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Short Communication

Design and development of a date palm pruner

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Abstract: Date palm pruning is one of many services to be carried out in the date palm growing fields. It is the elimination of a great part of dry frond bases around the tree trunk to protect the tree from the inhibitors and accumulated rain and the possibility of infection with fungal diseases. An experimental prototype of a hand held pruner is developed, fabricated and tested under laboratory conditions. The developed pruner can be operated using various types of prime movers such as drills, hydraulic motors, pneumatic actuators or mechanical drivers. A cordless drill drive is used to drive the pruner and has been tested. Test results showed that low feed rates produced a cleaner cut surface. More field tests are needed to examine prototype performance under field conditions.

Keywords: date palm, pruning, tree trimming.

تصميم و تطوير جهاز لتكريب نخيل البلح

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ملخص: يعتبر تكريب نخيل البلح واحدة من العمليات المتعددة التي تجرى لأشجار النخيل سنويا حيث يتم ازالة جزء كبيـر من قواعد الأوراق حول جزع الشجرة لحمايته من الحشرات التي يمكن أن تقطن هذه الأماكن بالإضافة لتقليل كميـة ميـاه الأمطار المتجمعة و التي تهدد الأشجار بالإصابة بالأمراض الفطرية. و قد تم تصميم و تصنيع نموذج أولـي تجريبـي و اختباره تحت الظروف المختبرية. يمكن تشغيل الجهاز عن طريق عدة أنواع من مصادر القدرة مثل آلات الثقب الكهربائية و المحركات الهيدروليكية و الهوائية و مصادر القدرة الميكانيكية. و قد تم استخدام آلة ثقب تعمل بالبطارية لتشغيل الجهاز و قد تمت عملة الاختبار التي أظهرت أن سرعات التغذية المنخفضة أدت الى حدوث قطع نظيف أفضل منـه فـي حالـة سرعات التغذية العالية. ويحتاج الجهاز الى المزيد من التجارب الحقلية لاختبار قدراته تحت الظروف الحقلية.

كلمات مفتاحية: نخيل البلح، التكريب، تهذيب الأشجار.

Introduction

Growing date palm trees in the Middle East is a traditional life style where the domestic weather provides an excellent environment for such plant. There are more than 40 million date palm trees in the United Arab Emirates, producing about 760,000 tons of dates (FAO (2005)). Servicing date palm trees used to be carried out manually and consumes many man-hours all round the year. Palm tree pruning is one of the traditional services done annually. Workers use a chisel and a medium duty hammer to cut the base of the leaf from the tree. Even though this method is the dominant procedure for palm pruning, it consumes lot of time and energy.

The objective of this research is to design and manufacture a novel pruning tool to help farmers to get the job done with less effort. The developed pruner should be light in weight and could be driven via various prime movers such as cordless drills, pneumatic and hydraulic motors, as well as mechanical power sources. It also should give the user full control over the sawing specifications, such as direction, feed rate and cutting depth.

Although manual and mechanically driven pruning shears are widely used in horticulture industries, the available tools for date palm pruning are very basic and wasteful of power. A market survey in the United Arab Emirates showed that various pollinators and general purpose sprayers are available on the market, in addition to different models of shrub trimmers, but there is no mechanical palm pruner.

Zaid and Wet (1999) pointed out that the trunk of the date palm tree is composed of tough, fibrous vascular bundles cemented together in a matrix of cellular tissue which is much lignified near the outer part of the trunk. They added that the trunk is covered for years with the bases of the old dry fronds, making it rough, but with age these bases weather and the trunk becomes smoother with visible cicatrices of these bases. Depending on the variety and age of the palm and environmental conditions, leaves of a date palm are 3 to 6 meters long. The greatest width of the frond midrib attains 0.5 m, 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.

The benefits of palm tree pruning are to clean the tree trunk so it would not be suitable for insects' accommodation; in addition less rain would accumulate on the trunk area. That reduces the risk of fungal diseases.

Yamashita (2001) studied a cutting system with a fixed blade on top of a rotary blade; he focused on protecting the operator from the scattering chips, and Womac et al. (2005) investigated shearing characteristics of biomass for size reduction and concluded that the moisture content of the biomass influenced failure stress and energy requirements.

Parish (1998) compared the operating force requirements for manual pruning shears. He stated that there are many references to pruning and pruning shears in the literature, but they did not address hand force or efficiency. He added that many references mention cooperative extension services to educate growers, in addition to some research papers detailing various aspects of pruning.

