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A REVIEW ON THE MECHANIZATION OF DATE PALM CULTIVATION

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Abstract: *Date palm is an important cultivation for arid regions and its cultivation is expanding, though challenges for its modernization still remain partially unsolved: the mechanization of the most important farming operations is not fully developed, though various attempts have been carried out over time. The aim of this review paper is to provide an overview on the most characterizing research works directed at mechanizing farm operations for date palms on the three main morphological zones: crown, trunk, and roots. Various parameters such as maneuverability, working height, payload, cost, and working capacity have been considered by different authors for the performance analysis of their proposals, though safety is considered by all the main driver of the research. The projects that have been developed and the relevant results can provide a useful reference for those who want to engage in further developing this sector or in applying some of the more effective proposed solutions. In order to promote this field of research, these attempts of mechanization of date palm cultivation need to concretize it with commercialised devices and machines mainly by strengthening the channels of technological transfer between the university and the socio-economic world on the one hand, and by encouraging the industry to adopt these research results, on the other.*

Keywords: *date palm, mechanization, harvest, pollination, rural development, mechanical equipment, service machine.*

1. Introduction

The date palm (*Phoenix dactylifera* L.) is one of the oldest known crops; this plant first appeared in the fifth millennium B.C., in the south of Mesopotamia. During the Bronze Age (around 3000 B.C.), oasis agriculture experienced a notable development and this type of agro-system could be located in various parts of the Middle East [62].

Nowadays date palm is cultivated in 30 countries with a total yearly production of 8.1 million tons. The first five producers are Egypt, Iran, Algeria, Saudi Arabia, and Iraq, which contribute to more than 60% of the total world production [25]. Most of this production is consumed locally, as in

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Egypt 90% is used as animal feed and in Algeria only 2% goes for export.

The date palm is a large palm tree, 15 to 30 m high, with a cylindrical stipe (often improperly called trunk), bearing a crown of leaves (fronds or palms). The leaves are 4 to 7 m long, pinnate, finely divided into leaflets, and inserted on the stipe through a large petiole. The species is dioecious: male and female flowers are carried by different trees; they are clustered in inflorescences, called spadices and enveloped by a large membranous bract, the spathe. The female flowers have three independent carpels, only one of which develops to form the fruit. Due to the length of the vegetative phase of the palm, the sex of a plant is detectable only after 6 to 8 years. The fruit, called dates, are grouped in spikelets to form bunches: they are drupes, with sweet flesh surrounding a bony "core" which is the seed.

The date palm requires special tending, due to its particular structure. Cultivation operations can be divided into three categories, namely: work related to the soil, to the trunk, and to the crown [47]. Concerning the trunk and the crown, the characteristics and height of the plant oblige the farmers to timeless and physically demanding and dangerous efforts, which raise costs and reduce skilled labor availability and timeliness of operations. Ferry [26] reports that the increase in workload for the date palm sector is due to several factors, among which the increase in the number of cultivated plants and the scarcity and aging of the skilled work force. As for other crops, it is foreseeable that mechanization could address these issues, but until now this sector has not sufficiently advanced for this crop.

Agricultural mechanization is the process of improving farm labor productivity through the use of agricultural machinery, implements and tools [32].

Attempts to mechanize date palm cultivation go back to the half of the last century: from 1924 until 1979, in the United States, the cultivation of date palm knew a notable evolution in terms of production, changing from a family scale to an industrial scale cultivation, which is witnessed by the large number of patents registered, especially in the packaging sector [18], and in 1961 a program to mechanize the cultivation was launched [55]. Among the results of this program, six types of pollination machines were marketed at the end of 1973. Perkins and Brown [54] mention that in 1966 about 65% of the date harvest was done mechanically, though this refers more to mechanically assisted operations. Later on efforts were addressed mainly to the harvesting operations, and these efforts principally consisted in adapting equipment from other sectors than in the development of new, special machines, though various specific tools and machines have been designed and tested for this crop.

The purpose of this work is to review the main studies that have been carried out in the field of date palm mechanization, in order to provide an overview that can be useful for those who want to engage in further developing this sector or in applying some of the more effective solutions.

Other attempts have been carried out to provide a synthesis of what has been done in this field, most of which were presented in international or national conferences or seminars. Akyurt [8] gave a presentation

on the mechanization of the date palm, mainly focusing on the crown operations, and so did Abounajmi [4] in the annual international meeting (Canada), showing the mechanization attempts of date fruit harvesting, as well as Al-Janobi [11], [12], who presented the efforts made to mechanize cultivation operations at the top of the tree, while Nourani [49] reviewed a list of machines that allow the operator to reach the crown of the tree.

Differently, this work focuses on all the cultivation operations for the three levels, soil, trunk, and crown, reviewing prominent scientific literature but also presenting minor works and unpublished documents on this topic. Previously, Garbati Pegna [28] had published a pamphlet on machinery and equipment suitable for date palm cultivation, but it was limited to Italian products that were available on the market.

