Proceedings:
International Conference on
Mango and Date Palm: Culture and Export.
20^{th} to 23^{rd} June, 2005.
Malik *et al.* (Eds), University of Agriculture, Faisalabad.

DEVELOPMENT OF A DATE PALM DETHORNING DEVICE

Ahmad Mosttan
Date Palm and Tropical Fruits Research Institute of Iran
Ahwaz, Iran, P.O.Box: 61355-16
Email: madham_m@yahoo.com.

ABSTRACT

Date palm dethorning means removing the spines (or thorns) off the palm fronds and plays an important role in date quality. This operation is done traditionally by means of different types of sickles in Iran and nearly all over the world. In this way the operation intensity is high, and takes about 5-10 minutes for each palm, and frond midrib injuries are high. The workers also sustain many injuries during the operation. Consequently this operation has been neglected in recent years. In this research, a hand-held date palm dethorning device is designed, developed and evaluated for overcoming the aforementioned operation problems. The device is consisted of a 1.5 meters aluminum pole, a jaw mechanism, two counter moving blades, some rollers to facilitate the device-frond interaction, a lever on its lower end to actuate the blades, and two shielded cables to transmit force and movement from the lever to the jaw. It requires only manpower and only one worker is able to do the operation.

Preliminary evaluation of this device showed that it reduces the operation time to less than 3 minutes for each palm, and also decreases the frond midrib injuries in comparison to the traditional devices. Its maximum operation height is about 2.5 meters.

Keywords: Date palm, handheld, frond, spine removing, mechanization

INTRODUCTION

Total date production in Iran was more than 870 thousand tones of 183,269 hectare by 2002, from which 122,084 tones were exported for $29,375,400. Currently date palm is cultivated in 13 province and about 500 thousands farmers are engaged in date production. Also more than 50 product or by-products are producible from dates and the palm itself. Date palm has a remarkable value in economic, occupation, and foreign exchange of the county. Application and development of suitable methods especially mechanization of date farming is essential to optimize this industry (Albozahar, 2003).

Date palm (*Phoenix dactylifera* L.) is characterized from other spices by its cylindrical, no branching, and relatively tall trunk and sucker producing. Date palm is a dioecious species and its bearing begins 4-5 years after planting, depending on variety (Hashempur, 1995).

Date palm lengthwise growth is upward and is provided by means of leaf growth from apical meristem and is a function of cultural practices such as fertilization, irrigation, pruning etc.

Overall height of date palm depends on variety and location such as Shahani variety in Jahrom grows up to 20 m height and even more (Hashempur, 1995).

An adult date palm has approximately 100 to 125 green leaves with annual formation of 10 to 26 new leaves. The functional value of the leaf to date palm declines with age and two leaves are not at the same age. Furthermore, leaves which are four years old are only about 65 percent as effective in photosynthesis per unit area compared to leaves of one year old. Under good cultural conditions a leaf can support the production of 1 to 1.5 kg of dates (Zaid and De Wet., 1999a). New date palm fronds are located in top and center of the crown and the old ones are in the lower and outer part (Albozahar, 2003).

Depending on variety, age of date palm and environmental conditions, leaves of a date palm are 3 to 6 m long (4 m average) and can persist for 3 to 7 years. The greatest width of the frond midrib attains 0.5m, but elsewhere it is only half this size and rapidly narrows from the base upwards. The frond midrib or petiole is relatively triangular in cross section with two lateral angles and one dorsal. It is bare of spines for a short distance but full of spines on both sides thereafter (Fig. 1). Intermediate zones have spine-like leaflets, also called leaflet-like spines (Zaid and De Wet., 1999a). At the tip of the leaf, there may be a single terminal leaflet or two leaflets forming a V-shaped leaf structure, is variety and environment dependant, but usually the whole length of a frond has the following proportions (Zaid and De Wet., 1999a):

- The distance from the fiber at the base of the frond to the base of the spine-leaflet is bout 28% of the whole frond;
- The spine-leaflets occupy about 4%;
- The leaflets occupy about 62%; and
- The terminal leaflets occupy about 6%.

