CHOICE OF A SERVICE SYSTEM FOR PALM TREES

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SUMMARY: Design criteria are presented for the development of machine systems for the servicing of the crowns of closely-packed, randomly distributed and clustered palm trees where the row middles may be inter-cropped. A generic service platform is then introduced, along with a universal trailer for transporting and initial-positioning of the platform. Six different palm service systems are then described and briefly discussed. The proposed machine systems, along with the date service machine of KSU, are judged according to the stated design criteria. It is concluded that all of the new PSS machines possess sufficient potential to warrant further investigation.

Key Words: Palm tree, crown, platform, trailer.

INTRODUCTION

An account of mechanization efforts that are directed to crown activities in palm trees in general, and the date palm in particular, were outlined in a previous communication (1) where the equipment currently in use was also briefly described. It was emphasized that currently available date field equipment requires date fields to have a minimum clear space of 7 to 9 m between trees, and the same minimum clear spacing between the rows of palms. Some uniformity of variety is also required. Furthermore, to facilitate operations with the heavy equipment, row middles need to be clear of inter-crops or irrigation ditches. It was pointed out that the bulk of the existing date orchards in the primary date-producing regions, including the Kingdom of Saudi Arabia, do not conform to these norms and planting patterns. It was deduced that, for any attempts of mechanization of crown-related operations to be viable in the Kingdom and the region, it is imperative that two basic requirements be satisfied, i.e., a) The proposed machinery must be capable of serving the status quo, and b) The proposed machinery must be affordable.

In what follows we present the design criteria that are considered essential for applicable new designs that meet the above overall requirements. A number of service systems are then introduced. All of these machines enable the undertaking of crown-related operations, and meet the primary requirements. Each design is briefly evaluated, and subsequently comparisons are made, based on the adopted design criteria.

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DESIGN CRITERIA

The constraints listed below, i.e., navigability, affordability, reliability and safety, and performance, are considered to be the generic requirements that must be met by any Palm Service System (PSS). Due to the special significance of performance, an objective function Y of the following configuration is proposed for the comparative evaluation of the PSS machines.

Y=P (N+R+A) where

P=Performance

N=Navigability

R=Reliability and Safety

A=Affordability

During evaluation, the proposed designs will be assigned a grade that ranges from a minimum of zero to a maximum of 3 points for each criterion.

Performance

The PSS must allow the servicing of a tree when it is located on soft and wet/flooded soil; it must be provided with stability measures to allow this operation. It must further allow servicing operations to be performed on a tree when the PSS is situated on uneven and rough terrain.

The PSS must allow the servicing of trees with trunk diameters ranging from 30 to 75 cm. Tree (crown) heights may vary from 3 m to 10 m. The PSS must permit the servicing of trees that possess a work area comprising a radial clearance of 1.5 m about the tree trunk and of 3 m from ground level.

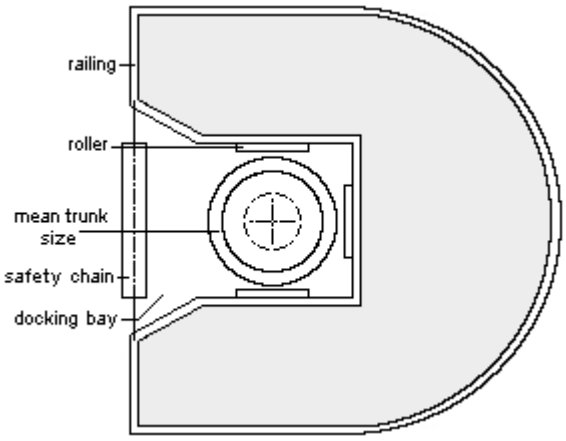
The PSS must enable the proper undertaking of all cultural operations related with the crown of palm trees. The performance of the PSS must be such that the time required for the harvesting of a tree must not be longer than that needed for manual harvesting. The PSS must allow the lowering of the harvested fruit without causing loss of quality.

