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Field Tests of the KSU Date Palm Service Machine

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ABSTRACT. Dates are one of the most important crops in Saudi Arabia. Many of the cultural operations, and particularly harvesting, require the man to climb the tree and work at a considerable height from the ground. This is a dangerous operation further compounded by a severe labour shortage.

The overall size, reach, ground clearance and power required by a machine was decided after a survey carried out in Saudi Arabia in 1985.

A prototype machine has now been manufactured and completed a set of field trials in 1989. It is slower to move and position itself at the tree but the harvesting can be carried out more conveniently and faster than traditional (hand) method. Recommendations stated that the machine can be simplified and made to work more conveniently and faster as well as the need for economic evaluation.

Dates are a major crop in Saudi Arabia. They are high regarded and widely consumed as fresh fruit, as jam and as a sweetner. Dates as a food have a high energy content and contain many of the essential minerals required for a balanced diet. The total crop yield in the country is estimate to be 484,000 tonnes/year with a value of USA $\$300\times10^6$. The gross income to the farmer is approximately \$2,600 per ha/year with a good tree yielding in the order of \$20. About 26,000 tonnes are exported to other countries with a value of approximately $\$8.5\times10^6$, Agricultural Statistical Year Book (1986/1987). There are about 400 different varieties grown in Saudi Arabia, the more common ones being Barhi, Succari, Sellage, Khalas, Rothana, and Nuboot Sief.

The present method of carrying out all the operations on the trees is by the farm labourers climbing up the tree, either freehand or with a belt which is a dangerous task. The operations necessary are dethorning the base of the leaves, pollination, thinning, bagging, pruning, harvesting, insecticide spraying and leaf base trimming. These operations are carried out at different times in the year so a machine would have more or less continuous use.

In 1985 a survey was carried out on a number of date growing area in Saudi Arabia to determine the tree spacing and heights, bunch disposition, ground profiles and soil strength. From this information the specification for a prototype machine was drawn up. Details of the survey can be found in Al-Suhaibani *et al.* (1988).

The objective of this paper is to discuss the field tests of the date palm service machine conducted in 1989 and to analyze harvest, field and machine function efficiencies as well as comparing it with manual harvesting.

Materials and Methods

The date palm tree (*Phoenix dactyliferal* L.) commonly grows 10 to 15 m tall and consists of a slender trunk of more or less consistent diameter from the base to the rings of growing leaves at the crown. Flowers form between the new leaf stems at the top which, when fertilised, form bunches of dates which hang down between the leaves. In Saudi Arabia the trees are irrigated by flood irrigation from small channels supplied from a central borehole on the farm.

The detailed design of the machine was given in Al Suhaibani *et al.* (1990a). But a brief description is given as follows: Fig. 1 shows the machine in the transport position with the basket and stabilisers in the folded up position. Fig. 2 shows the machine in the field position with the stabilisers and basket extended.

The principle dimensions were: overall length 5.5 m, overall width 2.1 m, overall height 2.7 m, wheel base 3.5 m, track 1.75 m, underneath clearance 500 mm.

All the function units of the machine are powered by the hydraulic system. There are 3 main systems:

(a) The two speed 2/4 WD transmission system, giving up to 30 km/h on the road.

(b) The stabiliser circuit for the 4 stabilisers.

Fig. 1. Machine in Transport Position.

Fig. 2. Machine in Field Position.

(c) The harvesting circuit to control the movement of the basket when working at the trees.

There are a series of interlock valves so that the operator is constrained to work in a safe sequence. The hydraulic controls for the basket are controlled electrically using a load sensing valve with ramp control for accurate and safe positioning.

The safety system is micro-processor controlled and interacts with the hydraulic system via a series of solenoid valves, pressure sensors and microswitches which indicate the position of components. The system used at the moment only warns the operator if the machine is likely to become unsafe, *e.g.*: if a stabiliser sinks too far when under load, but future development could restrict the operator's choice of movement only to a 'safe' direction.

Field Tests

Preliminary field tests were carried out on a farm near to King Saud University in March 1989. These trials were primarily to train the test team in the use of the machine and to carry out minor improvements to the machine. The results are published in Al-Suhaibani *et al.* (1989).

The main field trials were carried out at Al Mughtarah Farm from 26 August to 20 November 1989, near to King Saud University, this being the main harvesting season in this area, Al-Suhaibaibani *et al.* (1990b). It is a commercially run farm which caused problems for the test team because in some cases the management chose not to allow enough time for all the measurements to be taken as they were anxious to maximise production each day. In these cases estimates were made.

There are two types of harvesting carried out. Kharaf, the picking of individual dates, and Saram, harvesting the whole crop. Kharaf is usually carried out for dates which are half matured or just matured (still soft) for marketing fresh. These dates have high value and require careful picking to avoid damage and dirt contamination. This kharaf period lasts from 26 August until 30 September. Saram is carried out on mature dates from 1 October to 20 November, when the dates are fully matured (or at least most of them). Whole bunches are cut from the tree with no bunches remaining.