One important date palm pruning process is the removal of spines also called thorns (Zaid and De Wet, 1999b), which have not been mechanized yet (Brown et al., 1983). It is advantageous to annually remove spines from the base of new leaves in order to facilitate pollination and handling of fruit bunches. Cut thorns, themselves are a source of some danger, because they lodge in leaf bases on the soil where they persist as a hazard (Zaid and De Wet, 1999b).

Date spines are usually removed from the new growth of fronds in the crown of the palm just before the pollination season to allow easy access to the palm spathes as they emerge. If the palms have dethorned the previous year, the new growth will be 2-3 rounds of fronds, each round developing 13 new leaves, a total of about 26-36 fronds to be dethorned (Zaid and De Wet, 1999b). Such operation will ensure:

- Avoiding of any risk of injury to laborers, especially the eyes, during technical practices such as tying down, protection of bunches, harvesting, etc (Zaid and De Wet, 1999b).
- Providing a safe approach to the spathes for their pollination and other related cultural practices (Al-Suhaibani et al., 1990, Hashempur, 1999, and Zaid and De Wet, 1999b).
- Reduction in fruit-spine interaction and as a consequence reduction of fruit damage (Albozahar, 2003).

It is common to use dethorning knives of various designs to remove these spines: a long sharp curved blade or pruner mounted on a wooden handle 30 to 45 cm long, or sickle type blade with a sharp cutting edge (Zaid and De Wet, 1999b). Now-a-days this operation is rarely done in dates producing regions of Iran. In some regions a regular sickle “Das” is used. By this tool, the spines of one side of the midrib are cut as the tool moves from the leaflet-like spines zone to frond base or vice versa, and then repeated for the other side. First way will led to a slow and tedious operation with increased midrib injuries. In the latter way the midrib injuries are less in comparison, but cutting of spines becomes incomplete and the operation must be repeated for many times. Another tool is also used in some regions. This tool, which is called “Kajak”, is consisted of a fine curved blade with a 40 cm wooden handle. By this tool, the spines of one side of the midrib are cut only in one direction as the tool moves from the frond base to leaflet-like spines zone and then repeated for the other side. Also in this case the operation is slow and tedious but the midrib injuries are less in comparison with the sickle. Handles of both tools are short and the worker is maintained in the hazardous region (Albozahar, 2003).

A hydraulic lopper is developed by Iran Scientific and Industrial Research Organization as a part of date palm service machine. It was suggested that this lopper could be used for dethorning in conjunction with the date palm service machine (ISIRO, 1998), but this tool also suffers from lack of safety and its capital cost is out of farmers' ability (Albozahar, 2003).

Ahmad et al. (1992) have measured the required force for cutting date palm midrib. Maximum of 3000 Pa have been attained to cut the midrib, which was belong to dry leaves. Marzban et al. (2005) has also reported the maximum cutting force of date palm frond midrib as 295.53 $N.cm^{-2}$.

There is no any device developed especially to dethorn the date palm fronds yet. Thus this research has been carried out in order to develop a suitable date palm dethorning device with the following criteria:

- Decreased operation time;
- Enhanced worker safety;
- Low cost.

MATERIALS AND METHODS

The design process is a complex and flexible intellectual process, the strategy used to solve the dethorner development problem is shown in figure 2. Based on the selected strategy, steps in the design process are as follows:

Step 1: The design criteria are defined in this step. These criteria restrict the design extent and will better guide the process. These criteria will be used as the key criterion in the tool design.

Step 2: Design alternatives are created in this step. These alternatives, which are mainly the designer's viewpoint, are produced regardless of the design restricting criteria.

Step 3: This step is allocated for filling the information gap needed for detailed design of the device. As the selected proposal has been defined in general, the design information is classified and unavailable information is gathered based on their importance and extent.

Force and dimension characteristics of the date palm frond are needed in this step. The characteristics were unavailable. Thus 40 date palm fronds selected randomly from each of the important two Iranian varieties, “Sayer” and “Barhee” and the dimensional characteristics have been measured. Cutting force is also calculated based on the findings of Marzban et al. (2005).

Step 4: Detailed design of the device is done in this step based on the design proposal and related definitions. In this way the Autodesk® Mechanical Desktop package has been used.

