Heat stress in date-palm workplaces
A study in the Algerian oases

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Introduction
The date palm (Phoenix dactylifera) is one of the oldest plants on earth, dating back perhaps 30–70 million years or more. Its cultivation is now undertaken in many countries. The number of date palms in the world is on the order of millions, with the number of farmers involved in this agricultural work also in the millions. In many date-palm growing countries, date palms are the main wealth of the people, and dates are a chief food. For profitable and good-quality production, the climatic requirements of the date palm are hot, dry weather and low rainfall. High humidity or rain during fruit ripening will cause the fruit to crack and ferment, and mould will develop. The maximum average daily temperatures in leading date growing countries ranges from 27° to 35° C, and date palms can withstand temperatures as high as 50° C. Indeed, a number of tasks in date-palm fields are carried out under hot conditions, which can be very stressful. Date-palm farmers must often work in hot conditions for a good proportion of the agricultural season. With regard to the effects of hot conditions on individuals, Khogali and Awad El-Karim (1) pointed out that working under thermal heat stress not only taxes an individual’s physiological function but also poses a serious threat to his health status. They also showed that casualties due to direct exposure to solar energy in outdoor agricultural activities are significant and require special handling, precautions and control. Also, Changnon et al. (2) stated that: “The loss of human life in hot spells of summer exceeds that caused by all other weather events in the United States combined including lightning, rainstorms, floods, hurricanes, and tornadoes. Weather hazards such as tornadoes, floods, lightning, and winter storms each result in about 100 deaths per year on average, while heat waves result in about 1000 deaths per year on average”. In addition, heat stress can cause multivariate problems to workers’ efficiency and productivity, especially when the workers are engaged in heavy or very heavy physical activity. It is well known that when doing dynamic physical work, about 30% of the energy is converted into mechanical work and the remainder into heat, which the body has to dissipate to the surroundings to maintain its normal temperature. If the atmosphere is very hot and humid, it becomes very difficult for the body to dissipate the heat, and thus the body temperature rises. In consequence, the human being is exposed to heat stress illnesses ranging from heat cramps to heat exhaustion and finally to heat stroke (sunstroke). Heat stress is a signal indicating that the body is having difficulty maintaining its narrow temperature range. As far as ergonomics of agriculture is concerned, this study was carried out to determine to what extent heat stress is prevalent in date-palm field workplaces.

Method
Sample
Initially, thirteen (13) volunteer male farmers were randomly selected from Zeb date palm zone (in the South of Algeria) to participate in this study. The subjects were informed about the purpose and procedures of the study. They were generally young, certified as healthy on the basis of medical examination and were fully acclimatized. Also, they have been engaged in date-palm work for at least two agricultural years. See Table 1 for a summary of the subjects’ demographic characteristics.

Table 1. Some of the subjects’ demographic characteristics

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Age (years)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>Seniority (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>28.08 ± 5.01</td>
<td>59.83 ± 7.6</td>
<td>169.1 ± 16.37</td>
<td>12 ± 4.33</td>
</tr>
</tbody>
</table>

Seniority means the number of years the farmer spends at work in agriculture.
Heat stress index and equipment

At present, there are many heat stress indices. One of them, which compiles climatic parameters to yield a single parameter, is the wet bulb globe temperature (WBGT), which was developed by Yaglou and Minard (3). It has been widely used in scientific research since its development. Two formulae are available for deriving the WBGT; one is the WBGT for indoors1 [Indoor WBGT = 0.7 nw (natural wet-bulb) + 0.3 gt (globe temperature)] and the other is the WBGT for outdoors2. [Outdoor WBGT (when a solar load is imposed) = 0.7 nw (natural wet-bulb) + 0.2 gt (globe temperature) + 0.1 db (dry-bulb temperature)]. Various tools and equipment are available for computing the WBGT index, ranging from very traditional to very sophisticated ones. In developing countries, where this work was carried out, modern and sophisticated equipment is scarce. For this reason, the following traditional equipment was used:

- Kata thermometer: This is an alcohol-filled thermometer with a large bulb coated with silvery material. When used, the bulb is heated in warm water until the alcohol rises into the upper reservoir. Then the bulb is dried with a clean dry cloth and suspended in the air. The time the alcohol takes to fall from the upper limit to the lower limit on the stem is timed using a stopwatch. From the cooling time, the dry-bulb temperature and the Kata factor, which is usually printed on the stem, air speed can be read from the monogram provided with the instrument.