The machine was driven by one of the KSU staff who, by that time, was well skilled in its operation. The other staff members took the various readings and recorded the results. The actual harvesting operations were carried out by the farm staff who were very skilled at their task. The number of labourers were 3 in Kharaf and 1 in Saram with the machine operator in addition.

The following tests were carried out for both Kharaf and Saram. Time taken per tree for:

(a) Preparation of machine and moving to new location *i.e.* fold up stabilisers and drive to next position.
(b) Stabilisation.
(c) Elevation.
(d) Basket position.
(e) Harvesting.
(f) Lowering dates.
(g) Moving to next tree, *i.e.* moving basket not the machine.
(h) Down *i.e.* move basket to ground for operator to dismount.

In addition, the following were recorded.

Weight of dates, kg/tree.
Height of tree, m
Moving distance to next tree, and
Number of labourers

In Kharaf the dates were placed in pots which contain about 3 kg of dates. Sometimes the pots were lowered with ropes as they were filled, other times. They were stacked in the basket and unloaded when the basket returned to the ground. For location 2 the labourers also cut out leaves (asseeb) before picking dates, this was counted as part of harvesting time. In location 5 it took an exceptionally long time to set the stabiliers correctly. Some of the locations, *i.e.* 14, had a low yield as the trees had been picked before. Location 19 was variety Menaify which had to be picked several times.

For Saram harvesting the whole bunches were lowered by ropes (traditional method) or by using the winch and small basket. On the low value varieties the bunches were just dropped to the ground below the tree. The labourers often climbed out of the basket into the crown of the tree to cut the bunches, which they found more convenient.

One of the machine general requirements was to work on a wide range of date palm plantations, with both regular and random spaced plantings, Al-Suhaibani *et al.* (1988). But sometimes the trees were too close to each other, *e.g.* location 6, which made machine rotation to get into a good position a difficult task. In location 9, stones had to be used under one of the stabilisers to allow the machine to be levelled. In location 10 the machine became stuck in the mud and it took 100 minutes to free it.

The positions of the trees, heights and distances were recorded on a location diagram. The rectangle in Fig. 3 shows the machine position. At some of the locations a hand held electronic soil penetrometer was used to determine the soil strength. Fig. 4 shows a typical wheel track. At location one for Kharaf, stones were used to partly fill an irrigation channel so that the machine could cross over.

The traditional method of harvesting kharaf was recorded as follows:

b' climb up tree (sec),
e' harvesting time (sec),
lowering time (of pots) (sec),
climb down time (sec),
weight of dates, (kg); and
height of tree, (m).

For Saram the following were recorded:

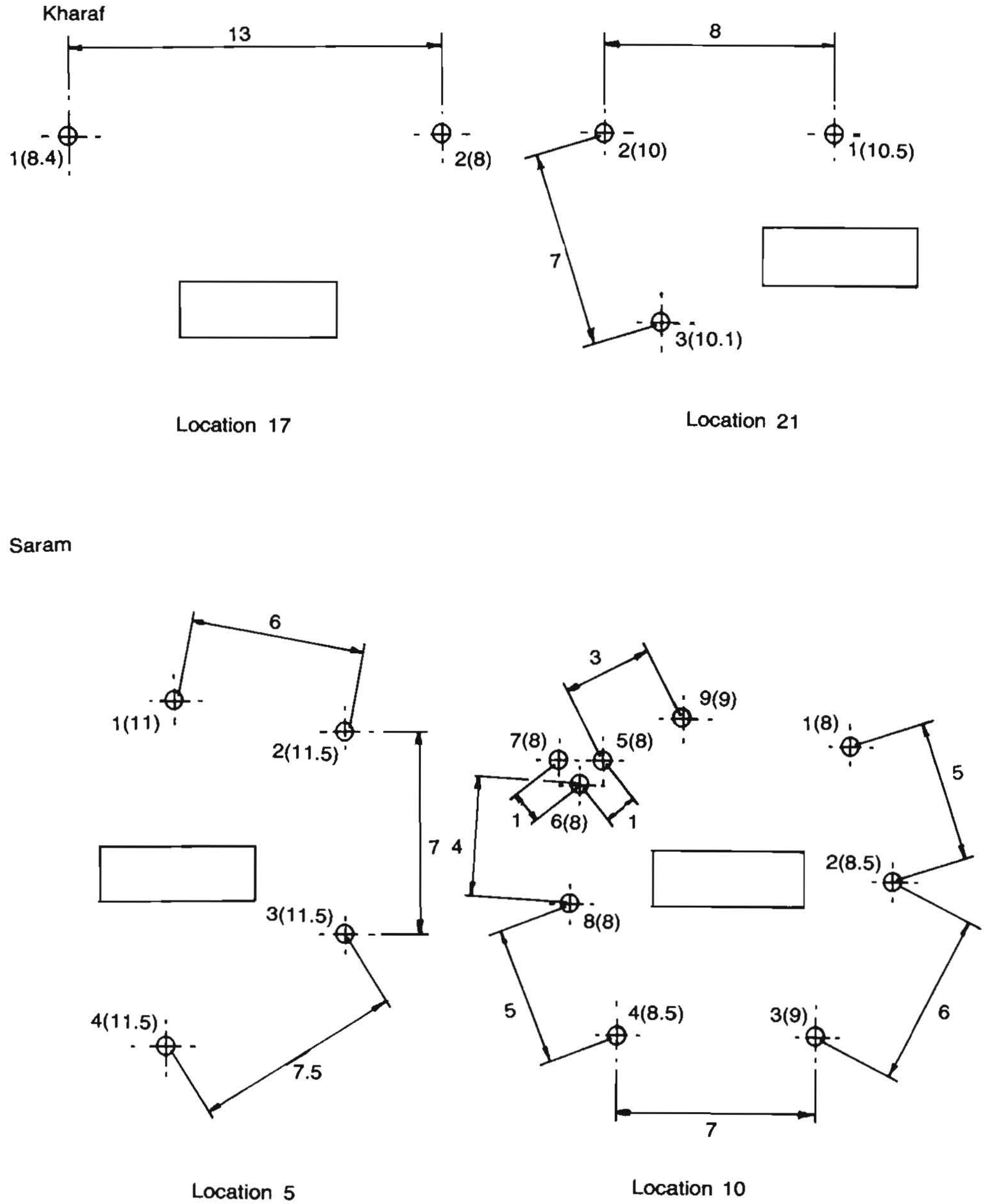
a' belt preparation time (sec),
b' climb up time (sec),
c' preparation on crown of tree (sec),
e' harvesting time (sec),
climb down time (sec); and
height of tree, (m).