2. Cultivation Operations at the Crown Level

Brown [20] reports that harvesting, pollinating, and pruning the palm takes over 80% of the cost of producing dates. The traditional method for reaching the top of a date palm, adopted in most producing countries, is climbing up the stipe with the aid of a strap. This tool consists of a band about 0.2 m wide and 0.8 m long, whose ends are connected to a rope about 2 m long. The climber passes one end of the rope around the stipe and then ties it again to the band which he has arranged on his lower back to act as a back rest or a seat. The operator then climbs up the tree using the scars of the old petioles as footholds and balancing himself by holding the rope tense at the level of his breast, making it slide upwards along the trunk while ascending (Figure 1).

This method is physically demanding and requires the operator to be skilled and to possess a significant physical condition besides patience and concentration, and to be able to carry out this task repeatedly during the working day. Sometimes farmers use ladders which allow to access lower palms or to limit the climbing effort to the upper part of the taller ones, but this case is rarer. The ladders used are standard leaning type, normally in the range of 3-5 meters and are usually used with no safety precaution, making it also a risky operation not much safer than climbing.

Fig. 1. *Rope for climbing*

In order to address the safety and hardship issues of reaching the top of the palms, researchers have proposed various solutions based on mechanical ads to lift an operator to the palm crown height. The simplest of these solutions are based on tree climbing devices, operated manually or powered by small engines, while the

most complex and efficient ones rely on hi-lift equipment, powered by larger engines and mechanical or hydraulic transmission.

Ahmed et al. [6] collected some basic information for use in machine designing in El Hassa Oasis in Saudi Arabia measuring tree height, trunk circumference, crown length, and leaf cutting resistance. Keramat Jahromi et al. [40] measured various morphological parameters of date palm trunks for the *Shahani* variety, such as the circumference in various sections, height, the distance between the lowest green leaves and the fruit, and crown height (the distance between the lowest green leaves and the initial point of the leaves at the top) for use in climbing machines design, finding that there is a correlation between these parameters. For this purpose, the same authors also [39] carried out various strength tests (flexural, compressive, hardness, and impact) parallel and perpendicularly to the trunk fibres. Similarly, Shamsi and Mazloumzadeh [60] studied trunk longitudinal tensile, compressive and shear strengths and radial compressive strength, together with leaf base longitudinal and radial compressive and shear strengths.

A survey, functional to developing a service machine for date palm cultivation, was conducted in 37 farms in Biskra province by Nourani et al. [53] who determined various parameters such as number of tractors, irrigation mode and ground profile, palm number, density and distance, and bunch position on the palm tree. However, these studies show the specificity of each region in terms of orchard architecture and cultivation technique.

Abdalla et al. [3] developed a walk-up elevator consisting of a long modular beam with a rail where two pedals are inserted with a hooking/unhooking mechanism which allows the operator to ascend and descend along the beam by acting on them as if pedalling a bicycle. A seat makes work more comfortable when the desired height is reached (Figure 2). In 1987, Al-Suhaibani et al. [15] developed a prototype of a machine for serving date palms within a research program launched by the University of KSA. The machine was a hydraulic lifting platform mounted on a 50 kW 4WD truck, able to reach a height of 14 metres. The platform was characterized by a U-shape that allowed the operators to reach all around the palm without having to move the boom once lifted. As shown in Figure 3, this machine was later tested and evaluated against manual work [14] proving it allowed to work fast and safely, though the cost was quite high; in addition, these authors designed a pair of portable bridges to facilitate machine movement across irrigation and drainage systems [13].

Fig. 2. *Walk-Up elevator* [3]

Bankhar and Akyurtin [17] designed a mechanical tree-climber and carried out computer based simulations to calculate forces and verify the stability of the machine during its movement. This machine basically consists of a power unit and a service platform with anchoring brakes, suspended through cables from a climbing gear composed of a 1.8 kW internal combustion engine and two sets of rollers, connected by a flexible system of four arms that can adapt to differences in trunk diameter (Figure 4).

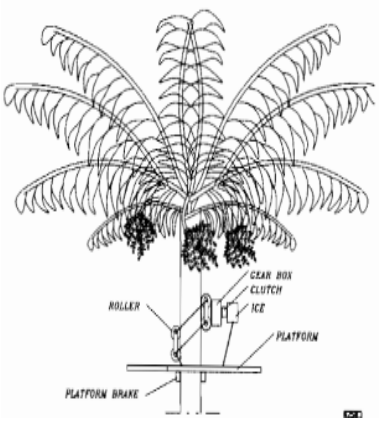

Fig. 3. *Prototype d'Al-Suhaibani et al.* [16]

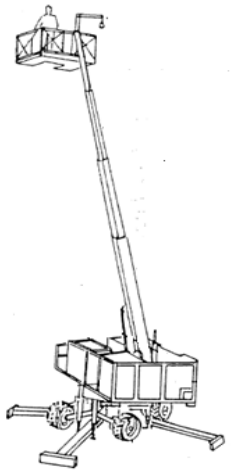

Fig. 4. *Plateforme élévatrice* [17]

