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Emigration and control of nitidulid beetles from dates using heat

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Abstract: Dates are subject to infestation by nitidulid beetles during and after harvest. Fumigation of dried fruits with methyl bromide (MB) upon arrival at the packing plant effectively controls infestation and causes a high proportion of larvae and adults to emigrate from the fruit before they succumb. This work was undertaken to investigate the effectiveness of heat treatment as an alternative to MB, which would remove insects from the dates, prevent insect development, and preserve fruit quality. Dates grown in Israel served as a model for development of the technology designed to be integrated into the pre-storage drying process. The test insects were *Carpophilus hemipterus* larvae reared on a synthetic food medium and held at 26°C and 75% relative humidity. Artificial feeding sites destined to simulate the dates were prepared consisting of cardboard rectangles placed on food medium contained in Petri dishes. Exposure to different treatments was carried out in 2.54 L desiccators. For each treatment, exposure times of 2 h after the feeding sites reached the target temperature were employed. Temperatures of 40°, 45°, 50° and 55°C were tested. The ratio of the number of larvae found outside the feeding sites to the total number of insects was used to describe the term "percent disinfestation". Disinfestation was greatest (92.3%) at 50°C and the difference was highly significant from exposure at 40° and 55°C. At 50° and 55°C 100% mortality was obtained. Conventional drying temperatures for most date varieties are in the range of 50° to 55°C. Since percent disinfestation and control was most effective at 50°C, application of heat appears an encouraging solution for the treatment of dates as a replacement to MB. The laboratory findings served as basis for two field trials carried out at a date drying station. This consisted of a hot-house holding pallets of stacked crated dates arranged in rows and covered by plastic liners to form drying ducts. One extremity of each duct was connected to a thermostatically control chamber supplying solar heated air, and the other end appended to large fans set to extract air from the ducts. Crates with artificially infested dates were positioned at strategic sites and the drying pass of 45ºC was preceded by a 2 hour pass at a target temperature of 50ºC. Results showed that although mortality after 2 h was incomplete at some sites, disinfestations was very high, and over the normal drying period of up to 72 h mortality would have been complete.

Key words: dried fruit, dates, disinfestation, Nitidulid beetles, *Carpophilus* spp., heat treatment, methyl bromide alternatives, IPM, storage pest control

Introduction

The problem of infestation in dried fruit is two-fold: Insects can cause serious damage to the fruit rendering it unfit for human consumption, but they also contaminate it, rendering it unacceptable for marketing in international trade. Furthermore, the stored-product insects commonly infesting dried fruit, particularly moths of the family Phycitidae and beetles of the family Nitidulidae, are also field pests. The initial source of infestation is frequently on ripening fruit on the tree, with infestation continuing in the packing-houses and during storage. Consequently it is an accepted practice both in the date and fig industries, as well as with other fruits and nuts, to fumigate the harvested fruit immediately upon arrival at the packing-houses, in order to break the chain of insect infestation. Both in Turkey (figs) and in Israel (dates), fumigation using methyl bromide (MB) in fumigation chambers is the accepted practice. Among the many advantages of MB is the fact that not only does the fumigant kill the insects rapidly, thereby permitting short turnover times, but has the additional effect of causing the adults and larvae to abandon the fruit before they die (Donahaye et al. 1991; Navarro et al. 1989). This decontamination effect is invaluable in actually decreasing the infestation levels of dead insects remaining in the fruit. Phosphine (PH_3) the only other widely used fumigant still acceptable under international legislation, has neither the rapid kill produced by MB, nor the all-important decontamination effect. Unfortunately MB is now targeted as an ozone depleting chemical, and under the Montreal Protocol of the UNEP (2002) its use must be phased out by 2005 for Non-Article 5 countries, and by 2015 for Article 5 countries. Although there are exemptions for quarantine and pre-shipment purposes, as well as the possibility to apply for exemptions where no existing alternative exists, the onus is on the applicant to demonstrate that every effort to is being made to research alternative treatments (TEAP & MBTOC 2003).