- Whirling (sling) hygrometer: This is a wooden sling with a handle. The sling, which can be rotated, consists of two similar mercury thermometers. The bulb of one thermometer is covered with a wetted fabric, whereas that of the other is left dry. After rotating the sling for a short time, readings of both the dry-bulb and the wet-bulb thermometers can be taken.

- Globe thermometer: This consists of a hollow copper sphere measuring about 15 cm in diameter, and painted black. A mercury-in-glass thermometer is inserted into the sphere to a point such that the bulb of the thermometer is at its centre.

- Barometer: This is a non-liquid barometer to measure the atmospheric pressure. It consists of a cylinder of about 10 cm in diameter, the wall of which deflects with changes in atmospheric pressure. This deflection is coupled mechanically to a pointer, which indicates air pressure from 960 to 1060 millibars (mb). The normal atmospheric pressure is about 1013 mb (one millibar = 0.75 millimetres of mercury).

Procedures

Thermometers were mounted on a stand, which was 120 cm above ground level. Data were collected five times—at 2.00 am, 5.00 am, 8.00 am, 12 noon and 3.00 pm—during the period when the experimental tasks were carried out. Soil digging was done in February, pollination in April, bunch lowering and balancing in July, dry leaves cutting and bunch covering in August, and bunch harvesting in October. Air velocity, relative humidity, and the WBGT index were obtained using the relevant monograms and formulae. It should be noted that all tasks were carried out as naturally and as similarly as possible to what the subjects have been doing for years, using the same working methods, equipment and hand tools.

Results

Heat stress was measured while the major tasks in date-palm fields were being carried out. Using various apparatus and equipment, measurements were taken and the outdoor WBGT was calculated. The results are shown in Table 2 above.

Discussion

Ramsey (4) pointed out that before WBGT results are interpreted, various factors such as the heaviness and nature of the work and air movement must be considered if meaningful heat stress evaluation is to be obtained. As to both the heaviness and nature of the work, some date-palm tasks (pollination and the lowering and balancing of bunches) are carried out inside the date-palm crown with one hand only, while the other hand keeps the farmer fixed at the workplace (crown) to avoid falling. It is obvious that such a working position involves a lot of static work. By contrast other tasks (bunch harvesting, dry leaf cutting and bunch covering) are carried out just below the crown in the belt (saddle) working position, when both hands are free while both feet are fixed to the palm trunk and kept tense and motionless for some time, suggesting that this posture, too, involves a lot of static work. It is well known that under certain conditions, especially where the proportion of static work is high, heart rate would perhaps paint a clearer picture about effects of stress and strain than do other work load measures, such as oxygen consumption and psychological measures. Mokdad (5) has shown that pollination and bunch harvesting tasks were moderate (each of these tasks required more than 100 beats per minute), whereas soil digging, lowering and balancing of bunches, cutting of dry leaves and covering bunches were heavy (each of these tasks required more than 120 beats per minute).

According to the table in Appendix 1 of the American Conference of Government Industrial Hygienist(6) (see next page), no heat stress is involved in the two moderate tasks (pollination and bunch harvesting). In addition, no heat stress is imposed on farmers in the heavy task of soil digging, as it is normally carried out during winter. However, in bunch lowering and balancing and dry leaf cutting tasks, farmers are exposed to heavy heat stress even at 8.00 am and 3 pm. For the bunch covering task, heat stress is experienced only in the second half of the day (at noon and 3.00 pm).