Ochs and Gunkle (1993) simulated the field performance of a robotic grape pruner and Tanaka (1997) developed a machine for removing stumps, while Mongkol (1997) designed three hand operated orchard pneumatic pruning machines. He used a reciprocating pneumatic cylinder to actuate the cutter blade.

Lehman (1995) defined the purposes of a saw tooth as to remove a chip from the wood being cut and carry the chips out of the cut. He formulated the maximum feed speed for a given depth. He added that the cutting force that pushes the blade sideways is not a single number. It is known, however, that it is affected by the characteristics of the wood such as density and moisture content. The one aspect of the cutting force that can be measured or calculated accurately is the power. It has the properties of being affected by the wood properties and cutting conditions.

Materials and Methods

Dimensions of frond bases were recorded and the average of each of them was considered in the design process. Figure 1 shows technical drawings of the developed pruner. The final design satisfied both operator and tree considerations. It was critical for the developed pruner to be safe, light, flexible and affordable.

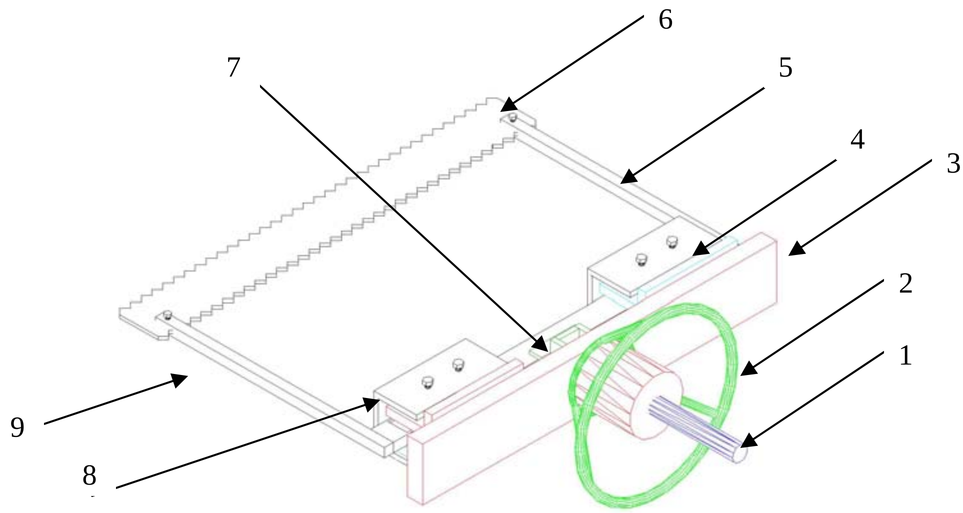

Figure 1. Three dimensional drawing for the developed pruner

It was necessary to keep the pruner open to be driven via any available prime mover. It drive shaft (1) is 10mm Carbon Steel and can be connected to a wide range of power sources such as an electric drill, pneumatic or hydraulic motor or even a connection to the PTO if it is more convenient for the operator. A group of ball bearings hold the shaft in a bushing welded to the main body (3). The drive shaft ends with a 10mm stroke crank (7) causing reciprocation of a rectangular bar which is sandwiched between four groups of 7 mm diameter rollers and four holding brackets (4 and 8). Two square bars (5 and 9) are attached to the rectangular bar on one end and hold the blade (6) on the other end. The operator can hold the pruner by the handle (2) in one hand and the prime mover in the other hand. This design helps the operator to rotate the whole pruner around the shaft to create an inclined cut if needed. A LG L272 cordless driver drill from LG Industrial Systems Co. Ltd. was used as the pruner driver, and the mechanism has been tested in the laboratory (Figure 2).

Pruner Specifications:

Total weight	1703 gm
Blade width	250mm
Blade linear speed	150m/min
Maximum depth	100mm

Driver specifications:

No- load speed	750 rpm
Maximum torque	12 Nm
Weight with battery	1300 gm

Straight and curved plain blades in addition to a champion tooth blade were used to test the pruner as shown in Figures 3 and 4.

Laboratory testing

The pruner was tested in the laboratory and it succeeded in performing satisfactorily. The cutting time was recorded, in addition to the cut surface roughness, in order to judge the pruner’s performance. Testing the champion saw blade was not possible due to its high vibration, and because the operator was not comfortable working with it. However, it was possible to test the straight saw blade, and it showed promising results.

Safety Precautions

The developed machine should be operated under strict safety rules. Safety gloves in addition to goggles must be used by the operator who should be well trained before starting the machine.

Frond base characteristics

Average dimensions of span (S), internal height (Hen), thickness (T), and external height (Hex) are 17.8, 2.2, 4.2, and 6.4 cm respectively.