Step 5: In this step the prototype of the device is developed and optimized against the design criteria. Repetition of one or more steps has been followed based on the design situation as it could be seen in Fig. 2. The optimized device would be ready at the end of this step.

Step 6: This is the last step and is consisted of evaluation of the device in the field. This was conducted in a randomized complete block design (RCBD) with three treatments namely; Sickle, Kajak, and the developed dethorner with 6 replications (palms). The measured factors, by which the devices evaluated and compared, were operation rate and workload.

Each palm has been selected as one replicate. Thus the evaluation has been done on 18 palms of cv. Sayer. The height of selected palms was in the range of 2-2.5 m. Dethorning is done for only two lower frond circles. The measured factors where number of dethorned fronds, operation time, and worker’s heart rate. Each block applied daily in order to prevent the environmental and worker health changes effects.

Mechanical tally counter and a strip meter were used to record the operated frond number and lengths and dimensions respectively. All time periods have been measured by means of a stopwatch. Worker heart rate has also measured based on multiplying of pulse counting in a 20 seconds by 3, and at last workload assessment has been based on the Table 1.

The data first normalized based on the average number of dethorned fronds for each palm which found to be 15 fronds and then dethorning time for each palm has been calculated according to the following formula by means of MSExcel2000® software.

$$T_{in} = \frac{N_i}{15} \times T_{ir}$$

T_{in} = normalized dethorning time for the *i* th palm

T_{ir} = measured (raw) dethorning time for the *i* th palm

N_i = number of dethorned fronds in the *i* th palm

The data then analyzed based on RCBD design using MSTATC® software. Comparison of treatments means was also based on Duncan's multiple test.

RESULTS AND DISCUSSIONS

A. Design

A.1 Criteria of the tool design

In order to clarifying the design boundaries, following criteria have been defined for the desired tool:

- High operation rate,
- Minimum worker hazards,
- Light weight,
- Low cost, and no need to any motorized power source,
- Low midrib injuries.

A.2 Creation of the design alternatives

The first step in development of the tool is reviewing of the current methods, operation principles and conditions and materials and then proposing of some alternatives for development of an optimum tool. Many alternatives have been created based on this method by the author. These alternatives then evaluated against design criteria and at last the one which is shown in fig. 3 has been proposed for the tool design.

A.3 Description of the proposed tool

In the proposed tool, a pole, which is long enough to maintain the worker out of the full of thorn zone, is used as the tool carrier, and has a head jointed on one side, which is held top in the operation. The joint pivot angle must be maximized as possible in order to fit large extent of operation conditions. The pivot must be fixed in the beginning of the operation, and on the other hand must be free to roll with operation progress, to follow the frond curvature. Two parallel counter moving blades are mounted on the head to clamp the frond midrib. In operation, the frond is restrained by the blades and the head frame, as a triangle clamp, and the thorns of two sides are cut by the blades as the head is moved in the thorn laying direction by the worker. The blade actuating mechanism is a simple lever which is mounted on the lower side of the pole. Two head and blade rollers are needed to facilitate the tool movement on the frond.

The blades actuating mechanism could be designed in two ways:

The blades are opened by the worker (via actuating lever) and are closed by the returning spring, or

The blades are closed by the worker and are opened by means of an opening spring.

Although the first mechanism could provide an almost constant force on the frond midrib, this force must be large enough in order to maintain the blades-midrib contact. In this way high spring constant is needed and consequently strength of the tool structure must be high. This will lead to a heavy tool, which restricts its applicability by the worker. In the later mechanism, in comparison, the opening force is small and the tool could be made light. In this way the tool-midrib compatibility could be obtained by means of providing a blades floating mechanism.

In the case of the tool fail, in the first choice, the tool head remain clamped on the frond and the worker must release the tool with difficulty. The problem is eliminated in the second mechanism. Thus the latter has been selected for the design of actuating mechanism.

A.4 Filling the information gap

Dimensional and cutting force data of the date palm frond midrib and spines were needed in the design. Cutting force has been estimated based on the findings of Marzban et al. (2005) and the following formula:

$$F_c = F_s \times A$$

F_c = thorn cutting force (N),

F_s = Specific cutting force ($N.cm^{-2}$),

A = Thorn cross section (m^2).