There is some information in the literature on the sensitivity of stored-product insects to high temperatures (Evans 1987, Fields 1992, Gonen 1977a, b, and Howe 1965), though all these studies were made on grain pests. . With regard to dried fruits, laboratory work of Lindgren and Vincent (1953) showed that to obtain 90% mortality of adult nitidulids, exposure to 49^{o}C for 4 to 20 minutes was needed, depending upon the relative humidity. Al-Azawi et al., (1984) showed that under laboratory conditions, adults of the dried fruit beetle, *Carpophilus hemipterus* (L.) is relatively tolerant to heat with exposures of from 25 to 60 minutes required to achieve complete mortality at 50^{o}C. For complete mortality of all stages of the Tropical Warehouse moth *Cadra cautella* infesting stored dates, 33 minutes were required at exposure to 60^{o}C (Al-Azawi et al., 1983). However, for dates, the technologically feasible temperature range lies between 45 and 55ºC since lower temperatures only produce mortality after prolonged periods whereas temperatures of 60ºC or above exert an undesirable drying effect on the fruit, or even biochemical alteration.

The study reported here, summarizes the laboratory work undertaken to determine the parameters of temperature and time required to obtain optimum emigration and optimum kill of the beetle *Carpophilus hemipterus* this being a typical representative of the other closely related species of *Carpophilus* that attack dried fruit in the region.

The second part of the study relates to field trials undertaken to apply the laboratory findings to a commercial scale date drying installation using an electrically assisted solar energy installation expressly designed for this purpose.

Materials and methods

Laboratory studies

Laboratory cultures of the test insect *Carpophilus hemipterus* originated from infested dates. They were reared under standard conditions of 26ºC and 75% rh on an artificial diet. To obtain larvae of uniform age, cultures were established by placing adults in 200 ml rearing jars containing the culture medium. After 2 days oviposition, the adults were removed and the insects were reared until they reached the required age. Larvae used in the experiments were 6-8 days old. The experiments to determine percent disinfestations and mortality levels of the *C. hemipterus* adults and larvae were carried out at four temperatures of 45º, 50º, 55º and 55ºC.

Artificial feeding sites were prepared to simulate the dates. They consisted of cardboard rectangles placed on food medium contained in Petri dishes. Larvae were placed in the Petri dishes, and penetrated beneath the cardboard rectangles. After 24 h, while the larvae inside, the feeding sites were placed in the exposure chambers. Exposure was carried out in 2.54 L desiccators. Temperatures within the artificial feeding sites were always 1^{o} to 2^{o}C lower than the nominal test temperature in the desiccators and it took approximately 60 min to reach to the test temperature from 26°. For each treatment, an exposure time of 2 h, after the feeding sites reached the test temperature, were employed. The ratio of the number of insects found outside the feeding sites to the total number of insects was used to describe the term "percent disinfestation". After each treatment, the number of survivors was examined and percentage of mortality calculated.

Field trials
Field trials were carried out in the commercial drying facilities of the Timura Company located at the agricultural cooperative Moshav Mehola in the north of the Jordan Valley. The drier takes advantage of solar heat supplemented by an LPG (liquid petroleum gas) heater, used to compensate for temperature drop at the cooler times of the day. Tests were carried out on dates of the Madjoul variety. Crates containing infested dates were exposed in strategic locations of the drier to verify if the heated air caused emigration of larvae as occurred in the laboratory. Below each crate, a second empty crate containing a liner was spread to collect the larvae that emigrated from the dates. In each bioassay, about 500 larvae per crate were used to test for emigration and mortality. Three subsequent trials were carried out. In each trial four crates were placed in strategic points; two crates on top and two crates at the lower extreme sections. Reported results are average of these three trials.