Results

The first tree serviced in the location called a primary tree where the elevation of the basket is an activity while those trees which require only moving the basket to it from the previous tree considered as a secondary tree.

Kharaf

The results were collected from 32 locations in the farm when 32 elevations and 12 repositions took place. Thirty-two primary trees were serviced and 18 secondary trees. Two trees did not require the dates to be lowered separately (dates taken down in basket at the end). A total of 50 trees were recorded. The yield in location 15 was low due to insect attack. Table 1 shows time in seconds to complete the various activities. Table 2 shows weight of dates, tree height and moving distances.



Key:
1. Notation: 1(9) = Tree number (height of tree).
2. All dimensions in metres.

Fig. 3. Tree Location diagram

Figs. 5,6,7 and 8 shows these results as bar charts to give a better visual picture. They show the various times of the activities for each tree.

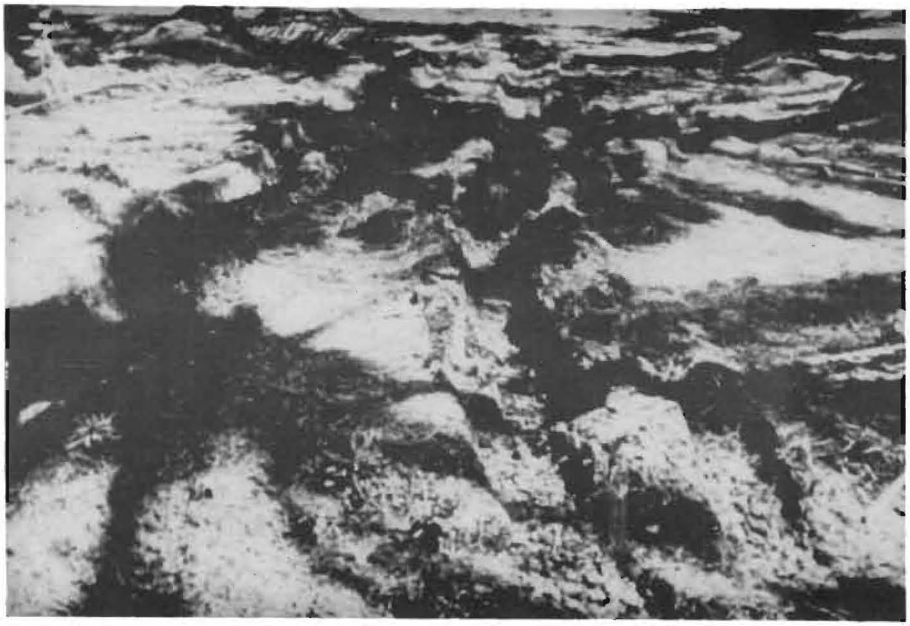


Fig. 4. Wheel ruts.

Table 1. Kharaf - time in seconds to complete the various activities

Activity	Average	Min.	Max.	Standard deviation	No. of observations
(a) Move to location	411.125	65	1161	259.7924	32
(b) Stabilization	102.8437	50	176	30.01469	32
(c) Elevation	93.71875	29	218	39.59974	32
(d) Basket position	71.22	0	267	77.85969	50
(e) Harvesting	3805.1	119	10007	2494.328	50
(f) Lowering dates	180.9791	20	520	106.3930	48
(g) Moving to next trees	161.4444	65	405	82.39418	18
(h) Down	79.28125	40	153	31.49427	32

Saram

Results were collected from 11 locations in the farm when 11 elevations and 17 repositions took place. Eleven primary trees were serviced and 13 secondary trees. A total of 24 trees were recorded. Table 3 shows time in second to complete the various activities and Table 4 shows weight of dates, tree height and moving distances.