The thorn cross section is estimated to be less than $0.5cm^2$ (Albozahar, 2003). Thus the cutting force needed in the tool design is as follows.

$$F_c = 295.53 \times 0.5 = 148(N)$$

Forty fronds from each of two major Iran's date varieties namely: Sayer and Barhee have been selected randomly in order to obtain dimensional data of the date palm frond midrib. Typical midrib cross section is illustrated in figure 4.

The measured parameters were leaf and spine zone length, number of spines, size and angle of short, medium, and tall spines, and cross sections at the beginning, middle, and end of fronds. The results were as follows:

- The spine zone (dethorning stroke) occupies 24% of the leaf length in both varieties. Its length in Sayer and Barhee varieties was 70 and 97 cm, respectively,
- Wing length to width ration was 1.8, 1.36, and 1.24 at the beginning, middle, and end of the spine zone, respectively (figure 5). Maximum and minimum limits of length and width of the frond wing, usable in the tool design, were 20-75 and 15-48, respectively.
- Average number of spines on the fronds was 32 and 24 for Sayer and Barhee, respectively. Thus the spine interval was 3 cm for both varieties. Spine length was in the range of 10-282 mm.
- Spine tilt angle, which was defined as the angle between the midrib and the spine extension, varies in a large extent and its average was in the range of 9-74 and 9-117 degree for Barhee and Sayer varieties, respectively.

A.5 Detailed design

Blades

Two regular straight edge blades have been selected as the tool blades. The sharpening angle has been selected to be 20 degree (Sitkei, 1986). The blade free body diagram and the forces acting on it are shown in figure 6. Detailed analysis has been made using Autodesk® Mechanical Desktop (Albozahar, 2005).

Head

Overall dimensions of the head were calculated as follows.

$$L_d = \frac{L_{max} + L_{min}}{2} = \frac{75 + 20}{2} = 47.5 \approx 48mm$$

L_d = distance between the blades pivots

L_{max} and L_{min} = maximum and minimum lengths of the frond wing

The head depth has been selected to be 70 mm. thus each blade has two supports of length W. Detailed analysis has been made using Autodesk® Mechanical Desktop (Albozahar, 2005).

$$W = \frac{1}{2}(70 - 25) = 22.5\text{mm}$$

Other parts

A semi-restrained joint has been selected to join the head and the pole. It is consisted of two side plates and 4 balls and 4 springs. One meter and half hollow extruded aluminum tube of 22 mm outer diameter and 17.5 mm inner diameter have been selected as the tool pole. Further analysis has shown that the pole length could reach 2.3 meters of this type (Albozahar, 2005).

The actuating lever has been selected to provide 15 mm longitude displacement. The force and movement is transmitted to the head via two shielded flexible steel cables of 1 mm overall diameter. Full analysis are made using Autodesk® Mechanical Desktop (Albozahar, 2005). The developed tool is shown in figure 7.

B. Evaluation

The results of variance analysis for the operation time and worker's heart rate are shown in tables 2 and 3.

B.1. Operation rate

Duncan's test has shown a significant difference in operation rate between the developed dethorner and the two other conventional devices (Fig. 8). Based on the results, the new device is 1.51 and 1.74 times faster than Kajak and sickle respectively. Also the related saving in operation time are 34 and 43 %.

B.2. Operation intensity

Although the worker's heart rate in the new device is lower than the others (Fig. 9), that there is no significant difference in operation intensity between the treatments (Table 3).

CONCLUSION

In this research, a new date palm dethorning device has been invented and developed to remove the spines (thorns) off the fronds safely and fastly. This device is consisted of 1.5 m aluminum pole, a jaw mechanism, two counter moving blades, some rollers to facilitate the device-frond interaction, a lever on its lower end to actuate the blades, and two shielded cables to transmit force and movement from the lever to the jaw. It requires only manpower and only one worker is able to do the operation.

Preliminary evaluations of the new device have shown that the operation time could be reduced up to 2 minutes per each palm. Based on the results, the new device is 1.51 and 1.74 times faster than Kajak and sickle respectively. Also the related savings in operation time are 34 and 43 %. Furthermore the long pole of the device eliminates the need for climbing the palm of heights up to 2.5 meters and also reduces the hazards of the worker being hurt by the date palm spines. Maximum operation height of the device is 2.5 meters and could be enhanced by using other optimum poles.