Fadel Moustafa [23] developed a prototype of an elevator for serving date palms; this machine was mounted on a tractor in order to exploit its 'self-displacement capabilities' and its hydraulic and electrical systems, and was based on a V-shaped basket-like structure, which is sustained by two hydraulically driven aerial booms, connected to a bar attached to the rear of the tractor's body via three hitching points (Figure 5). The machine can lift an operator up to the crown zone at a maximum height of 4.5 m; to allow the operator to reach around the trunk, the platform is provided with two extensions on the sides and a folding deck that can be lowered to help go around the tree, and then folded up again when the machine needs to move. A hydraulically driven winch was available to lower the harvested dates to the ground. The machine was forecast to cost about 14,000USD and the author calculated that the use of this device was more profitable than the traditional method in terms of safety and time saving. A self-moving ladder was developed by Garbati Pegna [27], consisting of a telescopic ladder extendable up to 15 m, mounted on a tracked carrier to make it self-displacing (Figure 6). The movement of the carrier is controlled by a hydraulic system, while the extension of the ladder is carried out with a manual winch. Extending and adjusting the ladder to the maximum height takes approximately 60 seconds. In the same year Keramat Jahromi et al. [41] proposed a study of a hydraulically operated climbing machine designed with Solidworks® software and based on two grippers connected to a complex telescopic frame which can be folded to embrace the palm stipe (Figure 7). The

grippers are opened and closed alternatively while the frame is vertically extended and contracted, thus simulating the movement of a person climbing up and down a pole.

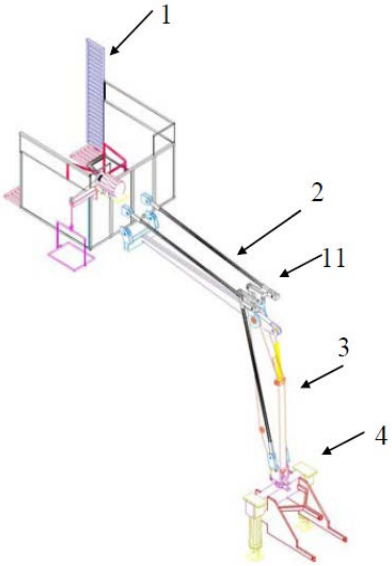

Fig. 5. *Elevator mounted on* tractor [23], [24]

Fig. 6. *Self-moving ladder* [27]

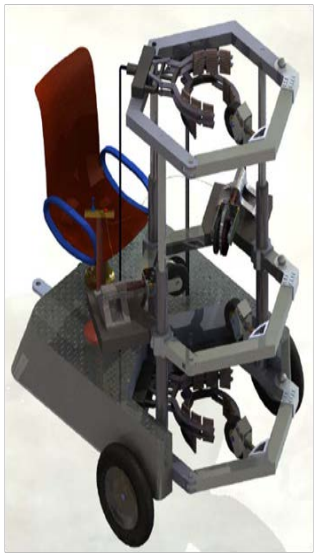

Fig. 7. *Climbing machine* [39], [41]

Other authors have focused their work on adapting or simply evaluating the performances of existing equipment, even if conceived primarily for different purposes. Hassan et al. [31] made an attempt to integrate in palm groves a self-moved hydraulic elevator and a tractor mounted aerial platform, intended for construction and public works, by evaluating their basic performances and carrying out some modifications, though only the aerial platform gave positive results. A more holistic analysis was carried out by Thwainy et al. [63] who compared and evaluated six different conceptual designs of machines for carrying out date palm crown related services: the evaluation was done on four criteria, i.e. performance, navigability, reliability and safety, and affordability; a value was given for each criterion and a formula used for assigning a score to each design.

Similarly, Mazloumzadeh et al. [44] used MFIS to evaluate and classify 10 different models of general-purpose lifters available

on the Iranian market to find the most suitable one for servicing date palm plantations in Iran, in similar work achieved by Alavi et al. [9] using another method which is AHP. The lifter parameters considered were working height, length, width, payload capacity and price, while the plantation parameters were inter and intra row spacing, distance to the nearest tree, yield and trunk height; the results were compared with the judgment of human experts and showed an average of correspondence of 85%. The lifter who was found the most appropriate for the region, though it only fell in between the third and fourth of the 5 ranking classes that were established, had a working height of 12 m, a length of 4.1 m and a price of 2,000 USD. More recently, Nourani et al. [51] used hierarchical multi-criteria analysis to determine the most appropriate aerial work platform machines for Biskra Region, in Algeria. The scores obtained showed that the tractor mounted type elevator is the more reliable, followed by elevators with articulated boom lift, which represent a concrete alternative to the palm tree climbing method.

In 2018, Bonechi et al. [19] evaluated a commercial model of light aerial platform, designed for moving on rough terrain with the aim of addressing problems of crossing ditches and other uneven spots and of soil compaction that are common for heavy equipment designed for building or industrial services or for “regular” palm layout. The platform, which was provided with electric and compressed air connections in the basket and was integrated in an 8.3 kW four-wheel drive small tractor, could reach a height of 11.8 meters and was found able to reach and easily work in areas where access for larger machines would not be possible, without upsetting the soil structure and the environment.

3. Dethorning

This operation consists in removing the spines (or thorns) from the palm frond petioles in order to facilitate other operations such as pollination and handling of fruit bunches and reduce fruit damage; this operation is traditionally done with the use of knifes or sickles of different design, hand-held or mounted on wooden poles [10], [65]. Mostaan [46] developed a hand-held date palm dethorning device consisting of a 1.5 m aluminium pole, a jaw mechanism and two counter moving blades (Figure 8) and proved it considerably reduces the operation time, thus increasing the operators’ safety.