The PSS, when properly serviced at the beginning of the season, must not require shop-level maintenance during a given season of operations. Field maintenance must not involve skills that cannot be expected from an unskilled farm laborer. The machine must be capable of tolerating/absorbing a certain degree of misuse, abuse, and overloading due to inexperienced operators.

Navigability

The PSS must be navigable on soft and wet soil. It must further be navigable on uneven and rough terrain; its center of gravity must be low, and the wheelbase must be sufficiently large to provide sufficient system stability during transposition. In case the machine is mounted on a purpose-built semi trailer, the drawbar forces must not deteriorate the stability and steer ability of the towing vehicle. The vertical forces that need to be exerted on the draw-bar must be limited such that

Figure1:The service platform.



one operator can carry out the hitching-unhitching operations. The design of any trailer, on which the system can be mounted, must allow the positioning of the trailer such that the trunk of the tree is central to the service platform (Figure 1) during servicing.

The PSS must be able to cross earth ditches that are 50 cm wide and 30 cm deep (2); the effective radius of the tires must be greater than 35 cm, and the minimum clearance from the ground must be 30 cm. The machine must be navigable through a clearing (path) 3 m in width.

Reliability and safety

The PSS must be safe to operate. It must incorporate emergency measures for the safety of the operator in case of malfunction of the equipment. Warning precautions must be taken, and emergency procedures must be established for preventing accidents. The PSS must also be safe for the tree. The tree must not be harmed during the execution of normal servicing procedures.

Affordability

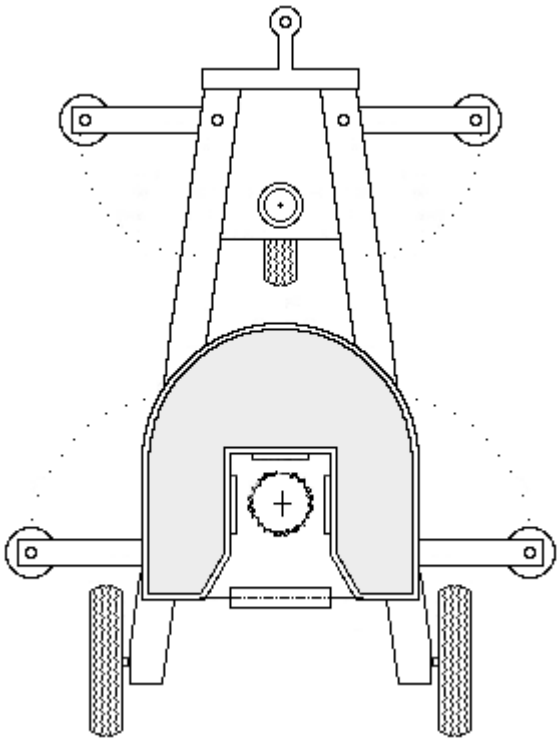
The cost of the PSS must not exceed the cost of a pickup truck. It is also considered desirable to restrict the annual routine maintenance and running costs.

DESIGN AND ALTERNATIVES

A number of conceptual designs are presented below to be considered for adoption as a PSS. Conceivably such systems can range from hand-held poles and light-weight ladders to powered or self- propelled man-lift systems weighting several tons. As the satisfaction of the above design criteria in effect precludes hand-held systems, attention is focused below on powered designs. All designs call for a service platform, a trailer or a semi trailer for transportation and positioning, and a lifting mechanism.

Figure 1 shows the plan view of a generic platform, which is to be utilized by all of the proposed machines, with minor modifications in several cases. The platform provides a safe working area during servicing operations.

Figure 2: Three-wheeled trailer for the PSS.



It features anti-slip decking and continuous railing that is one meter high. A docking bay is provided with a tapered opening for facilitating the docking of the platform to the trunk of the tree. The smallest, mean and largest trunk diameters to be handled by the PSS device are marked by circles in Figure 1. The platform is further equipped with rollers around the docking bay for minimizing friction and damage during the raising and lowering operations.

