP	8.3 ef	0.7 ef	0.0 f	3.0 g	12.0 j	88.0 d
	SM	11.0 cd	7.0 b	4.0 e	4.3 gh	26.3 g	73.7 f
	Control	11.7 cd	11.0 a	14.3 a	16.7 d	53.7 c	46.3 j
Timour	Ladder	3.7 g	0.0 f	0.0 f	0.0 i	3.7 l	96.3 a
	MPP	6.7 e	3.0 cd	3.7 e	1.7 hi	15.1 j	84.9 d
	SM	7.7 cd	4.3 c	4.0 e	2.3 gh	18.3 f	81.7 g
	Control	12.7 bc	7.3 b	13.0 a	14.0 e	47.0 d	53.0 i
Abu Sama	Ladder	4.0 g	0.0 f	0.0 f	0.0 i	4.0 l	96.0 a
	MPP	11.0 bc	2.7 cde	0.7 f	3.3 gh	17.7 h	82.3 e
	SM	13.0 b	7.7 a	6.7 c	3.7 gh	31.1 e	68.9 b
	Control	14.7 a	12.0 b	8.7 b	28.7 a	64.1 b	35.9 k
Gulbeltour	Ladder	7.0 f	0.0 f	0.0 f	0.0 i	7.0 k	93.0 h
	MPP	12.7 bc	3.7 cd	0.7 f	4.3 g	21.4 h	78.6 c
	SM	12.7 bc	10.3 a	10.3 b	7.0 f	40.3 e	59.7 h
	Control	14.7 a	10.7 a	13.3 a	23.0 c	61.7 a	38.3 l
Sig. level		*	*	***	***	***	***
C.V (%)		29.78	27.6	16.58	22.67	11.79	6.11

* and *** indicate significance at 5% and 0.1% probability levels, respectively.
MPP and SM indicate modified picking pole and straw mattress, respectively.
Means in the same column having different letters are significantly different according to DMRT.

Table 5 showed highly significant effects of harvesting methods on the time required to harvest one hundred mango fruits in both seasons. The longest duration of time required to harvest one hundred fruits was obtained when using the ladder method, followed by the modified picking pole and the straw mattress, and the shortest time was obtained with the traditional method (control). This was because the movement of the ladder from one side of the tree to another, the adjustment of fruits to fall in the bag of modified picking pole and the subsequent movement of the straw mattress around the tree, all these activities need time as compared to the control. However, in the traditional method, the pickers used their traditional picking poles fast and the fruits dropped to the ground, thus taking the minimum period of time for harvesting mangoes as compared to the improved methods.

Table 4. Interaction effect of cultivars and harvesting methods on types of physical injury of mango fruits (season 2008).

Cultivar	Harvest method	Total of physical injury (%)				Total injured fruits (%)	Total sound fruits (%)
		Latent	Mild	Medium	Severe		
Kitchener	Ladder	3.3 i	0.0 j	0.0 j	0.0 h	3.3 h	96.7 a
	MPP	8.0 efg	2.3 i	3.7 hi	1.3 gh	13.3 l	86.7 c
	SM	13.7 bc	6.0 ef	6.7 d	5.0 ef	31.3 h	68.7 g
	Control	16.0 ab	6.3 ef	5.3 def	22.7 a	50.3 d	49.7 k
Alphonse	Ladder	6.0 gh	0.0 j	0.0 j	0.0 h	6.0 m	96.0 b
	MPP	7.0 fgh	4.3 fghi	3.3 fgh	0.3 h	15.3 k	84.7 d
	SM	13.0 c	8.7 d	6.3 de	4.3 ef	34.3 g	65.7 h
	Control	16.0 ab	10.7 e	12.0 b	17.0 d	53.7 c	46.3 L
Timour	Ladder	5.3 hi	0.0 j	0.0 j	0.0 h	5.3 m	94.7 b
	MPP	6.7 fgh	4.0 ghi	3.7 fgh	1.0 gh	15.3 k	84.7 d
	SM	9.3 de	6.0 efg	3.7 fgh	2.0 gh	21.0 i	79.0 f
	Control	14.0 bc	8.0 de	12.3 b	15.0 d	49.3 d	50.7 k
Abu-Samaka	Ladder	5.3 hi	0.0 j	0.0 j	0.0 h	5.3 m	94.7 b
	MPP	8.7 d	3.7 hi	2.7 gh	1.0 gh	16.0 j	84.0 e
	SM	10.7 ef	13.7 ab	12.0 b	3.0 fg	41.7 f	58.3 i
	Control	18.0 a	14.7 a	13.3 b	18.7 c	62.3 b	37.7 m
Gulbetour	Ladder	5.3 hi	0.0 j	0.0 j	0.0 h	5.3 m	94.7 b
	MPP	10.0 de	5.7 fg	4.7 efg	0.3 h	20.7 i	79.3 f
	SM	13.0 c	11.7 bc	9.0 c	6.3 e	41.0 e	59.0 j
	Control	14.0 bc	12.7 abc	13.3 b	14.0 b	53.0 a	47.0 n
Sig. level		*	*	***	***	***	***
CV.%		28.78	17.09	16.17	20.83	6.31	6.17

* and *** indicate significance at 5% and 0.1% probability levels, respectively.