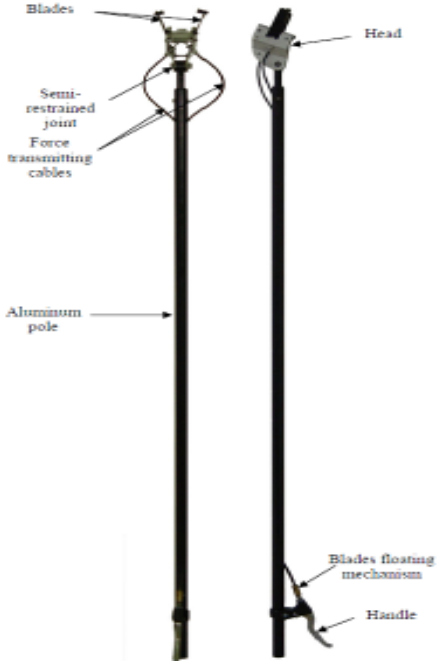

Fig. 8. *Dethorning device* [46]

4. Pollination

As the date palm is a dioecious plant, manual pollination is a fundamental operation which increases the quality and quantity of production; traditionally it consists in tying two or three male spikelets vertically to the female spathe. The pollen is harvested just after the opening of the male inflorescence and the spikelets are separated and kept in a cool and ventilated room until they are needed.

This operation is laborious, especially if the palm trees are high, because it might require climbing up from two to five times. Because of the importance and the labor intensiveness of this operation, several works have been conducted to attempt mechanizing the pollination. Ibrahim et al. [33] developed a mechanical date palm pollinator called Al-Nahreen pollinator (Figure 9).

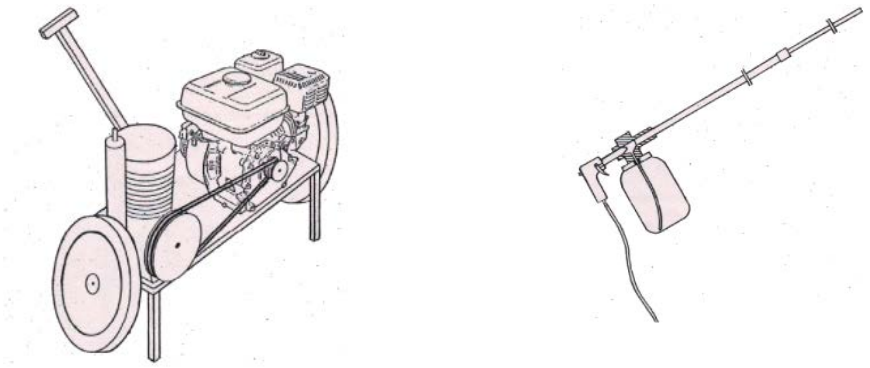

Fig. 9. *Al-Nahreen Pollinator* [33]

It is based on a small compressor carried in a wheel barrow and a driven heat engine which supplies air to a spray gun with a pollen basin and an 8 meter aluminium pipe. The tests conducted with this machine showed a considerable increase in profitability, with a 60% reduction in the use of labor and an operating cost of only 8% of that for traditional hand pollination. A similar pollinator device has been designed, developed and, tested by Loghavi [42] on palms ranging from 3 to 15 m, for two successive years in Iran (Figure 10).

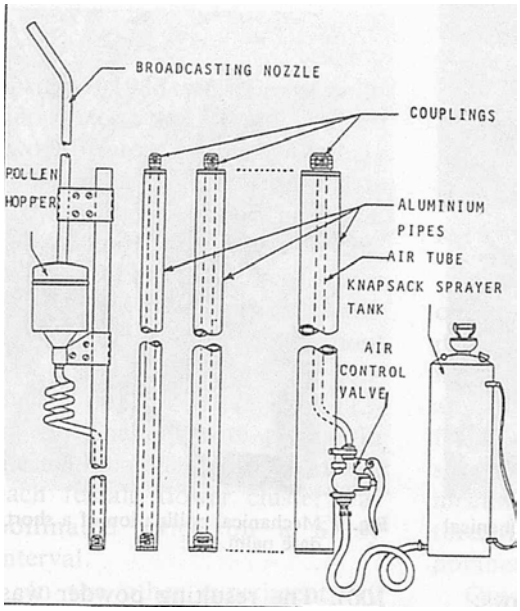

Fig. 10. *Pollinator* [42]

An electric micro-duster for delivering pure pollen was developed and tested by Haffar [29]. The duster consisted of a dusting system, a power and control system, and an extension and reaches system, and was battery operated; this duster, though able to manage pollen without causing any damage, had a maximum outreach of about 2.5 meters (Figure 11). Also, Yahia [64] proposed an electric pollinator with a hopper and a plastic vibrating drum driven by a battery powered 12 V gear motor (Figure 12). In 2010, Mostaan et al. [48] published a research on an innovative electric pollinator with improved pollination feasibility and controllability and smaller size, weight, and cost compared to existing mechanical pollinators; the pollen reservoir had a capacity of 200 cm^3, sufficient for treating about 120 palms (Figure 13).