This device is patented in Iran's Patent Office.

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TABLES

Table 1: Assessment of worker's workload (Smith et al., 1994)

Workload assessment	Worker heart rate (pulse/minute)
Very low	60-75
Low	75-100
Moderate	100-125
High	125-150
Very high	150-175
Extremely high	>125

Table 2: Analysis of variance of operation time

Source	df	SS	MS	F	Probability
Treatment	2	32601.444	16300.772	13.995	0.0004^{**}
Replication	15	17471.667	1164.778		

cv. 17.43, ** significant at probability of 1%

Table 3: Variance analysis of worker's heart rate

Source	df	SS	MS	F	Probability
Treatment	2	143.444	71.722	2.337	0.1308^{ns}
Replication	15	460.333	30.689		

cv. 5.78, ^{ns} non-significant

FIGURES

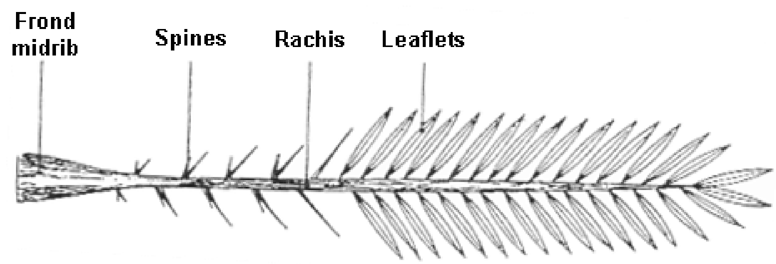

Figure 1: Date palm leaf characteristics (Zaid and De Wet. 1999a)

