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CRITICAL TEMPERATURE CHANGE AS IMPORTANT FACTOR OF *CALLOSOBRUCHUS CHINENSIS* L. MANAGEMENT IN CHICKPEA GRAINS

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ABSTRACT

Pulse beetle, *Callosobruchus chinensis* L., is a major pest of stored chickpea. To reduce infestation of chickpea grains by this pest, the impact of short temperature changes on various life cycle aspects of this pest on chickpea grains was studied. Shifts of temperatures, from the average storage temperature of 30^{o}C, of plus or minus 5, 10 or 15^{o}C for either five or ten minutes each day for two days, was sufficient to affect the life cycle of the pest and reduce infestation. In general the larger the temperature shift and the longer the time at the shifted temperature, the greater was the effect. The treatment of 15^{o}C for 10 minutes proved to be the most effective reducing the number of days to death from 19.77 to 4.97 days, the number of eggs laid per grain from 3.92 to 1.21 eggs, the number of F_1 adults per test sample from 13.71 to 0.93 adults, the lifespan of F1 adults from 18.39 to 2.75 days, the number of holes per grain from 1.63 to 0.18 holes and the percent weight loss of grains from 29.61 to 8.69%. These data suggest that short, but significant, changes in temperature can adversely affect the physiology of this pest and provides a potential method for reducing product loss.

Keywords: Temperature, *Callosobruchus chinensis*, mortality, chickpea grains, weight loss

INTRODUCTION

Chickpea (*Cicer arietinum*) is the major leguminous grain crop and is cultivated on large scale in the rain-fed areas of the world including Pakistan, Europe, Syria, India, Spain, Mexico, Algeria, Iran, Australia and Turkey (Baloch and Zubair, 2010; Ali et al., 2009). In Pakistan, it is being farmed on more than 985,000 hectares area and covers about 75% of total land of pulses with production of 673,000 tonnes in 2012-13 (GOP, 2013).

The chickpea in storages is liable to both quantitative and qualitative losses. Quantitative damage results loss in seed weight and qualitative loss decrease aesthetic and nutritional value (Padin et al., 2002). Insects often cause extensive damage to stored products, which may amount to 5-10 % in the temperate zone and 20-30% in the tropical zone (Nakakita, 1998). Food grain losses are highly locality specific and high temperature and humidity usually favour the growth of such insects. The pulse beetle, *Callosobruchus chinensis* L., is one of the most destructive pests of stored products particularly chickpea. Despite a large investment in management of the pest (Yusof and Ho, 1992; Subramanyam and Hagstrum, 1995), a sustainable strategy remains elusive because of some limiting factors such as development of new insecticides and fumigants, resistance, toxic residues on food grains and environmental pollution (Fishwick, 1988; WMO, 1995).

Temperature is a crucial environmental factor that influences the development and growth of insects. Heat treatments have received an increased interest in recent years as a means to disinfest storage commodities and this approach is expected to continue with the impending removal of restrictions on methyl bromide usage (Mahroof et al., 2003 a, b; Roesli et al., 2003). Alice et al. (2013) worked on effect of hot and cold treatments for the management of pulse beetle in pulses and revealed significant results. The use of high temperature is a well-known technique to control stored product pests, for example a temperature greater than 40^{o}C is lethal for most stored food pests (Gwinner et al., 1996). Low temperature treatment of grains may also provide a degree of control, as this treatment in combination with drying is more useful for protecting grain from attack and deterioration than for disinfestations (Evans, 1987). At low temperature, the fecundity of the insect is reduced and its development is slowed down to a point where it fails to cause significant damage (Flinn and Hagstrum, 1990). Temperatures below 14^{o}C result in the death, particularly of immature stages, of almost all insect pests (Ghosh and Durbey, 2003).

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However, the expense of maintaining a storage temperature of above 40°C or below 14°C is significant, and therefore not necessarily a cost-effective means of pest control.

In the present study, the impact of short temperature shifts on various life cycle aspects of *C. chinensis* was determined in an attempt to develop strategies for the management of this pest. The objectives of these studies were to determine whether such shifts would affect the activity of the pest enough to provide a cost-effective means of damage control.

MATERIALS AND METHODS

Insects and grains

C. chinensis infested samples of stored chickpea were collected from stores / godowns containing chickpea and were kept in the laboratory at 30 ± 2 °C, 70 ± 5 % relative humidity (Talekar, 1988) and a 14:10 L: D photoperiod. The insects were reared on chickpea variety CM-2000 (National Agriculture Research Centre, Islamabad, Pakistan). The grains were fumigated with Agtoxin for two weeks to kill any pests already in the grains (Riaz et al., 2000).