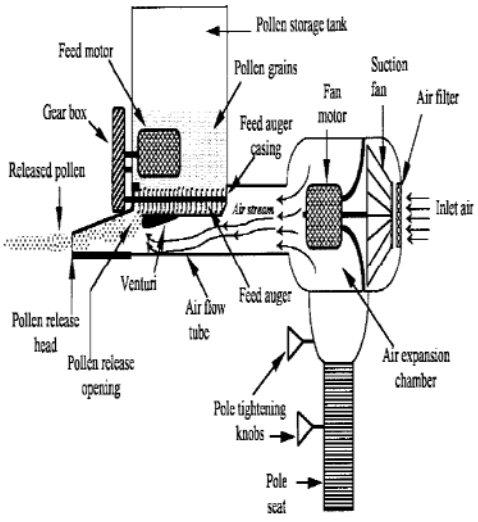

Fig. 11. *Micro-Duster for pollination* [29]

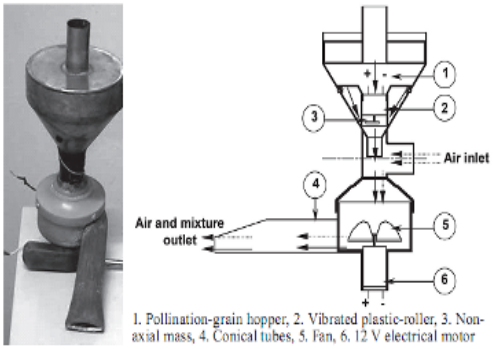

Fig. 12. *Pollinator by Yahia* [64]

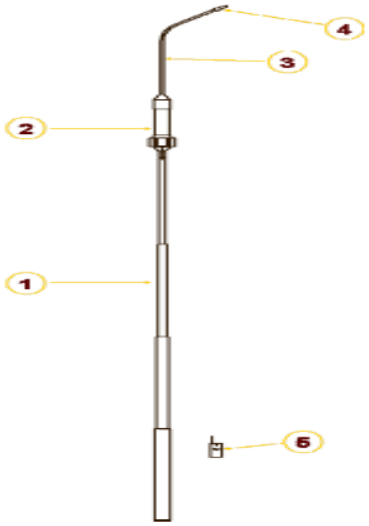

Fig. 13. *Electric pollinator, extending pole (1), dispenser (2), pollen pipe (3), nozzle (4) and remote controller (5)* [48]

Hany [30] patented a pollinator composed of a hand-held air blower with a pollen bag connected to the blower's pipe through a mixing chamber, in order to create a pollen cloud to direct towards the flowers; in order to serve taller palms more pipes could be added to the blower up to a total length of 20 meters (Figure 14). A pollinator has also been developed by Nourani et al. [52], consisting of a manual operated duster mounted on a telescopic pole, extendable up to 6 m and

operated through a strand (Figure 15). The device was inexpensive and could pay for itself after pollinating only about 25 palm trees, allowing for halving the time needed with the traditional pollination method, though maintaining the same results in terms of fruit yield. Akhavan et al. [7] developed an ultra-light electrical date palm pollinator consisting of a polyethylene terephthalate body and a 6.5 m long carbon fibre boom with a total weight of less than 2 kg (Figure 16). The pollen container capacity was about 70 grams that were sufficient for pollinating about 140 trees. The pollinator was tested at different pollen concentrations, finding that there was no significant difference concerning the pollination and fruit setting efficiencies and that the pollinator could properly replace the traditional method.

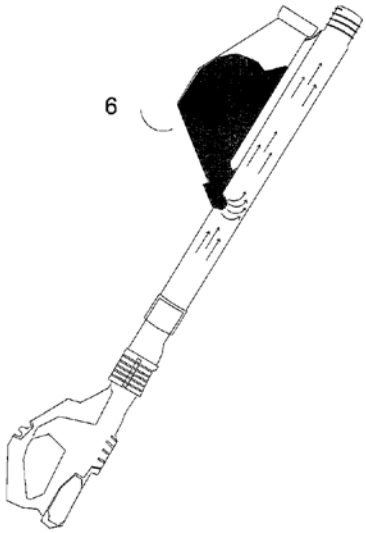

Fig. 14. *Pollinator by Hany* [30]

Fig. 15. *Pollinator* (Nourani et al.) [52]

Fig. 16. *Akhave's Pollinator* [7]

5. Phytosanitary Treatments

In some countries, such as Algeria, during the date mite (*Oligonychus afrasiaticus* McGregor) control campaigns, pickups equipped with a sprayer for fighting desert locusts (*Schistocerca gregaria Forskål*) were used. This allowed

a prompt intervention with minimum need for specialized workers; however, not being conceived for localized spraying, this system brings to an excessive release of pesticide (Figure 17). Abass et al. [1] have built a sprayer consisting of a 4,500 cm^3 tank, a battery operated 12V electric centrifugal pump and a nozzle mounted on a telescopic pole (Figure 18). According to the author, the tool has worked well compared to a backpack sprayer. Testing of this machine showed that its efficiency is higher than the traditional backpack sprayer by 42% and the field efficiency is 90%. Shapiro et al. [61] stated that lifting workers up to the top of the palm is a dangerous operation, even if done with the use of platforms, and proposed an autonomous field robot for pollinating and spraying. A scaled down prototype was developed, based on a tractor mounted sprayer with a visually controlled robotic arm that directs the jet to the target, and tested to evaluate the performance of the tracking system, which proved to be sufficiently reliable up to a speed of 1.25 $m \cdot s^{-1}$ (Figure 19).