Table 2. Weight of dates, tree height and moving distances

Activity	Average	Min.	Max.	Standard deviation	No. of observations
Weight of dates (kg)	47	9	109	26.222289	50
Height of tree (m)	8.84	7	10.6	0.868138	50
Moving distance to next tree	7.53	1	14	3.120150	18
No. of labourers	2.68	1	3	0.545527	50

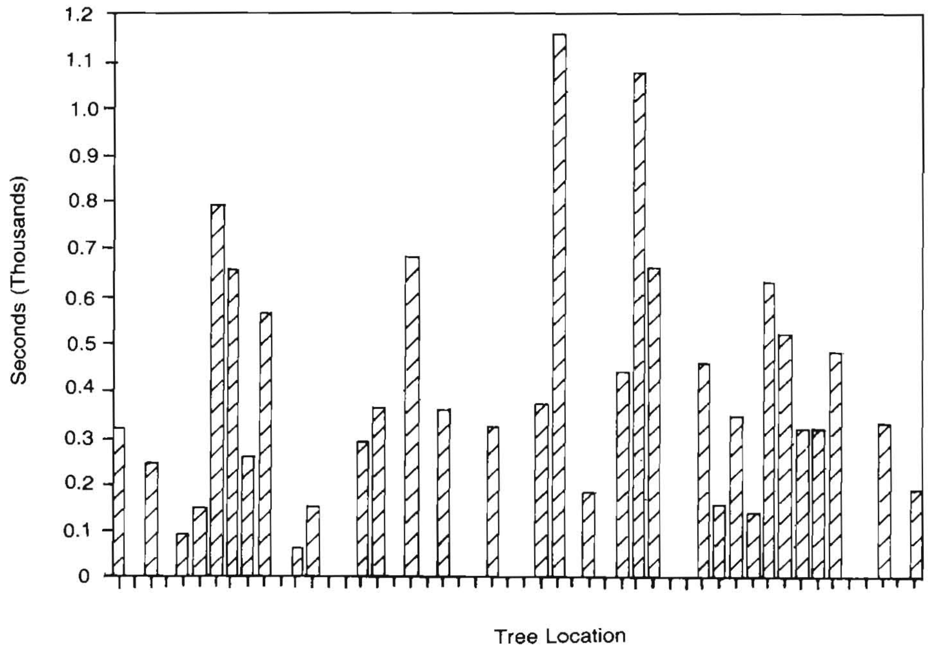


Fig. 5. Kharaf - Preparation and moving time.

Manual labour - Kharaf

A total of 36 trees were recorded. Table 5 shows the time in seconds to complete the activities.

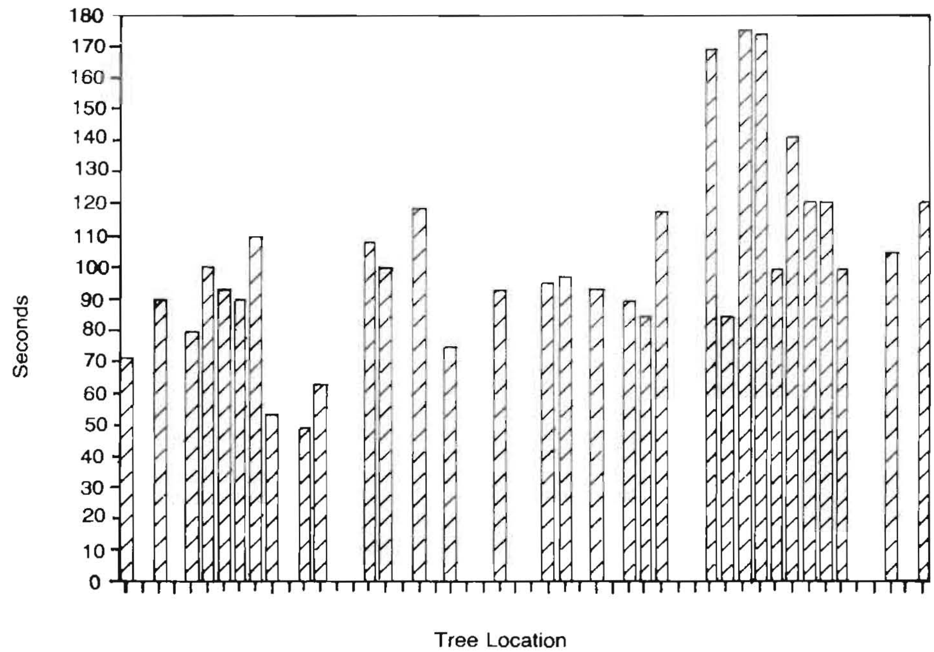


Fig. 6. Kharaf - Stabilisation time.

Table 3. Saram - time in seconds to complete the various activities

Activity	Average	Min.	Max.	Standard deviation	No. of observations
(a) Move to location	445.6363	80	950	326.2899	11
(b) Stabilization	148.4545	76	558	134.0884	11
(c) Elevation	81.3636	29	214	50.1674	11
(d) Basket position	38.625	0	98	25.7646	24
(e) Harvesting	205.6857	50	697	122.0713	35
(f) Lowering dates	153	84	288	80.8269	4
(g) Moving to next tree	68	15	127	30.4302	24
(h) Down	946	33	182	42.90581	11

Manual labour - Saram

A total of 30 trees were recorded. Table 6 shows the time in seconds to complete the activities.