The service platform is to be of light-metal construction, and is designed to allow the servicing of virtually all parts of the crown. A safety chain with a roller (Figure 1) is furnished for preventing accidental separation of the tree trunk from the platform. It is envisaged that a docking system, which consists of a locking device, can be utilized to firmly anchor the platform to the trunk of the tree during the servicing operation. A rope ladder will be available on the platform for emergencies. The operator will be required to wear a safety harness.

Figure 3: The trailer and platform at service positions

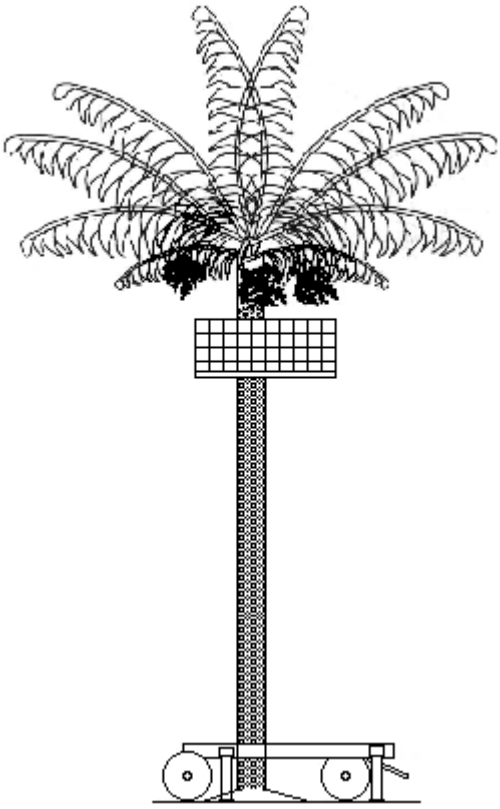


Figure 2 displays the top view of a universal three-wheeled trailer to be utilized by all PSS machines. The low pressure tires are large enough in diameter to result in a contact pressure in the range of 300-1000 k N/m^2 (3, 4) for trouble-free operation on soft and wet soil. The rear axle is provided with a wide U-opening to allow for the positioning of the trailer such that the tree trunk is located inside the docking bay of the platform while the platform is still on the trailer. The trailer is about 4.5 m in length and its road-width is 2.5 m. Figure 3 shows the trailer in its stabilized position and the platform docked to the tree in its service area.

The trailer can be towed by a farm tractor or a pickup truck. Two outriggers (Figure 2) swing out from the rear of the trailer to impart stability to the system during servicing operations. Two additional outriggers are provided at the front of the trailer primarily for leveling purposes. These can be also pulled out from the trailer body to enhance stability. The trailer is to be supplied with a battery-operated hydraulic power pack that can be charged by the towing vehicle.

PSS-A

Figure 4 depicts the PSS-A, featuring a multi-stage hydraulically operated boom that is mounted on the trailer. The joint between the platform and the tip of the third stage of the boom is to be such that some horizontal relative translation is possible, and some relative rotation about the vertical axis is also allowed. The multi-stage boom is to be brought to its vertical position by means of a single-stage hydraulic actuator. It is expected that the hydraulic pump for the system will be powered by the power-pack mounted on the trailer.

At the start of a servicing operation, the trailer is positioned so as to have the tree trunk located inside the docking bay of the platform (Figure 2). The front and rear outriggers are extended, and the trailer is leveled by means of the outriggers. The boom is brought into the vertical position by the erection cylinder, and the operator climbs into the platform, via an (unshown) static ladder. He links the safety chain (Figure 1) across the docking bay, and starts raising the platform