Results and Discussion

An experimental prototype of the designed pruner was fabricated locally and tested in the laboratory. Several modifications took place before acceptable performance was achieved.

Figure 2. The manufactured pruner

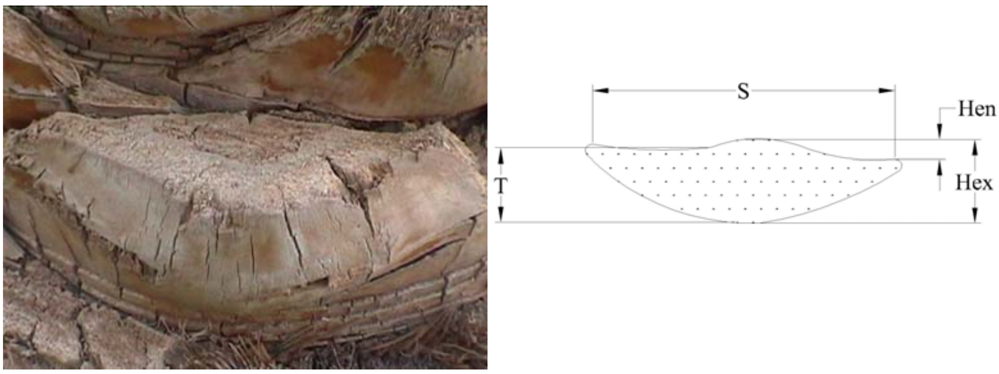

Figure 3. Frond base schematic

Figure 4. Normal blade (above) and Champion blade (Down)

System force analysis

Generally speaking, the summation of forces needed to cut the material, eject the formed chips, overcome friction and the components' inertia should be considered as the total force required to be generated by the prime driver. The total force required to drive the pruner may be classified into four categories, cutting, chips ejecting, friction, and forces due to inertia of the blade, rectangular bar and square bars. Cutting force is the summation of the cutting forces on all acting teeth in the same time. It was suggested to use a straight saw blade in order to reduce number of teeth effectively cutting the parabolic frond base at the beginning of the cutting operation; hence more force would be available on each acting tooth to cut the hard surface material.

Friction forces consist of the sliding friction force due to moving the blade through the frond texture (gullet friction) and rolling friction due to moving the rectangular bar through the rolling bearings between the holding brackets.

Gullet friction

$$F_b = \mu_b \times N_b$$

Where

- F_b friction force between blade gullet and frond material
- N_b Normal force between blade gullet and frond material
- μ_b coefficient of friction

Rolling friction

$$F_r = \frac{\eta_r}{r} \times Nr$$

Where

- F_r friction due to moving the rectangular bar between roller bearings
- η_r rolling friction coefficient
- r roller radius
- N_r normal force between rollers and rectangular bar

Inertia force

$$F_h = W_s \times R \times \omega^2 \times \cos\phi_c$$

Where

- W_s mass of the blade holder and blade
- R radius of crank pin rotation
- ω crank angular velocity
- φ_c angle of crank rotation

Cutting force plus friction force between tooth and the generated chip

Cutting force

$$F_c = K * S_c * F$$

Where

F_c cutting force, N
K cutting stiffness of frond material, N.min/cm^2
S_c span being cut, cm
F federate, cm/min

The force is then dependent upon the feed rate. Also, the time is inversely dependent on feed rate

$$time = H_{ex} / F$$

Where

Time cutting time, min
Hex fond height, cm

Total operational force

The total operational force for the pruner could be concluded as FT

$$FT = F_c + F_h + F_r + F_b$$

Testing results

As shown in Table 1, laboratory testing results showed that the experimental prototype of the pruner performance was excellent when the feeding speed was low.

Table 1. Laboratory testing results

Test #	Feeding speed	Cutting time min.	Cut surface condition
1	Low (5-7 cm/min)	1.25	Excellent
2	Medium (8-10 cm/min)	0.70	Excellent
3	High (10-15 cm/min)	0.42	Very Good

Conclusions

An experimental prototype of a hand held pruner was developed, manufactured and tested in the laboratory and performed satisfactorily. The developed pruner was tested under different feeding rates; the resulting cut surface was excellent when the feed rate speed was low (5-7 cm/min.) and medium (8-10 cm/min.), whereas the surface condition was very good when the feed rate speed was high (10-15 cm/min). The feeding force exerted by the operator was difficult to measure and left to future research work. On the other hand, field testing will be addressed in a future research paper.

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