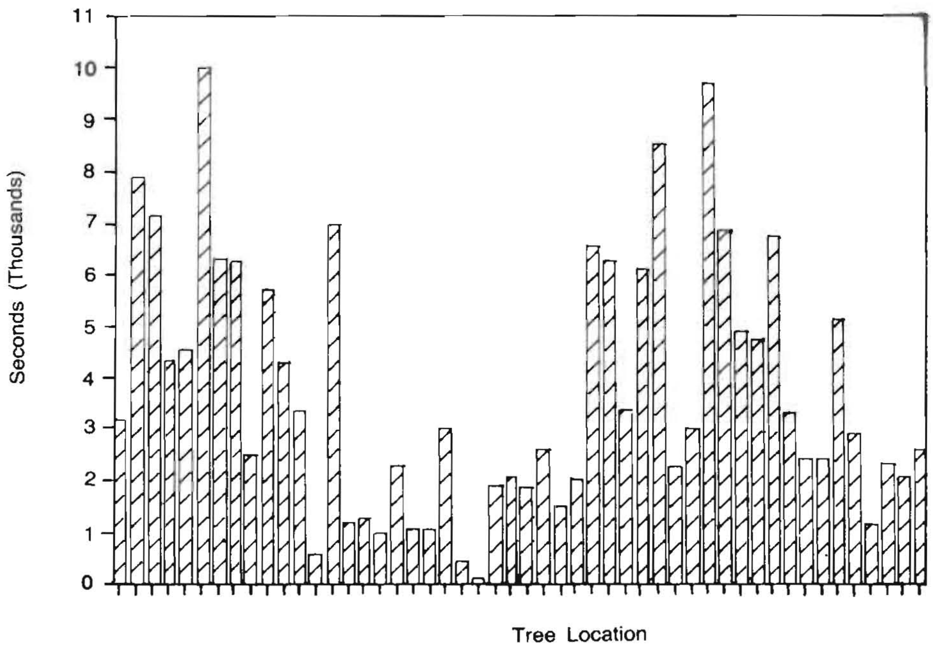


Fig. 7. Kharaf - Harvesting times per tree.

Table 4. Weight of dates, tree height and moving distance

Activity	Average	Min.	Max.	Standard deviation	No. of observations
Weight of dates (kg)	70				
Height of tree (m)	9.26	7	11.5	1.426140	35
Moving distance to next tree	5.54	1	9	2.188590	24
No. of labourers	1	1	2	0.318157	35

Table 5. Kharaf - Time in seconds to complete the various activities

	b' Climb Up	e' Harvest	Lower Dates	Climb Down	Weight	Height	Labourers
Average	37.53	5204.69	128.75	26.78	32.67	8.99	1
Standard	31.81	2146.46	65.33	11.58	16.28	1.1	0

Table 6. Saram - Time in seconds to complete the various activities

	a' Belt Prep.	b' Climb Up	c' Crown Prep.	e' Harvest	Climb Down	Height
Average	19.5	13.3	37.37	390.8	46	9.15
Standard	7.75	14.06	12.03	227.27	14.42	1.01

Penetrometer readings

Penetrometer readings were taken at 9 locations at times spread throughout the harvesting season. Fig. 9 shows the average, maximum and minimum of all readings in relation to depth below the surface.

Analysis of Results

The following formulas were developed to calculate the values of the various parameters of the field test.

Overall harvest efficiency

This is defined as:

$$\frac{e}{abcdefgh} \times 100\%$$

See Table 1 and Fig. 5 for values.