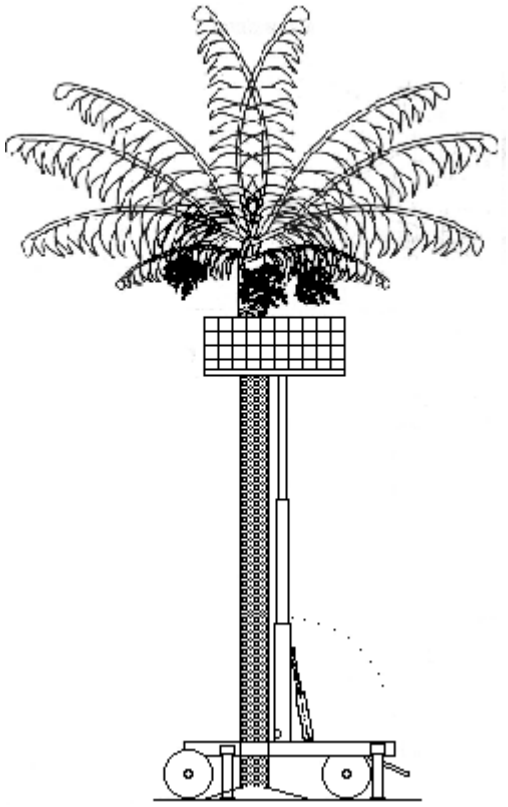
by utilizing the controls located inside the platform. The platform can be raised to a height ranging from 3 to 10 m. When the desired height is reached, the operator firmly docks the platform to the trunk of the tree by means of a gripper-like mechanism (5-8). Then the necessary crown operations are undertaken. When harvesting fruit, the fruit is lowered to the ground by rope as it is harvested. When the operation is finished, the operator undocks the platform, and then lowers it, while the safety chain is still in place.

PSS-C

Figure 5 illustrates the PSS-C in the servicing position. The figure shows a multi-stage hydraulically operated telescopic boom system that is mounted on the trailer. The third stage of the boom is equipped with a pulley system (not shown). The telescopic boom assembly is erected by means of a single-stage hydraulic cylinder, as in PSS-A. A winch on the trailer lifts the service platform to the required height via the pulley at the tip of the boom. A modified service platform, shown in Figure 5, is fitted with hand-operated gripper-like clamps to lock itself to the trunk once it is at the desired location.

At the start of a servicing operation, the trailer is positioned so as to have the tree trunk located in the docking area of the platform. The front and rear outriggers are extended, and the trailer is leveled by means of the outriggers. The boom is brought to its upright position, and then extended to the desired height. The operator then climbs into the platform, and links the safety chain. The winch is then operated to raise the platform. Finally clamps are applied at the service height to lock the platform to the tree trunk during servicing operations.

Figure 4: The PSS-A at work.



PSS-D

Figure 6 illustrates the PSS-D, which features a pivot able multi-stage hydraulically operated boom system that is mounted on the trailer. The design of the joint between the platform and the tip of the third stage boom is similar to that used in PSS-A. The boom-platform assembly can be pivoted clockwise through an angle of 90° to bring it to its upright position from its contracted road position. At the vertical configuration the boom is locked at the base to prevent further boom rotation.

During operation, the operator parks the trailer at the appropriate location, and then stabilizes and levels it. Then the boom is pivoted into its upright position. The operator climbs into the platform via an unshown ladder, and chains the entrance of the docking bay. The platform is then raised up to the desired height, where the operator docks the platform to the trunk of the tree as in PSS-A.

PSS-F

Figure 7 illustrates the PSS-F, featuring a hydraulically or power-screw operated scissors system which is mounted on the trailer. The platform (Figure 1) is mounted at the top of the scissors system such that the

docking bay ends at the left hand row of hinges. The platform and the trailer are the same as those used in PSS-A, except for a guide extension protruding from the bottom of the platform (Figure 7).

During operation, the operator locates the trailer in such a way that the trunk of the tree is inside the docking area of the platform. The outriggers are utilized as usual. The operator climbs on the platform via an unshown ladder. The docking bay is chained. The scissors system is then raised to the level of the crown of the tree. The rest of the service procedure is the same as for PSS-A.

PSS-G

Figure 8 depicts the PSS-G, which is a self-propelled buggy for tree climbing. The machine is operated via an inboard gasoline engine. The system consists of an IC engine complete with clutch, brake, and speed reducer, the traction system for climbing up and down, the service platform with docking equipment, and the trailer for transporting the buggy.

It may be readily shown that an IC engine of a power rating of 3 to 5 hp will be satisfactory. The engine as well as the rest of the power train are mounted on the platform. The platform itself is essentially of the same design as used in PSS-A.