As concerns air movement, it is well

<table>
<thead>
<tr>
<th>Date-palm tasks studied</th>
<th>WBGT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.00 am</td>
</tr>
<tr>
<td>Digging the soil</td>
<td>08.16</td>
</tr>
<tr>
<td>Pollination</td>
<td>12.89</td>
</tr>
<tr>
<td>Lowering and balancing of branches</td>
<td>23.37</td>
</tr>
<tr>
<td>Cutting of dry leaves</td>
<td>21.67</td>
</tr>
<tr>
<td>Covering bunches</td>
<td>20.72</td>
</tr>
<tr>
<td>Harvesting bunches</td>
<td>17.87</td>
</tr>
</tbody>
</table>
known that an individual feels comfortable when metabolic heat is dissipated at the rate at which it is produced. Astrand and Rodahl (7) have shown that for an average, sedentary, lightly clothed person, this occurs most readily when the air in a standard room has a temperature of 24.5°C, a relative humidity of 40%, and an air velocity of 0.25 m per second. Air movement enhances heat transfer between air and the human body and accelerates cooling of the human body. It is then essential for bodily comfort, as it helps the body to dissipate heat gained from all sources by increasing the effects of convection and evaporation. To be effective, air movement should not exceed 0.5 m per second. Air movement above this limit (i.e., wind) makes people feel uncomfortable. In the Algerian desert where this study was carried out, two types of hot wind, i.e., the Simoom and the Sirocco, frequently blow through the date-palm fields—especially in mid-spring, late summer and early autumn—at a rate of about 8 m per second. These types of wind may be stressful and may have various negative consequences. Apart from the climatic effects, the Simoom and the Sirocco can also affect health, causing headaches, boredom, fatigue and sleeping problems. Generally, they last one to four days. During this period, not only work, but normal life is hardly possible. Therefore, this hot wind may also be considered as another source that makes heat stress more serious in date-palm work, particularly if it comes during busy times, for example, when performing pollination and bunch harvesting tasks. However, if it comes during less busy times, its effects may be negligible.

It can be concluded from all the above results that heat stress is a real problem at least in the performance of some date-palm tasks, such as the lowering and balancing of bunches and dry leaf cutting, as it is experienced even in the mid-morning (at 8.00 am).

Heat stress management in date-palm workplaces

Since heat stress occurs in date-palm work, at least in the performance of some field tasks, what is done to control it? Three strategies and interventions are suggested. These are:

1) Organizational interventions: As can be seen from Table 2, the WBGT values indicate that at the beginning of the working day, i.e., in the early morning (at 2.00 am, 5.00 am and 8.00 am), the working conditions were free of heat stress for almost all tasks. Summer work could therefore be adjusted by changing the working hours. Instead of working during periods of heat stress around mid-day and in the afternoon, the work could be during periods of optimal comfort and no risk of heat stress, i.e., at night and in the early morning, when farmers would feel more comfortable and would perform better. If such an arrangement is opted for, then various factors should be taken into consideration. The facilities, such as workplace lighting and transport, should allow for work at night and in early morning. The farmers’ attitudes towards night work must also be considered, because social problems may appear if work is changed to the night shift, etc.

2) Mechanization interventions: Twentieth century engineering, such as the tractor, the reaper, the combine harvester, and hundreds of other machines, gave farmers the mechanical advantage they had long needed to ease their burdens and make their lands truly profitable. Agricultural mechanization enormously increased farm efficiency and productivity. While mechanization is widely used in industrialized countries, the situation in many developing countries is very different. Beyond crop production, mechanization is uncommon. As to date-palm work, it has been and still is done by traditional methods and using hand tools. No machines have been invented to climb the palm trunk, to pollinate the date flowers (inflorescences), to lower and balance the bunches, to cut the dry leaves, to cover the date bunches and to harvest the fruit. If mechanization is introduced into date-palm fields, not only work stress will be reduced, but both production quality and quantity will be increased as well.