Treating Callosobruchus chinensis with different temperature shifts

Temperature 30°C was chosen as the baseline temperature since it was found to be the average temperature at which chickpeas are usually stored, as well as being the traditional rearing temperature for laboratory cultures of *C. chinensis*. Ten pairs of one to three day old *C. chinensis* adults were released into jars containing 50g of CM-2000 grains and the jar openings were covered with muslin cloth. To study the effect of temperature shifts the jars were removed from the 30°C incubator and placed in a separate incubator at 15°C, 20°C, 25°C, 35°C, 40°C or 45°C for a period of either 5 or 10 minutes. This treatment was performed at the start of the experiment and then once more after 24 hours. In between treatments the jars were maintained at 30°C alongside the control samples. The experiment was laid down in complete randomized design (two factor) and each treatment was replicated thrice. Following this treatment regime a number of insect life cycle parameters and grain damage indicators were measured. The time taken for all of the original adults to die was measured and at this point the number of *C. chinensis* eggs laid per grain was assessed. The number of F_1 adults emerging was measured as was the time between the first one emerging and the last F_1 adult dying. Once all the F_1 adults had died the grains were removed and the mean number of holes per grain was measured. The grains were then sieved to separate the powder that had been released as a result of the larval infestation and the percentage weight loss calculated.

Statistical Analysis

The data recorded were subjected to statistical analysis as Two Factor Completely Randomized Design (CRD) using SPSS 16.0 for Windows and MSTAT-C programmes. Duncan's Multiple Range Test (DMRT) was applied to the means.

RESULTS

Effect of temperature shifts on *C. chinensis* mortality

Figure 1A shows the effect of two short shifts of temperature, twenty four hours apart, on the survival of adult pulse beetles. Any shift away from the baseline temperature of 30 °C resulted in a reduction in the longevity of the beetles. The most dramatic results were observed when the insects were twice cooled to a temperature of 15°C for ten minutes each time. Following this treatment all the adults died within 4.97 days compared to 19.77 days for the control sample. Increasing the temperature to 45°C for two ten minute periods also resulted in a significantly shorter lifespan of 6.21 days. A pattern can clearly be seen in that shifts further from the control temperature or longer in time resulted in greater mortality.

Egg production and the lifespan of the F_1 generation

Once all the initial adults had died then the mean number of eggs per grain were assessed for each experimental condition. Figure 1B shows a similar pattern to that seen with adult mortality in that the larger the temperature shift and the greater the exposure time then the lower the amount of eggs observed. The number of F_1 adults that subsequently emerged and the lifespan of that F_1 generation are shown in Figures 1C and 1D respectively. These two parameters both show a reduction in value upon greater or longer temperature shifts although it should be noted that these responses are dependent upon the altered mortality of the original adults and so it is not possible to ascertain whether there has been a direct affect of the temperature shift.

Damage to the grains

Following the death of the F_1 adults the grains were removed and the mean number of holes per grain was measured. Figure 1E again shows that there is a strong correlation between the extent and duration of the temperature shift and the damage caused by the beetles. The same pattern was observed when the percentage weight loss of the grains was assessed (Figure 1F).

DISCUSSION

Temperature plays a vital role in the development of stored grain insect pests and high temperature is mostly used to manage them. Lethal high temperature is 40ºC for most of the stored pests (Iqbal *et al*., 2006). According to Alice et al. (2013), effect of sun drying and cold treatment on pulse beetle showed 100 percent egg and adult mortality during the second, third and fourth months. It was observed that there is no significant difference among the exposure periods. Lethal low temperature is also effective in controlling stored grain insect pests. At higher temperature, metabolism rate is increased and food reserves are decreased. At lower temperature, insect development is slow and fecundity is reduced (Flinn and Hagstrum, 1990). It has long been established that exposure to extreme temperatures can protect stored products by killing insect pests (Fields, 1992). The downside to this approach though is that the treatment is both expensive to administer and can result in damage to the quality of the food. In this present study we investigated the potential effectiveness of the less expensive practice of exposing stored chickpea grains to two short changes in temperature. Our results showed that all perturbations from the ambient temperature resulted in an increase in mortality of the pulse beetle and an associated reduction in damage to the grains. The greatest effects were observed when the temperature perturbations were largest and when the duration of the perturbation was longer. These results are in agreement with previous studies where exposure to either high or low temperatures was found to cause 100% mortality of all immature stages of *C. chinensis* (Ghosh and Durbey, 2003; Saxena et al., 1992). Heat can affect the physiology of insects in many different ways (Neven, 2000) and affect both the ability of the individual insect to survive and its ability to reproduce. As well as physiological defects temperature changes have been shown to affect the mating behaviour of *C. chinensis* with changes observed in mating duration and sperm transfer (Katsuki and Miyatake, 2009). Although this study observed a reduction in infestation no attempt was made to establish the mechanism for this. A number of life cycle parameters were measured such as the number of eggs laid, the number of F_1 adults emerging and the lifespan of this F_1 generation. All of these parameters though are related to the effect of the temperature changes on the initial adult population. In conclusion we have demonstrated that whilst short shifts in temperature do not protect the grain as much as longer, and/or more extreme, exposures a significant degree of protection is achieved and in a manner that is likely to prove less expensive and potentially have less direct effect on the product.