During operation, the trailer is located such that the trunk of the tree is inside the docking area of the platform. Traction and guide rollers are next brought into contact with the trunk. The operator enters the platform, chains the docking bay, starts the engine, and engages the clutch/brake for the climb. When the service location is reached, the platform is docked to the trunk as in PSS-A, and the engine is stopped. The return trip is by gravity, using the clutch and the brake to regulate the speed.

Figure 5: The PSS-C.

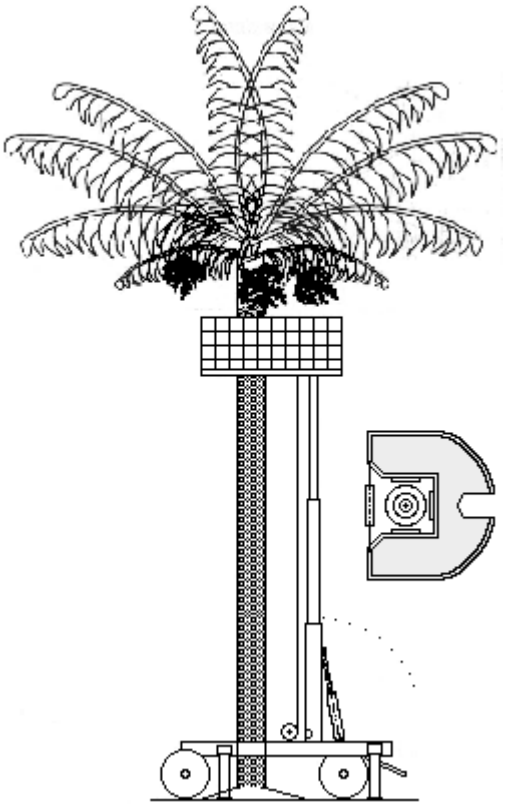
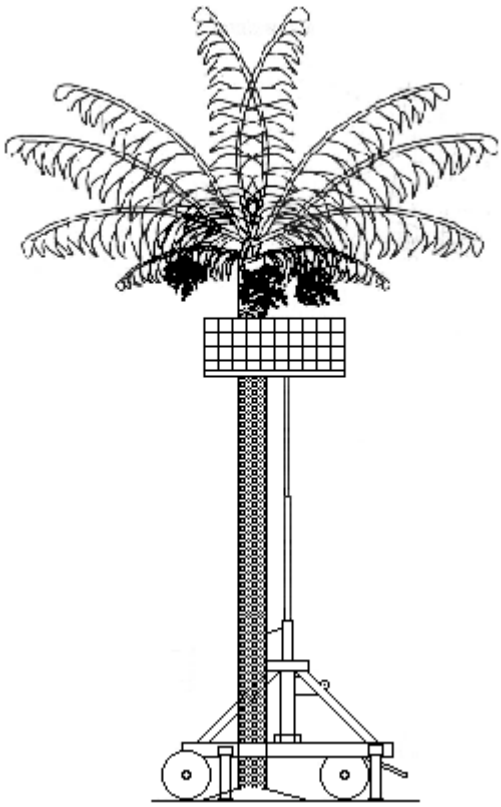


Figure 6: The PSS-D.



PSS-I

Figure 9 represents the PSS-I, which features a multi-stage telescopic system mounted on the trailer of PSS-A. The service platform is attached to the final stage of the telescopic system as in PSS-A. Individual elements of the telescopic lifting system are prismatic in shape, and are provided with U-channels for guide rollers. The lifting action is affected by a series of pulleys and rope. The system is powered by a winch located on the trailer. Alternatively a hydraulic actuator may be employed for actuation.

The procedures for operating the device are the same as for PSS-A.

DISCUSSION AND CONCLUSIONS

Table 1 summarizes the evaluation of the six machines described above according to the stated design criteria. A seventh machine, the purpose-built KSU date palm service machine (DPSM) of King Saudi University (KSU) is also listed for comparison.