Fig. 17. *Pick-up equipped with a sprayer*

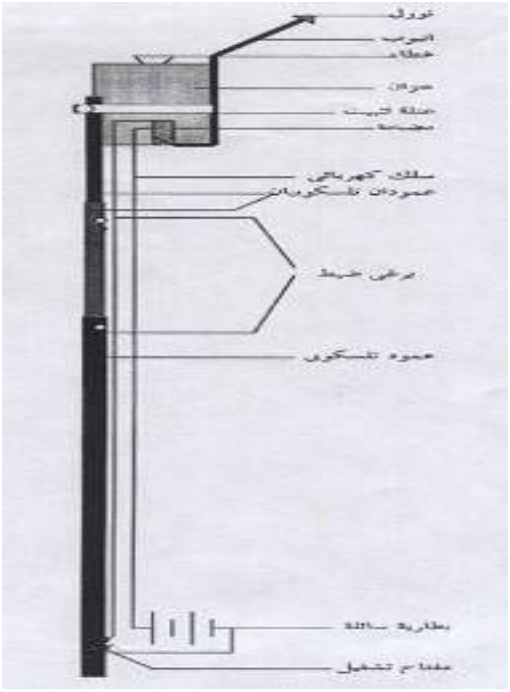

Fig. 18. *Electric Sprayer* [1]

Fig. 19. *The 1:6 scaled-down prototype in a folded configuration* [61]

6. Harvesting

The harvesting season ranges from June to the end of December, depending on the earliness of the variety and the region. The harvest is generally done by climbing up the palm, cutting the bunch and throwing it on a tarpaulin laid at the bottom of the palm tree. For more valuable varieties, the bunch is carefully lowered with a rope. In some cases, dates are picked singularly, time by time as they ripen. Harvesting is a critical stage that requires time and skilled labor. The use of machines, as normally done in the United State of America, can reduce harvesting costs by 50% [43], so various harvesting techniques and prototypes have been proposed over time to facilitate the farmers in this task.

In southern California, during the sixties in the past century, harvesting was carried out using towers and platforms that allowed the operators to move from one tree to another, but this method was very expensive [54] (Figure 20). Later on, self-propelled or trailed platforms started to be used to lift operators up to the crown level, but these machines were heavy, expensive and difficult to manoeuvre, so other more sustainable solutions were sought; a 4-WD, remotely controlled tree climbing machine for servicing date palms was developed at the University of Cranfield [59]. This robot uses the same pneumatic wheels used for moving on the ground, for climbing up the trunk, since these wheels were linked by levers and springs to change configuration and maintain sufficient friction with the trunk (Figure 21). The robot was able to move up and down the palm trunk at a maximum height of 30 meters and at a speed of about 0.2 $m \cdot s^{-1}$, carrying a device for cutting and accommodating date bunches up to a load of 100 kg.

Fig. 20. *Towers and platforms for harvesting* [54]

As all of the fruit in a bunch do not ripen at the same time, which means that in some cases it is necessary to pick several times during the season, Abounajmi and Loghavi [5] proposed a shaker powered by a continuous variable speed motor for vibratory date detachment (Figure 22). The rotating output power of an electric motor was transmitted to a small flywheel through a belt drive system, where it was converted to a reciprocating motion by a slider-crank mechanism, for oscillating date bunches in vertical, horizontal and hanging modes. The result showed that the bunch shaker was capable of detaching ripe fruit from the bunch in 5-7 seconds without any damage to the fruit.

Fig. 21. *Climber robot by Shamsi* [59]

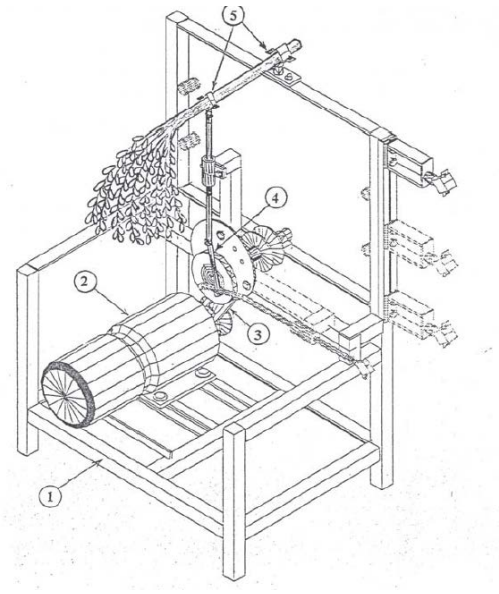

Fig. 22. *Schematic diagram of shaker* [5]

Also, Ibrahim et al. [34] experimented with a shaking system for selectively collecting ripe dates from the bunch; based on a slider crank mechanism producing a vertical stroke of 50 mm, the prototype was tractor-mounted and powered by the power take off shaft (Figure 23). Out of the three tested frequencies, 7.5 Hz was the one that gave the best results, separating the ripe dates in about 4 s.