Field efficiency

This defined as

$$\frac{cdefgh}{abcdefgh} \times 100\%$$

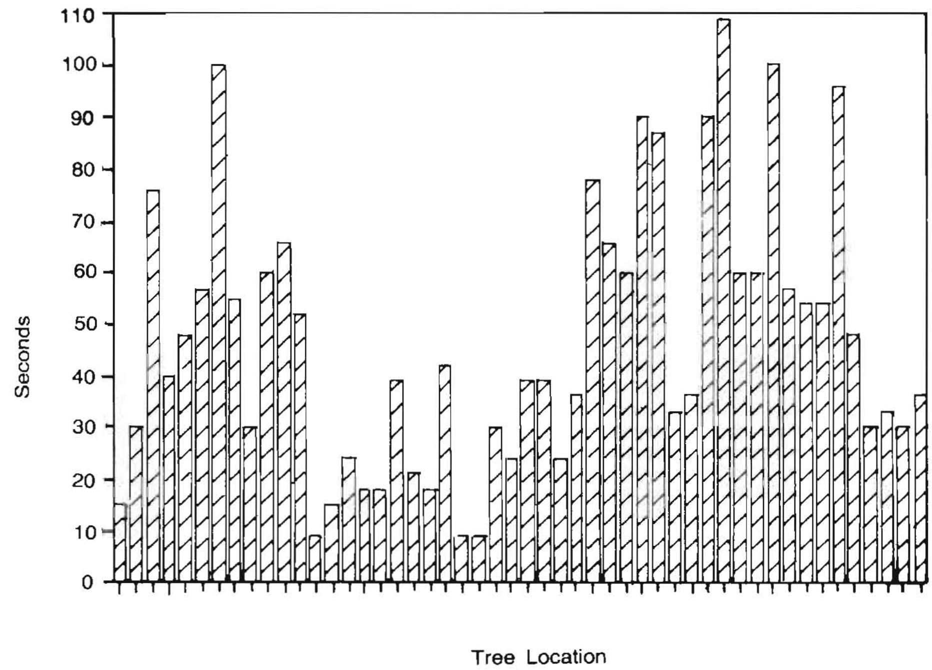


Fig. 8. Kharaf - weight of dates per tree.

Machine function efficiency

This is defined as:

$$\text{Gross} = 1 - \frac{cdfgh}{cdefgh} \times 100 \qquad \text{Net} = (1 - \frac{cdgh}{cdegh}) \times 100$$

Machine/Labour Ratios

Elevate/Climb

$\frac{c}{b'}$ net (up tree)

$\frac{c + d}{b' + c'}$ (up tree + in position)

Prepare $\frac{b}{a'}$ (activity at tree before elevate or climb)

Harvest $\frac{e}{e'}$

$$\text{Basket speed} = \frac{\text{height of tree}}{c + d}\ ;\ \text{m/s}$$

Tables 7 and 8 show the summary of the results for Kharaf and Saram.

Table 7. Kharaf Results Summary

Overall efficiency	(u)	0.84	Field efficiency	(u)	0.93
Machine function	(gross u)	0.90	Machine function	(net u)	0.94
Move to location	(s)	411	Stabilise	(s)	103
Elevation	(s)	94	Position basket	(s)	71
Harvest			Lower dates	(s)	181
Kharaf	(s)	3805	Moving basket	(s)	161
No. of Labourers		3	Down	(s)	79
Field speed	(m/s)	0.018	Distance between trees	(m)	7.5
Lift speed	(m/s)	0.094	Tree height	(m)	8.8
Yield time	(s/kg)	80.96	Tree yield	(kg)	47
Basket speed	(m/s)	0.047	Tree time	(s/tree)	4905
Trees/move	(trees)	1.56	Yield/man	(kg/man)	15.67

Table 8. Saram Results Summary

Overall efficiency	(u)	0.38	Field efficiency	(u)	0.65
Machine function	(gross u)	0.59	Machine function	(net u)	0.62
Move to location	(s)	446	Stabilise	(s)	148
Elevation	(s)	81	Position basket	(s)	39
Harvest			Lower dates	(s)	153
Saram	(s)	212	Moving basket	(s)	74
No. of Labourers		1	Down	(s)	86
Field speed	(m/s)	0.013	Distance between trees	(m)	5.75
Lift speed	(m/s)	0.443	Tree height	(m)	9.2
Yield time	(s/kg)	3.03	Tree yield	(kg)	70
Basket speed	(m/s)	0.08	Tree time	(s/tree)	1239
Trees/move	(trees)	3.18	Yield/man	(kg/man)	70

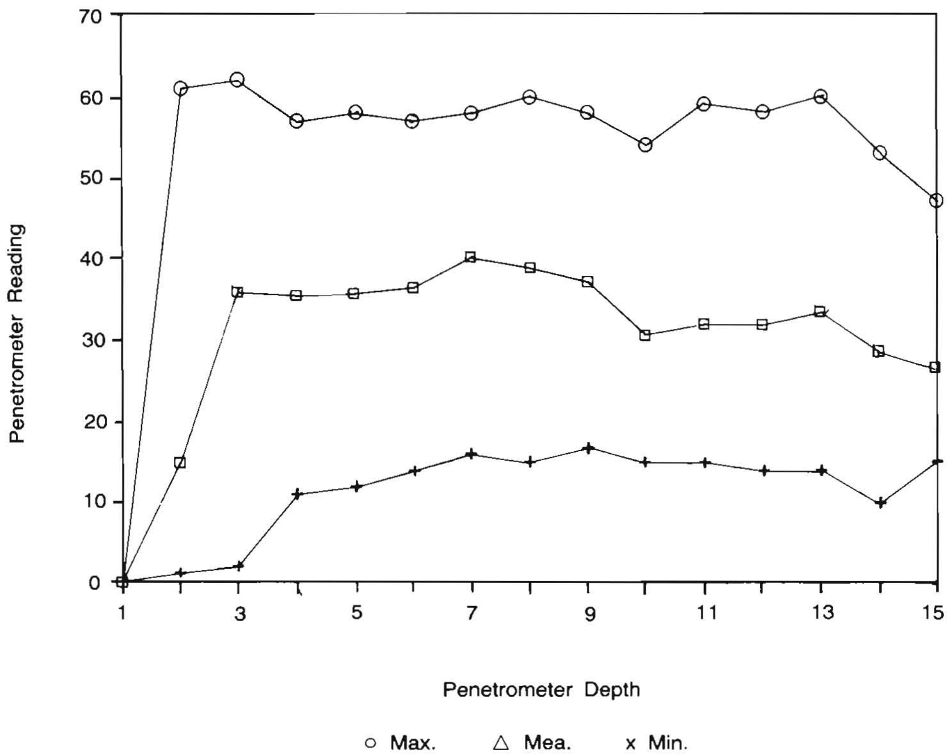


Fig. 9. Penetrometer readings vs depth.