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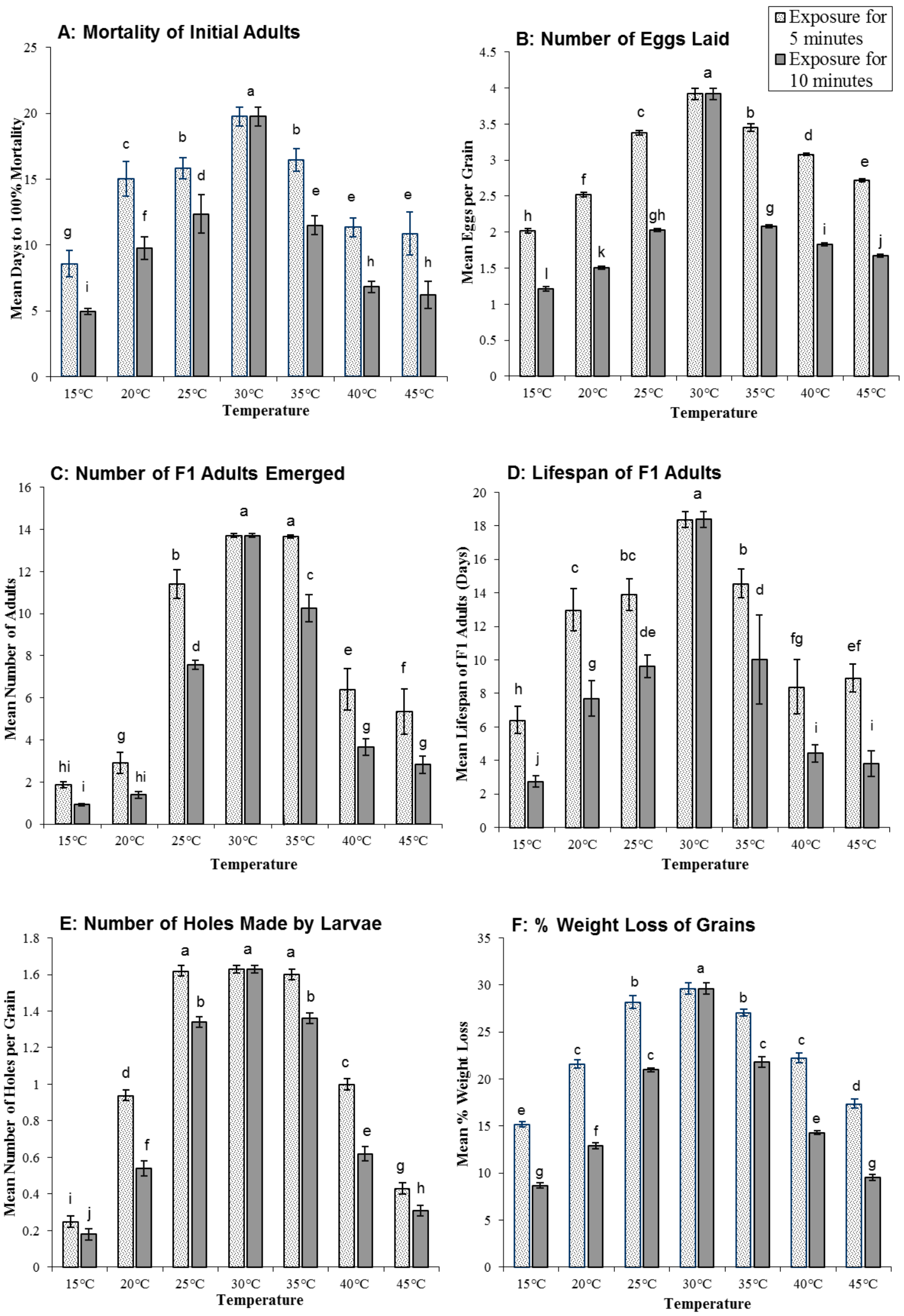

Figure 1. Effect of temperature on *Callosobruchus chinensis* L. in chickpea grains