Zine [66] recorded an international patent about a machine for harvesting dates, operated from the ground, without any need to climb up the palm, thus avoiding all the risks involved in this operation. This machine consists of a wheeled frame sustaining a pantograph elevator with an arm at the top to which various tools can be connected (a wire cutter in the case of harvesting); the machine is designed to be manually operated through a crank, but hydraulic or electric power sources can also be used (Figure 24).

Fig. 23. *Shaking system by tractor* [34]

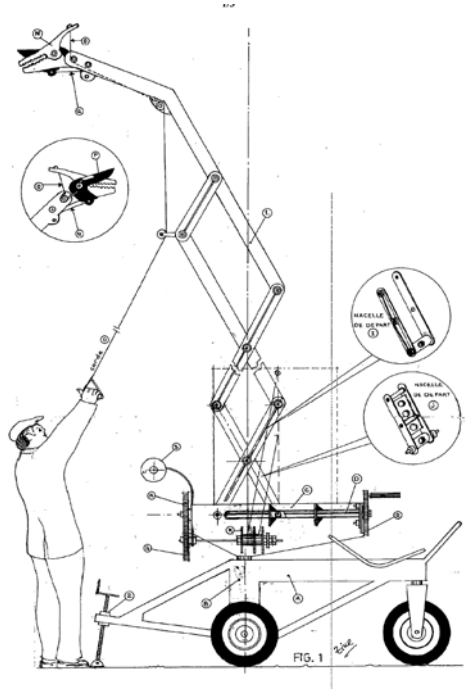

Fig. 24. *Date-harvesting machine* [66]

Al-Janobi et al. [10], [11] installed an industrial robotic arm provided with a bunch cutter unit on a hydraulic telescopic elevator and evaluated the mechanism. The results showed that the system could complete the harvest of a palm tree having 5 bunches within 6 min with a field efficiency of about 41% (Figure 25).In another study, Razzaghi et al. [56] made a mechanical analysis of the static/dynamic stability of a so called "robotic manipulator", the main component of an envisaged date harvesting machine, and developed a prototype. The manipulator ran along a rail placed around the trunk and was provided with an electric chainsaw, while further developments contemplated a telescopic elevator to move the machine up to the fruit level (Figure 26). An effective, though simple, solution was developed by Nourani et al. [50], [52], who designed a harvesting aid composed of a stabilizing platform, a lifting device, a lowering device, and a cutting device. The tool can be carried around manually and can be fixed at the base of any palm trunk and used to cut and lower whole bunches without the need to climb the palm. The trials that have been carried out show that with the use of this device a bunch at a height of 6.5 m can be collected and lowered in about 3 min, after the gear has been set into position (Figure 27). Mekhtiche et al. [45] patented a robotic arm which is mounted on the movable platform for selectively operating and manipulating a tool for performing tree harvesting and pre - harvesting operations (Figure 28).

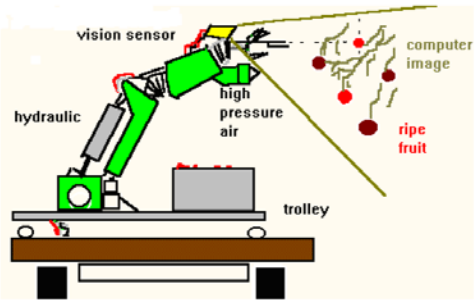

Fig. 25. *The fundamental blocks of agricultural robots* [12]

Fig. 26. *Proposed date harvesting manipulator* [56]

Fig. 27. *Date harvesting device* [52]

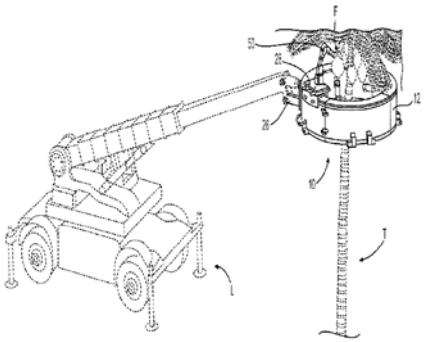

Fig. 28. *Tree harvesting tool* [45]

7. Cultivation operations at the trunk level

7.1. Pruning

This operation consists mostly in removing from the date palm trunk the dissecting organs which clutter the tree, hamper the cultural work and often shelter the parasites; these organs are dry fronds and frond stalks, flower stalks and aerial shoots, and the operation should be repeated every year. Pruning is mostly done manually using a manual saw, a sickle or a chainsaw or, in some cases, a chisel and a hammer. There have been a few attempts to make this operation easier for the farmer. Ismail et al. [35], [36] developed an AC-portable pruning machine based on an electric drill and found that the power needed for cutting was inversely proportional to the moisture content of the petiole (Figure 29). Also, Fadel Moustafa [24] tested a prototype of a hand held pruner based on a reciprocating saw activated by a rotating shaft, under laboratory conditions (Figure 30). The pruner can be operated using various types of prime movers such as drills, hydraulic motors, pneumatic actuators or mechanical drivers.