Discussion

Harvesting

In Kharaf harvesting the overall and field efficiency were high as the harvesting activity takes a higher proportion of the time. The machine function figures were high showing a small proportion of time spent on these activities. The difference between the net and gross figures show the advantages of lowering the dates during the harvest time. The harvesting time was directly related to the weight collected (Figs. 7 and 8).

In Saram harvesting the overall and field efficiencies were much lower reflecting the shorter harvesting time in relation to the total spent. This shows the importance of the need to move the machine much faster.

The preparation, moving, and stabilize times were very similar to the Kharaf situation as would be expected (Figs. 5 and 6). The average basket speeds, *i.e.*

time taken to position basket were very slow, while the machine could move at a maximum speed of 1 m/s. Important features here are the degree of skill of the operator and reducing all unnecessary movements to a minimum. Perhaps a faster machine speed - a function of the pump size - should be increased.

The average tree height was between 8.8 and 9.2 m and the spacing ranged between 5.7 to 7.5 m, which was well within the original machine specifications but only an average of 3 and 1.6 trees per move, were harvested for Saram and Kharaf respectively, while the original proposal was to reach 6 trees at a time. The reasons for the low number of trees needs more evaluation as it might be that it was too difficult in practice to harvest more than 2 or 3 times per move. If this were so then it leads to the thought that a simpler machine without 360° rotation would be adequate and considerably simpler and lower in cost.

The comparison between the machine and hand harvesting is shown by the machine/hand ratios in Table 9.

Table 9. Comparison between the machine and hand harvesting

Ratio		Kharaf	Saram
Elevate	net	2.49	2.590
	gross	4.39	1.74
Prepare Harvest		.73	.52

This shows quite dramaticallly that the machine was much slower at positioning itself in the correct position for harvesting compared to the hand method. However, once the machine was in position, the time required by the machine in Saram was 52 percent of that by hand which made the operation time nearly half that of hand harvesting.

This further emphasises the point that more effort should be put into modifying the design and operating technique to improve the machine moving times both between the trees and between locations.

It should be noted, however, that one of the machine design objectives was to carry out the harvesting using unskilled labour (not skilled climbers). These tests were conducted using skilled labour so the advantages of the machine were less apparent but next season it is hoped to carry out the field tests using more appropriate labour.

Operators and labourers comments

From the labourers point of view they liked the machine for pruning and dethorning and Kharaf harvesting when a long time was spent up the tree, and the machine made it easier to move about. They did not like the machine for Saram as the labourers felt they could work faster by hand (in fact they did not as shown in Table 9).

The labourers said they felt unsafe in the machine basket when working on trees higher than 10 m due to the boom swinging. The KSU staff felt this was a strange comment as the taller trees swinging more than the machines does.

Soil strength

The penetrometer readings showed that the soil had on average a reasonable strength and was able to support the machine satisfactorily. It only became stuck on one site, when it took 100 minutes to recover it from the ruts. Fig. (4) shows the ruts made on a soft soil where it was just possible to drive out unaided. If machines were to be more widely adopted, then more planning is necessary regarding the irrigation water control so that the soil is not soft when it is intended to drive the machine between the trees; smaller cheaper types could then be used.

Machine failures

Throughout the test period there were no significant machine failures, except for one of the stabiliser feet when the fixing bolts sheared off (Fig. 10). The reason for the failure not clear but the strength of the bolts for the load imposed will be checked. One hydraulic hose failed due to an accident, otherwise the hydraulic system worked satisfactorily. There were no electrical or structural failures.

Safety system

The system worked satisfactorily on eah occasion. On one location it took an exceptionally long time to set the machine level - about 46000 secs. It was not clear, whether this was due to the particular conditions at that location - *i.e.* soft even soil or due to the operator.

During the test period the stabiliser feet did not sink into the soil during harvesting so perhaps such an elaborate system was not required in practice. Further study is needed in this area to come to a valid conclusion and recommendation.