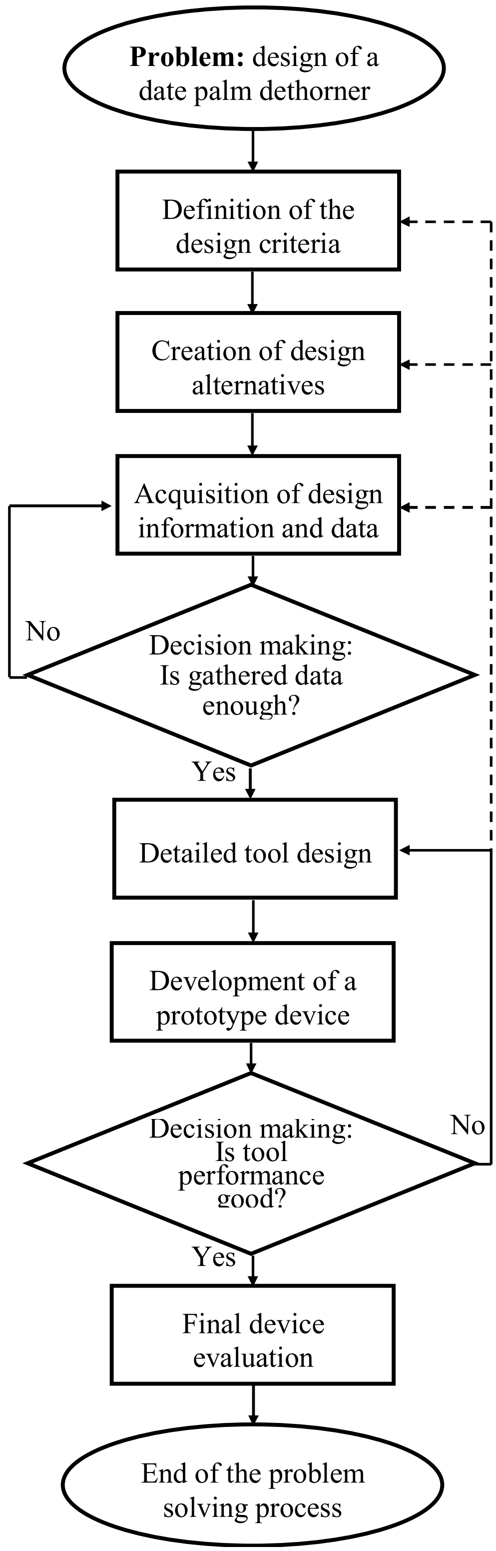

Figure 2: Strategy used to solve the dethorner development problem

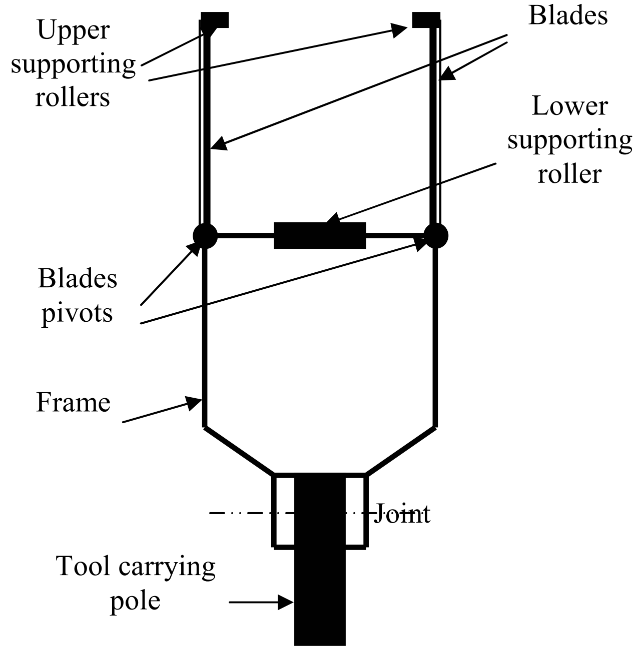

Figure 3: Proposed alternative for the dethorner design

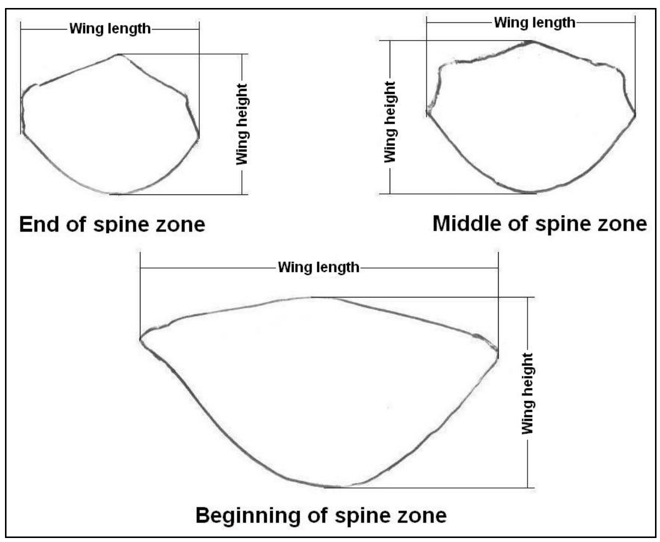

Figure 4: Typical cross section of date palm frond midrib (Albozahar, 2003)