All six of the PSS fully satisfy the criterion of navigability; they all utilize the same wide-track trailer with large wheels, ensuring a minimum clearance of about 40 cm from ground level. The center of gravity of the loaded trailer is less than 2 m from ground level in all cases. The trailer is readily navigable through a clearing of 3 m by 3 m. The self-propelled KSU machine, however, does not have wheels large enough to be navigable on soft and wet soil (4). Partly due to its larger mass, it is also difficult to maneuver on uneven and rough terrain. Thus, it has difficulty crossing irrigation ditches. Due to its larger size, the KSU machine is not navigable through the specified clearing of 3 m by 3 m.

The criterion of affordability is based on the current cost of a popular pickup truck used by farmers. Table 1 lists the weighed grades for the cost estimates made on the PSS machines (9). The cost of the KSU machine is about 15 times the cost of the pick-up truck.

Figure 7: The PSS-F.

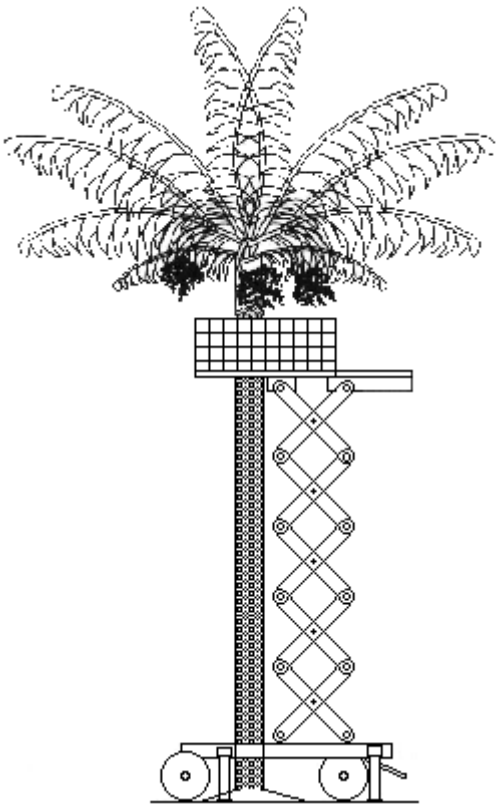


Figure 8: The PSS-G.

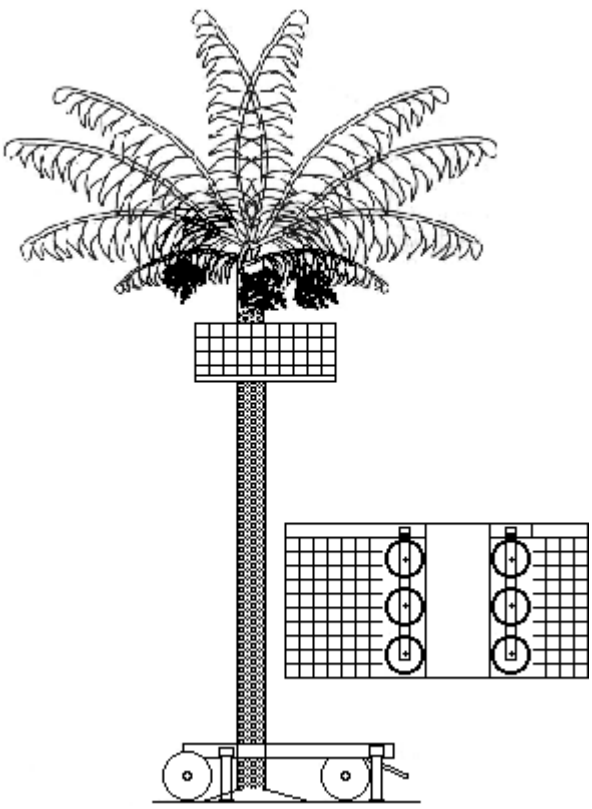
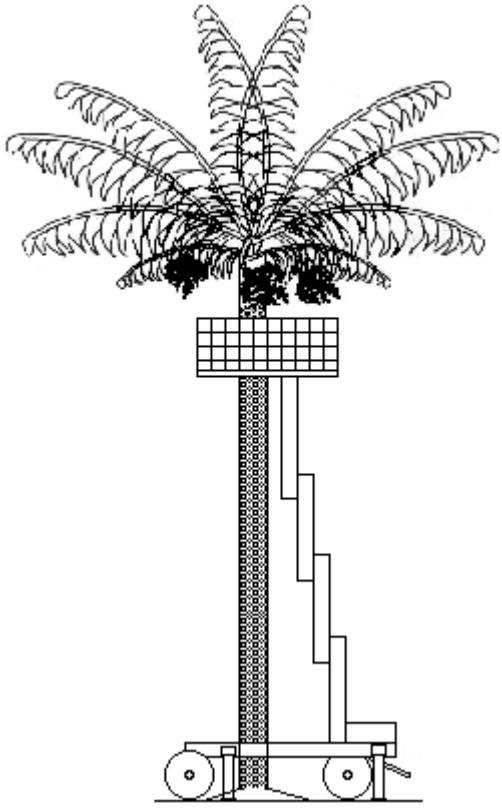