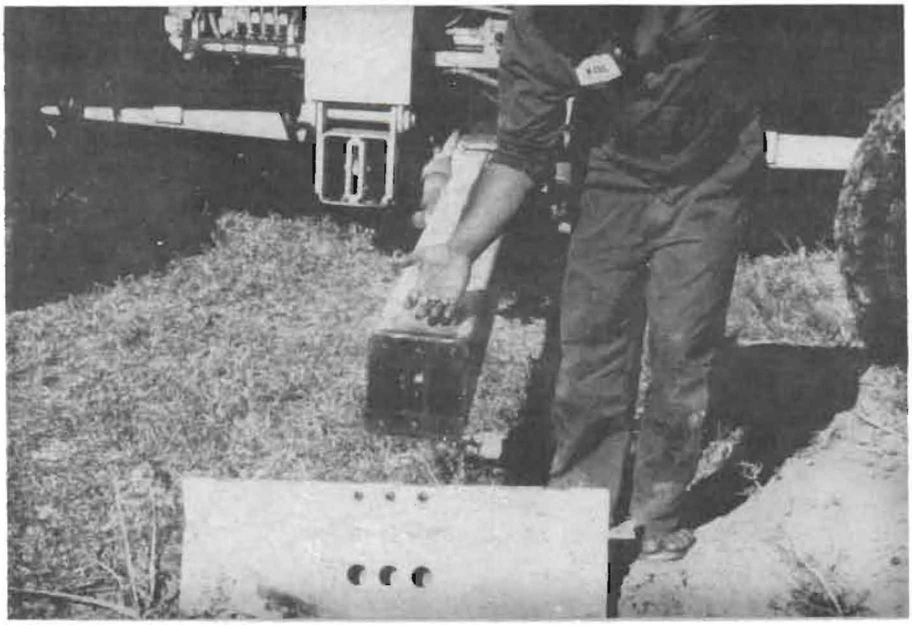


Fig. 10. Machine Failure - Stabiliser leg.

Conclusion

The machine can be used satisfactorily to harvest dates in Saudi Arabia. Although it positions itself more slowly than the hand labourers, it is possible to harvest the dates faster than by the traditional hand methods.

The operational procedures in the field require improvement to reduce the time taken. The design of the machine requires careful analysis as it appears that it would be possible to simplify the machine and to improve its speed.

Further studies will be undertaken on the economic performance of the machine, taking into account the predicted performance improvements suggested. Recommendations will be made as to its acceptability to Saudi Arabian date farms.

Recommendations for Future Work

The design of date palm service machine should be reappraised to find areas where the machine can be simplified and made to work more conveniently and faster. The economic performance should be evaluated. If it appears that a reasonable number of machine is required then plans should be made to produce a number for wider acceptance trials by the farmers.

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الاختبار الحقلي لآلة خدمة محصول النخيل

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تعتبر التمور أحد المحاصيل الرئيسية في المملكة العربية السعودية وتتطلب رعاية النخلة المنتجة عدداً من العمليات مثل التلقيح، والخف، التكميم والحصاد (الصرام)، ولا نجاز هذه العمليات يلزم أن يتسلق العامل النخلة حتى قمتها وهذه عملية خطرة ويزيد من تعقيدها النقص في الأيدي العاملة المدربة. وقد تم إجراء مسح في عام ١٩٨٥ م لمزارع النخيل في عدد من مناطق المملكة العربية السعودية وقد تم تحليل المعلومات وتحديد مواصفات آلة الحصاد اللازمة، حيث تم تحديد أبعاد الآلة، أقصى إرتفاع لسلة رفع العامل، إرتفاع الآلة عن الأرض والقدرة اللازمة لتشغيل الآلة. وتم تصنيع نموذج للآلة، كما تم اختبارها في الحقل في موسم الحصاد لعام ١٩٨٩ م. وكان اختبارها في نوعين من الحصاد، الخراف الذي هو قطف التمور باختيار الناضج منها ويتم القطف عدة مرات، والصرام الذي يتم بقطع جميع العذوق ولمرة واحدة.

وقد تم تجميع معلومات أثناء خراف ٥٠ نخلة وصرام ٢٤ نخلة، وشمل تسجيل المعلومات الوقت اللازم للفعاليات التالية: التحرك من موقع إلى آخر، تهيئة الآلة في الموقع، رفع سلة العامل وتثبيتها، عملية الحصاد وإنزال المحصول

والتحرك من نخلة إلى أخرى بالاضافة إلى المسافات وأوزان المحصول. وتم تحليل المعلومات لتحديد كفاءة الحصاد الكلية والكفـاءة الحقلية والـوظيفية لـلآلة. وقـد أظهرت النتائج أنه في حالة الخراف كانت كفاءة الحصاد الكليـة والكفاءة الحقليـة ٨٤ ٪، ٩٣ ٪ على التوالي، بينـما كانت تلك الكفـاءات في حالـة الصرام ٣٨ ٪، ٦٥ ٪ على التوالي وهي منخفضة وهذا يـوضح أهميـة سرعة تحـريك الآلـة والذي يعتمد أساساً على مهـارة العامـل لتشغيلها حيث كـان تحريـك السلة حول النخلة بطيئاً ويقارب حوالي ١٠ ٪ من السرعة القصوى.

كما تم جمع معلومـات للطريقة التقليـدية لعـمال مهرة أثنـاء خراف ٣٦ نخلة وصرام ٣٠ نخلة. وأظهرت المقارنة أن الآلة كـانت بطيئـة في الفعاليـات ما عـدا الحصـاد حيث كانت الآلـة أسرع في عمليـة الحصـاد. وقـد أُقـترِح أن تتم بعض التعديلات لصنع النموذج الثـاني للآلـة والتي يجب أن تحسن الأداء وتجعل قيـادتها أسهل وإنتاجيتها أقل تكلفة.