3) Genetic engineering interventions: Genetic engineering is a method of changing the inherited characteristics of an organism in a predetermined way by altering its genetic material. It has been widely applied to agriculture. Therefore, it may be applied to date-palm agriculture, to alter some of the characteristics of the palm. A substantial proportion of the work stress in date-palm culture is attributed to the tall trunk of the date palm. Climbing the trunk is in fact unnecessary work, but it has to be done to reach the crown where the dates are found. One of the main differences between date-palm fruit and the fruits of other palm trees—for example, the coconut palm—is that dates must be cared for and maintained (bunch lowering and balancing, bunch covering,) if a good quality is to be obtained. If engineers could develop a palm that does not grow very tall—for instance, not beyond 2 metres—this would be a very significant achievement. Not only would the dwarf (short) date palm minimize heat stress; it would also minimize workload as well as handicaps, and/or deaths resulting from falls. In addition, work efficiency would eventually be in-

### APPENDIX 1: PERMISSIBLE HEAT EXPOSURE THRESHOLD LIMIT VALUES (6).

<table>
<thead>
<tr>
<th>Work/rest regimen</th>
<th>Work load*</th>
<th>Light</th>
<th>Moderate</th>
<th>Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous work</td>
<td>29.5°C (86°F)</td>
<td>27.5°C (80°F)</td>
<td>25.0°C (77°F)</td>
<td></td>
</tr>
<tr>
<td>75% Work, 25% rest, each hour</td>
<td>30.6°C (87°F)</td>
<td>28.5°C (82°F)</td>
<td>25.9°C (78°F)</td>
<td></td>
</tr>
<tr>
<td>50% Work, 50% rest, each hour</td>
<td>31.4°C (89°F)</td>
<td>29.4°C (85°F)</td>
<td>27.5°C (82°F)</td>
<td></td>
</tr>
<tr>
<td>25% Work, 75% rest, each hour</td>
<td>32.5°C (90°F)</td>
<td>31.1°C (88°F)</td>
<td>29.5°C (86°F)</td>
<td></td>
</tr>
</tbody>
</table>

*Values are in °C and °F, wet bulb globe temperature (WBGT). These threshold limit values are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should be able to function effectively under the given working conditions without exceeding a deep body temperature of 38°C (100.4°F). They are also based on the assumption that the WBGT of the resting place is the same or very close to that of the workplace. Where the WBGT of the work area is different from that of the rest area, a time-weighted average should be used. These TLVs apply to physically fit and acclimatized individuals wearing light summer clothing.
Work-related diseases and occupational injuries among workers in the construction industry

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Introduction
The construction industry is not only the process of building. It involves many other types of work aside from the building process, such as painting, landscaping, electrical supply, telecommunications, plastering, and paving. All these types of work make up one industry, but each of them involves different exposure and thus differing health hazards.

The two broad categories of construction projects are building and civil engineering. Building applies to projects involving houses, offices, shops, factories, schools, hospitals, power plants, railway stations, and so on. Civil engineering applies to all the other built structures in our environment, including roads, tunnels, bridges, railways, dams, canals, and docks. In addition, there are structures that appear to fall into both categories – for instance, an airport involves extensive buildings, as well as civil engineering in the creation of the airfield proper and a dock may involve warehouse buildings, as well as excavation of the dock and erection of the dock walls (1).

Construction workers are exposed to a wide variety of health hazards at work. The exposure differs from job to job. The hazards for construction workers are typically of four classes:
- chemical hazards such as dusts, fumes, mists, vapours, or gases
- physical hazards, including extreme heat or cold, work in windy, rainy, snowy, or foggy weather, non-ionizing ultraviolet radiation usually from exposure to the sun, and electric arc welding
- biological hazards; for instance, animal attacks and histoplasmosis (a lung infection caused by a common soil fungus). Workers may also be at risk of malaria or yellow fever if they work in areas where these organisms and their insect vector are prevalent.
- social hazards. Employment is intermittent and constantly changing; many projects require living in work camps away from one’s home and family. These features of construction work, as well as heavy workload, limited control, and limited social support are the factors associated with increased stress (2).

In Egypt, there are about 4 million

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