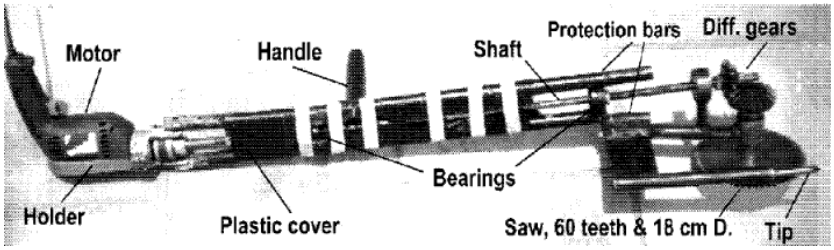

Fig. 29. *Portable pruning machine* [36]

Sarkari and Reza [58] carried out a modification on a motorized pole-pruner for date palm leaf and leaf-end pruning, taking into consideration the Iranian conventional pruning method, the geometric dimensions of the sickle, locally named Acfea, and the morphology of the date palm tree.

Fig. 30. *Date palm pruner* [24]

Abbood et al. [2] and Jasim et al. [38] designed and tested a motorized knife moved by a backpack 2-stroke engine, able to reach up to 2.5 m, finding that the best cutting angle was 45° and that it took about 4 s to cut one frond.

7.2. Phytosanitary treatment

The Red palm weevil (*Rhynchophorus fierrugineus* Olivier) is the most dangerous pest for this part of the tree. Refaat et al. [57] developed and tested a hydraulic injection device on young date palms of the *Hayani* variety in Egypt, finding that the best results were obtained with an injection pressure of 150 kPa, a palm tree diameter of 30-40 cm and the use of chlorpyrifos insecticide. Also, Eliwa [21] and Eliwa and Kotb [22] developed an injection device for controlling the red palm weevil and found that the highest productivity of 7.5 palm/hour was recorded when using an electric drill on infested palms having a diameter $\leq$ 25 cm.

8. Cultivation operations at ground level

Garbati Pegna [28] provided an exhaustive list of operations that are needed at ground level for date palm cultivation: most of these operations are common with other crops, while the collection of offshoots is an important and demanding operation, typical of date palm.

The separation of offshoots from the mother plant is done by cutting them at the level of their point of attachment, using a chisel or an iron bar pointed on one side and with a cutting edge on the other, called *Baramila* in Algeria (Figure 31). The operation is done every five-seven years, depending on the development of the offshoot. No study has been conducted to mechanize this operation; however, there have been some attempts to use a tree-digger for off-shooting. Ismail and Abo-Habaga [37] developed a mechanism for uprooting plantlets from the nursery. This unit is hydraulic powered by four contact links, moving on it a link that slides on the vertical arm, where a disc is fixed to cut the soil in turn on the vertical axis.

Fig. 31. *Baramila*

9. Conclusion

Attempts to address the main constraints of date palm cultivation by designing specific mechanical aids or adapting existing machines date back many decades, due to the high labor intensity and difficulties of this cultivation that are incompatible with the costs and principles of modern agriculture.

Though all the studies carried out on this subject firstly take into consideration the operators' safety and the machine profitability, two main lines of research can be distinguished in the attempts to mechanize date palm cultivation. The first one aims to propose a specific tool for each operation, while the second believes that it is sufficient to raise the operator to the palm crown level quickly and safely, for solving most of the problems of this cultivation. There are also two concepts in designing the equipment: the first requires that the machine rest on the soil during the work, while the second sees the palm trunk as support for lifting.

Although most of the publications and prototypes were developed by researchers from date-producing countries, we note that the TRL of these research works does not exceed the 3 third levels (Analytical and experimental critical function and/or characteristic proof-of-concept) which explains a flagrant absence of machines and tools for date palm cultivation in commercial markets. This observation is due mainly to the weakness of the channels of technological transfer between the university and the socio-economic world on the one hand, and the non-maturity of the industry of these countries, which are developing countries, to promote these results of research, on the other hand.

As perspective, in order to promote this sector, this brief overview on the development of mechanization of date palm cultivation provides a number of examples of what has been done in this sector, in order to direct the efforts of those who will address the challenge in the future, taking advantage of the strengths of previous works and taking into consideration their weaknesses.

Furthermore, this review paper is a particular advantage to placing oneself in the hands of those who work on date palm mechanization for both the community, and the academic and industrial sector. Also, this study allowed to identify other farm operations, such as removal, thinning, tying and covering of bunches, where no attempt of mechanization has been made, and which are important for the commercial growing

of valuable varieties and still present risks or high costs for the growers.

Conflict of Interest Statement

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Abbreviation table

B.C.	Before Christ
KSA	the Kingdom of Saudi Arabia
USD	United States Dollars
kW	Kilowatt
4WD	Four-Wheel Drive
MFIS	Mamdani Fuzzy Inference System
AHP	Analytical hierarchy process
V	Voltage
kg	Kilogram
$m \cdot s^{-1}$	Meter by second
Hz	Hertz
hp	Horse power
TRL	Technology Readiness Level
AC	Alternative Current
kPa	Kilo Pascal