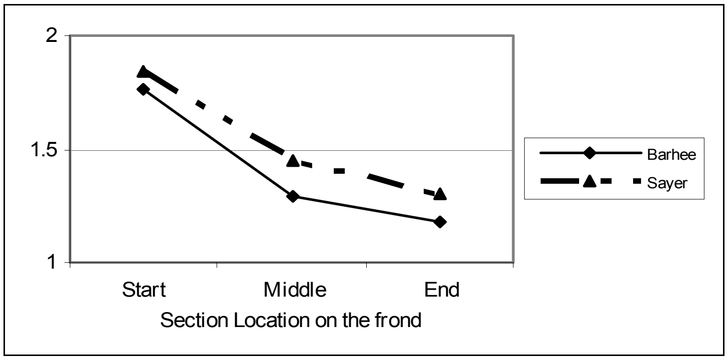

Figure 5: Changes of (L/W) dimensional ratio of the date palm frond midrib

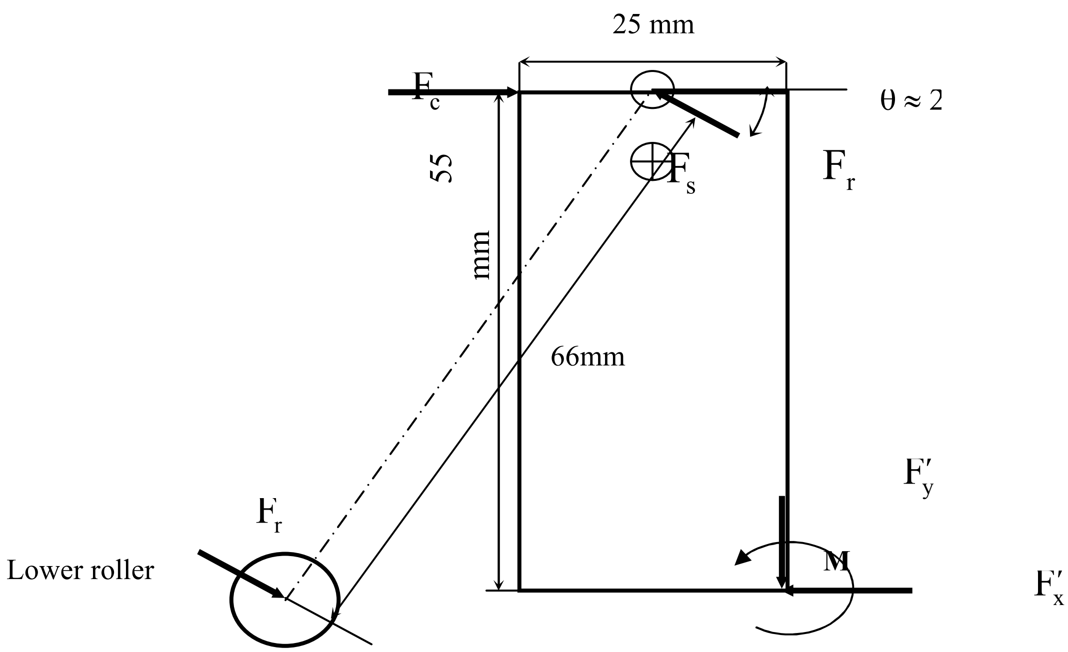

Figure 6: Blade free body diagram and the forces acting on it (Albozahar, 2005)