Results

Laboratory studies
The disinfestation value was greatest at exposure to 50°C (92.3%) this level being highly significant and different from disinfestations at 40° and 55°C (Fig. 1). Previous data that reported on disinfestation levels using MB indicated that the highest disinfestation did not exceeded 90% (Donahaye et al., 1991; 1992). The highest mortality reached was 100% and was obtained at 50° and 55°C (Fig. 2).

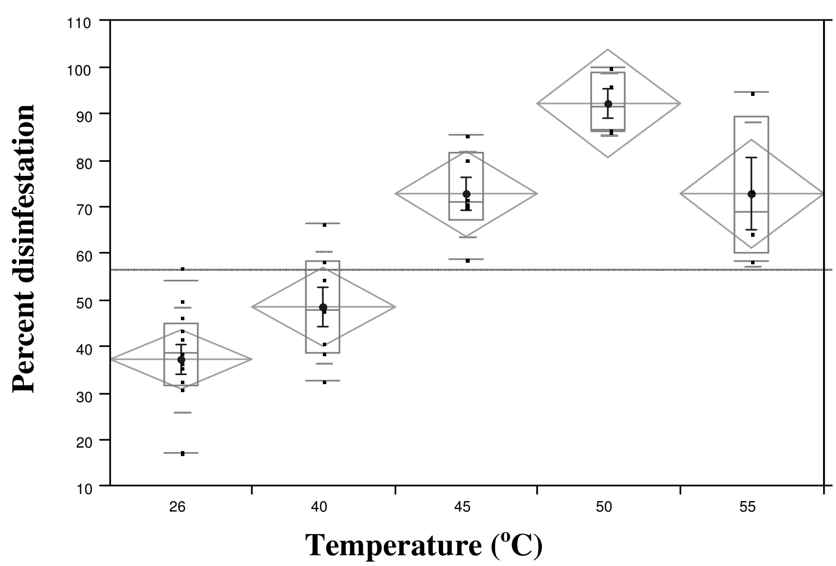

Fig. 1. Percent disinfestation of *C. hemipterus* larvae from artificial feeding sites at various temperatures for 2 hours of exposure after the test temperature was reached. .

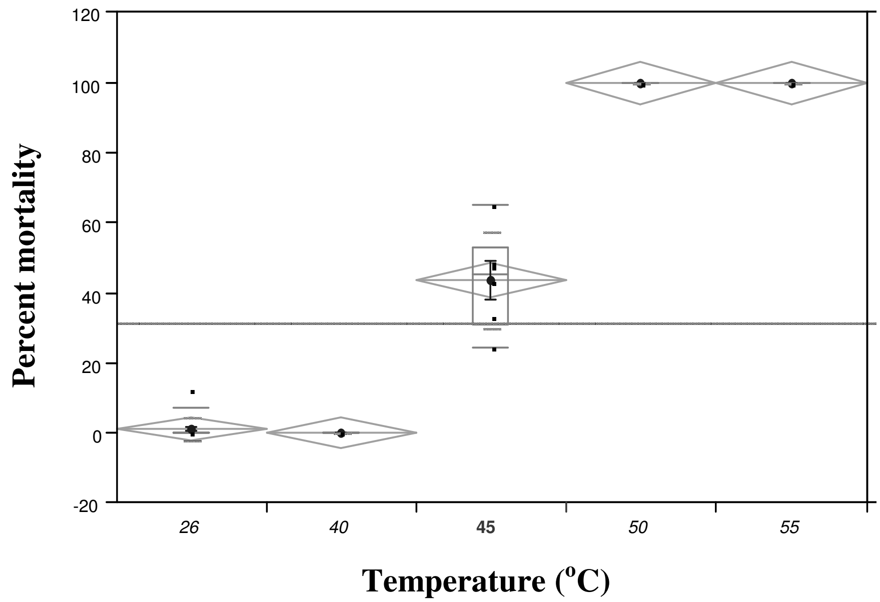

Fig. 2. Percent mortality of *C. hemipterus* larvae exposed to various temperatures for 2 hours of exposure after the test temperature was reached.