Table 1: Evaluation of proposed designs.

PSS	Navigability	Criterion			Merit Function Y=P(N+A+R)
		Affordability-A	R and S-R	Performance - P	
A	3.0	1.8	2.5	3	21.9
C	3.0	1.8	1.6	3	19.2
D	3.0	2.0	3.0	3	24.0
F	3.0	1.3	2.9	3	21.6
G	3.0	2.9	1.6	3	22.5
I	3.0	1.8	2.9	3	23.1
KSU DSM	0.0	0.0	2.5	2.0	5.0

Table 1 also lists the results of preliminary reliability and safety studies (9) conducted on the PSS machines. The grade for R that is assigned to the KSU machine represents a rough estimate based on the reported characteristics and performance (1, 2, 4) of the machine.

Figure 9: The PSS-I.



The criterion of performance entails the ability of the machine to allow the execution of all servicing operations associated with palm trees (1). The machine must allow the servicing of closely-packed trees even when the radial clearance is restricted to only 1.5 m around the trunk. Based on the same stabilized trailer, and utilizing essentially the same service platform, all PSS machines seem to fully satisfy these service requirements. The KSU machine, however, requires a clearance of 5 m between trees, and is hence not suited to closely-packed tree formations.

It is concluded from Table 1 that all PSS machines presented herein are satisfactory in terms of the merit function. The final choice of a design would then be dictated by such supplementary factors as ease of design and manufacturing, and the availability of components and spare parts throughout the regions of possible deployment.

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REFERENCES

1. Ali T and Akyurt M : On the mechanization of palm crown operations. J Eng Int Dev, 1:19-26, 1991.

2. Al-Suhaibani SA, Babeir AS, Kilgour J, Flynn JC : The design of a date palm service machine. J Agric Eng Res, 40:143-157, 1988.

3. Crai RF : Soil Mechanics, 4th Ed, Van Nostrand Reinhold, 1987.

4. Al-Suhaibani SA, Babeir AS, Kilgour J, Blackmore S : Field tests of the KSU date palm machine, Proc 4th Int Agr Mech Energy Conf, Çukurova Univ, Adana, Türkiye, pp 364-373, 1991.

5. Mannaa AR, Akyurt M, El-Kalay AK : Enhanced gripping mechanisms for industrial robots, Int. J Rob Autom, 6:156-160, 1991.

6. Mannaa AR, Akyurt M, El-Kalay AK : Mechanisms for concentric gripping, Computers in Industry, 13:347-353, 1990.

7. Manna AR, Akyurt M, El-Kalay AK : Optimum design of a force-intensifying concentric gripper for industrial robots, Int. J Rob Autom, 5:101-106, 1990.

8. Mannaa AR, Akyurt M, El-Kalay AK : Six-link gripper for cylindrical objects. J Islamic Acad Sci, 3:6-10, 1990.

9. Ali T : Design of a Palm Harvesting and Maintenance Machine, unpublished MS thesis, Mechanical Eng Dept, KAU, Jeddah, (under preparation) 1993.

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