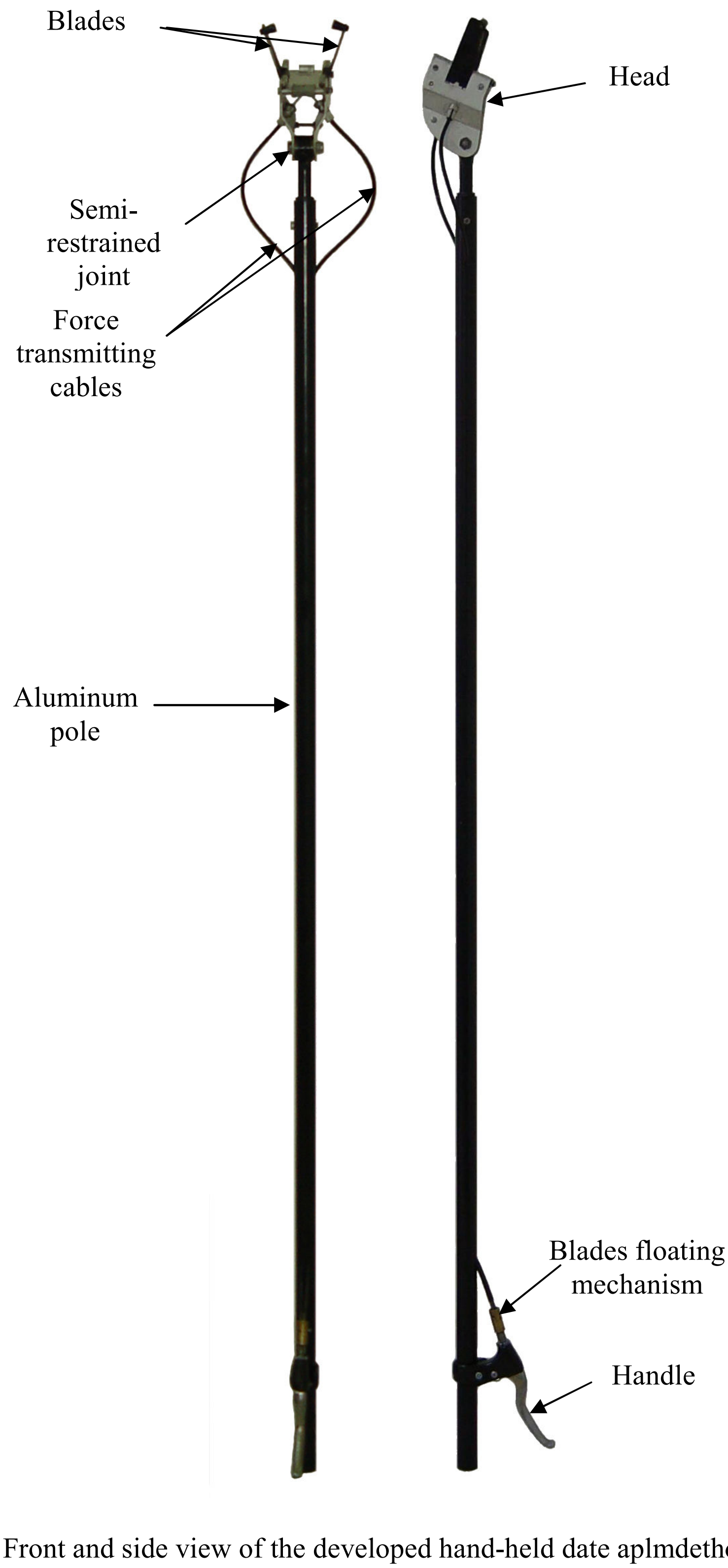

Figure 7: Front and side view of the developed hand-held date aplmdethorning tool

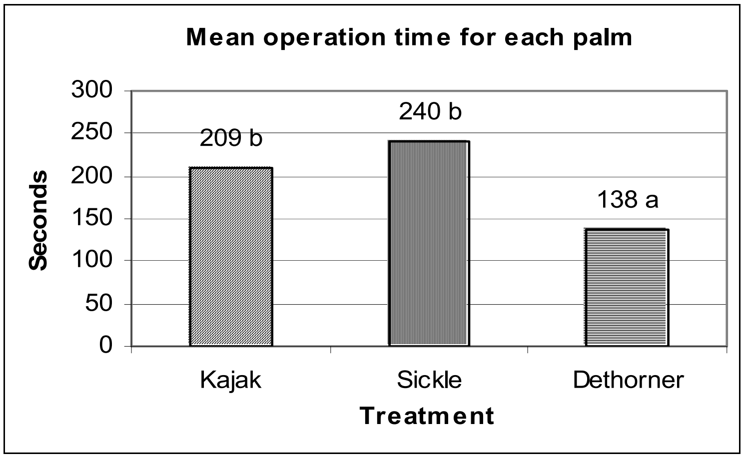

Figure 8: Comparison of operation time for three dethorning devices

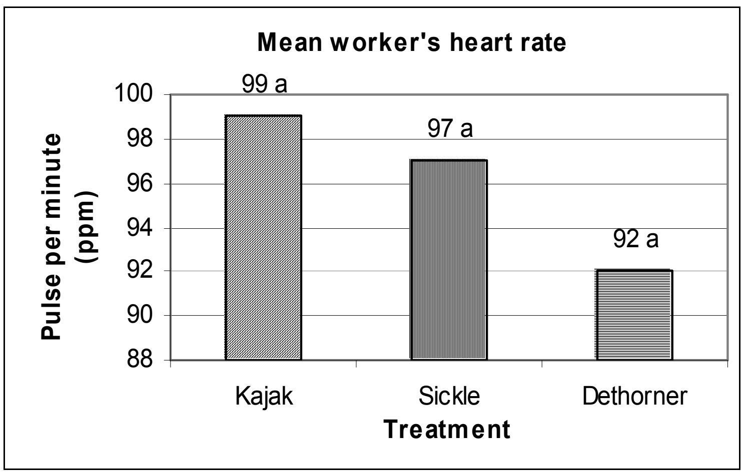

Figure 9: Comparison of operation intensity for three dethorning devices