MPP and SM indicate modified picking pole and straw mattress, respectively.

Means in the same column having different letters are significantly different according to DMRT.

Table 5. Main effect of harvesting methods on time required to harvest 100 mango fruits (season 2007 and 2008).

Harvest method	Time required to harvest one hundred fruits (min.)	
	Season 2007	Season 2008
1. Ladder	45 a	45 a
2. MPP	44 b	44 b
3. SM	19 c	19 c
4. Control	10 d	10 d
Significance level	***	***
C.V. (%)	3.54	3.54

*** Indicate significance at 0.1% probability level.

MPP and SM indicate modified picking pole and straw mattress, respectively.

Means in the same column having different letters are significantly different according to DMRT.

Table 6 showed highly significant effects of cultivar on the time required to harvest one hundred mango fruits in both seasons. Alphonse, Kitchener and Timour cultivars which had small-sized fruits, required less time to harvest one hundred fruits, whereas Gulbeltour and Abu Samaka, which had large-sized fruits required more time to harvest. This was because cultivars with small-sized fruits had more fruits per tree as compared to those cultivars with large-sized fruits. Therefore, it took the pickers less time to harvest small fruits than large ones.

Table 6. Main effect of cultivar on the time required to harvest 100 mango fruits (season 2007 and 2008).

Cultivar	Time required to harvest one hundred fruits (min.)	
	Season 2007	Season 2008
1. Kitchener	27 d	27 d
2. Alphonse	29 c	29 c
3. Timour	25 e	25 e
4. Abu Samaka	31 b	31 b
5. Gulbeltour	36 a	36 a
Significance level	***	***
C.V. (%)	4.33	4.33

*** Indicate significance at 0.1% probability level.

Means in the same column having different letters are significantly different according to DMRT.

It could be concluded from this study that mangoes intended for export may preferably be harvested using the picking pole provided with a bag or ladders in order to reduce harvesting losses and the traditional picking pole is suggested to be avoided.

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تقليل الفاقد في ثمار المانجو باستخدام طرق الحصاد المحسنة

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الخلاصة

أجريت هذه التجربة في مزرعة خاصة للفاكهة على شاطئ النيل الأزرق بحنتوب ، ولاية الجزيرة في موسمي (2007 و2008) بغرض استخدام بعض طرق الحصاد المحسنة لتقليل الأضرار الميكانيكية التي تحدث لثمار المانجو أثناء الحصاد. استخدم في ذلك نظام تصميم القطع المنشقة بثلاثة مكررات، حيث وزعت الأصناف على القطع الرئيسية وطرق الحصاد على القطع المنشقة. استخدمت خمسة أصناف من المانجو وهي (كتشنر، الفونس، تيمور، أبو سمكة وقلب التور). تم حصادها باستخدام طرق الحصاد الآتية: وهي السلم، الجبادة المحسنة ذات الآلة القاطعة وكيس من القماش و فرشة من الخيش مليئة بأوراق المانجو الجافة بالإضافة إلى الطريقة التقليدية (الجبادة). أوضحت النتائج أن السلم أعطى أفضل نتيجة (4.4%) في تقليل نسبة إصابة ثمار المانجو ثم يأتي بعده الجبادة المحسنة (16.0%) وثم الفرشة (29.5%). بينما أعطت الطريقة التقليدية أكبر نسبة إصابة لثمار المانجو (53.1%). الأصناف قلب التور وأبو سمكة أعطت أعلى نسبة إصابة للثمار بينما الصنف تيمور أعطى أقل نسبة إصابة. أما بالنسبة للزمن المستغرق في الحصاد لكل طريقة ، نجد أن الحصاد بالسلم استغرق أطول زمن (45 دقيقة)، تلاه الجبادة المحسنة (44 دقيقة) ثم الفرشة (19 دقيقة) بينما استغرقت الطريقة التقليدية أقل زمن (10 دقائق) في حصاد المائة ثمرة من المانجو. الأصناف الفونس وكتشنر وتيمور استغرقت أقل زمن لحصاد 100 ثمرة بينما استغرقت الأصناف قلب التور وأبو سمكة زمناً أطول لحصاد نفس العدد من الثمار.