Field trials

The drying facility consisted of a hot-house (Fig. 3) that accommodated rows of pallets covered by a plastic liner to convey the heated air through the boxes containing dates (Figures 4 and 5). The drier thermostat was set to 50°C and laboratory-infested dates were used as bioassay (Fig. 6). After treatment, the infested dates were analyzed for survival in the laboratory (Figures 7 and 8). The data indicate that the target temperature of 50°C could be achieved within one hour after the introduction of the dates into the drier. An additional two hours were necessary to achieve emigration and mortality of the insects. Of the dates used for bioassay that were placed at strategic locations near the lower periphery of the drying duct (where air circulation was suspected to be restricted), a temperature drop of between 2° and 3°C was found from the target temperature. These slight differences allowed larval survival at the end of two hours exposure. In the top layers of the drying rows, the bioassays of infested dates revealed total emigration and mortality of larvae. The slight temperature difference at the lower layer of the drying duct allowed insect survival of up to 60% while emigration was 70% of the total number of insects. However, it should be mentioned that the entire drying period at a temperature of 45°C could last as long as 72 h and even 96 h to cause insect mortality. These aspects of the heat treatment are currently under investigation.

Discussion

Post-harvest quarantine treatments using high temperatures have been studied on various commodities, but the present study is the first on dates to determine the emigration of nitidulid beetles. There is a wide range of insect pests that could be the target of heat treatments. To make heat treatments effective against insect pests, the effects of high temperatures on insect physiology must be understood. Insects, being cold blooded, are particularly sensitive to heat. Studies on the effects of heat in insect metabolism demonstrate some adaptability to thermally challenging environments. In our laboratory study, a heating

Fig. 3. General view of the drier consisting of a green house.

Fig. 4. Individual rows containing ten pallets each located inside the drier.

Fig. 5. Drying fan to circulate air through each individual row containing dates.

Fig. 6. Measuring 50.8°C inside dates during the disinfestation process.

Fig. 7. Drying box containing bioassay infested dates after treatment.

Fig. 8. Dead larvae collected on liner below the infested dates after treatment.

time of about 60 minutes was necessary until the temperature reached its target level. This heating time may also affect the emigration rate of the larvae. Respiration, as to be expected, is also affected by heat. As body temperature of the insect increases, there are concomitant increases in both metabolism and respiration up to an upper critical thermal limit. The effects of heat on the nervous and endocrine systems are another area where elevated temperature damage needs further investigation. Among the most studied responses of insects to heat is the elicitation of heat shock proteins. The impact of these proteins on thermo-tolerance needs investigation.

The heat treatment is intended to replace the conventional fumigation with MB, within the framework of studies to find MB alternatives. Since dates are first disinfested using MB and then dried when necessary, it is expected that this treatment will be most suitable for dates that are subject to drying before storage. As for dates that are already at their moisture content suitable for storage (such as the Deglet-Nur variety), exposure to heat will last no more than 2 hours after the dates reach the target temperature. Preliminary experiments have shown that at a short exposure of 2 hours an insignificant moisture reduction of dates is incurred.

Conclusions

Disinfestation from dates in the laboratory was greatest at 50°C and reached 92.3%. Complete mortality was obtained at 50° and 55°C. Since conventional drying temperatures for most date varieties are in the range of 45° to 55°C, application of heat appears an encouraging solution for the treatment of dates as a replacement to MB. This approach was tested at a commercial scale date drying facility and was shown to be feasible with no modification needed to the actual installation. Since at present, dates are first disinfested using MB and then dried when necessary, it is expected that this treatment will be most suitable for dates that are subject to drying before storage. As for dates that are already at their moisture content suitable for storage, exposure to heat will last no more than 2 hours after the dates reach the desired temperature.

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