SHORT, NON-REFEREED PAPER

IMPACT OF MASS-REARING AND GAMMA RADIATION ON THERMAL TOLERANCE OF *ELDANA SACCHARINA* WALKER (LEPIDOPTERA: PYRALIDAE)

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Abstract

Exposure of insects to gamma radiation to induce sterility, and mass-rearing to produce the large quantities required for the Sterile Insect Technique (SIT) are some of the many factors that may influence thermal tolerance at species and population level. The effect of mass-rearing and different radiation doses on the thermal tolerance of adult *Eldana saccharina* moths was investigated. Critical thermal maximum (CTmax) and minimum (CTmin) were determined and compared for both genders of *E. saccharina* from five different treatments namely wild, mass-reared and three sterility dosages (150, 200 and 250Gy). Results showed that both wild and mass-reared moths had similar high temperature tolerances (CTmax: 44.3 and 44.5°C respectively) and these values were significantly higher than those of moths exposed to gamma radiation (43.8, 43.7 and 43.5°C respectively). However, wild moths had a significantly higher tolerance to low temperature (CTmin) than mass-reared and sterile moths (3.7, 4.4, 4.8, 4.9 and 6.1°C respectively). In both CTmax and CTmin trials interaction between gender and treatment was highly significant ($F_{(4, 90)}$ = 4.19, P = 0.004, $F_{(4, 90)}$ = 3.71, P = 0.008 respectively). These results demonstrate the importance of knowledge of laboratory domestication and irradiation on thermal tolerance of *E. saccharina*. In addition to these data, further information on potential geographic and seasonal distribution will contribute to a better understanding of the working of SIT as an area-wide control strategy under different agro-ecological conditions.

Keywords: thermotolerance, irradiation, sterile insect technique, sugarcane, integrated pest management

Introduction

Eldana saccharina Walker (Lepidoptera: Pyralidae) is a major economic pest and well known stalk borer of sugarcane in West, East and South Africa, the distribution of which is limited by temperature among other factors (Atkinson, 1980; Chinheya *et al*., 2009; Goebel *et al*., 2005). It is a known fact that temperature affects a range of biochemical and physiological processes of arthropods (Nyamukondiwa and Terblanche, 2009) and, most importantly, determines mortality likelihood at extremes and therefore is of critical importance to insect population dynamics (Chown and Terblanche, 2007; Stotter and Terblanche, 2009). Feder *et al*. (2000) further state that insects are exposed to some form of thermal stress for much of their life cycle due to temporal and spatial environmental temperature variations. The ability to withstand thermal stress is therefore significant for the success of insect populations and evolutionary fitness in the wild (Loeschcke and Hoffmann, 2007; Sørensen *et al*., 2009).

Bahrndorff *et al*. (2009) state that environmental temperatures and insect thermal tolerance may be significantly correlated, and thus thermal tolerance could be involved in limiting a species' potential geographic distribution. According to *Manrique et al*. (2008) thermal tolerance of a species is one of the core components of bioclimatic modelling. Therefore any successful implementation of the sterile insect technique (SIT) as an area wide pest control strategy where laboratory reared insects are chilled for handling and sorting prior to field release (Carpenter *et al*., 2007), is dependent on sound knowledge of the effects of such pre-treatments following exposure to extreme temperatures which may compromise field performance of steriles under a SIT programme. Furthermore, exposure of insects to gamma radiation to induce sterility, and mass-rearing to produce the large quantities required for the SIT, are some of the many factors that may influence thermal tolerance at species and population level. Toolson and Hardley (1974) demonstrated that increasing the radiation dose significantly decreased the thermal tolerance of beet armyworm moths, *Spodoptera exigua* (Hübner) (Noctuidae), exhibited by reduced flight capability following exposure to heat stress.

The effect of gamma irradiation on *E. saccharina* thermal tolerance has never been studied. This study specifically investigates whether factors such as mass rearing and increasing radiation dosage influence thermal tolerance of adult *E. saccharina* moths.

Materials and Methods

Wild *E. saccharina* were collected as sixth instar larvae or pupae from mature sugarcane grown at Tinley Manor situated along the coastal region of KwaZulu-Natal province and reared to pupal stage on fresh *E. saccharina* diet at 26±1ºC and 12:12 L:D cycle. Laboratory reared *E. saccharina* were sourced from the insect rearing facility situated at the South African Sugar Research Institute in Mount Edgecombe, Durban. Pupae were then couriered by air to the entomology department at Stellenbosch University where all trials were conducted. Sterile moths were obtained by irradiating 0-day old laboratory-reared moths using a Co60 source at the SIT Africa® radiation facility in Stellenbosch.

Critical thermal limits, a measure of acute temperature tolerance (Nyamukondiwa and Terblanche, 2009) were determined and compared under relatively standard conditions for both genders of *E. saccharina* from five different treatments (wild, lab-reared, sterile: ST150, ST200 and ST250). Both critical thermal maximum (CTmax) and minimum (CTmin) experiments were conducted using the protocol described in Nyamukondiwa and Terblanche (2009). Nyamukondiwa and Terblanche (2009) also defined Critical Thermal Limits (CTLs; CTmin and CTmax) as the temperature at which each individual insect loses co-ordinated muscle function, consequently losing the ability to respond to mild stimuli (e.g. prodding).

The Shapiro-Wilk test for normality and a factorial ANOVA to determine the effect of mass rearing and irradiation differences on thermal tolerence was conducted on both CTmax and CTmin data using Statistica 9.0 (Statsoft Inc., Tulsa, Oklahoma, USA). Satistically heterogenous groups were identified using Tukey-Kramer's post-hoc tests.

Results

Critical thermal maximum

There were significant differences between treatments in CTmax of *E. saccharina* moths, $F_{(4, 59.31)}$, P = 0.000. Both lab-reared and wild moths had significantly higher CTmax values than moths exposed to all three different radiation dosages. However, the CTmax limits did not differ significantly between genders in all treatments except for moths treated with 150Gy of radiation. The results also showed that there was a significant interaction between gender and treatment in CTmax, $F_{(4, 90)}$=4.1865, P=00373 (Figure 1).

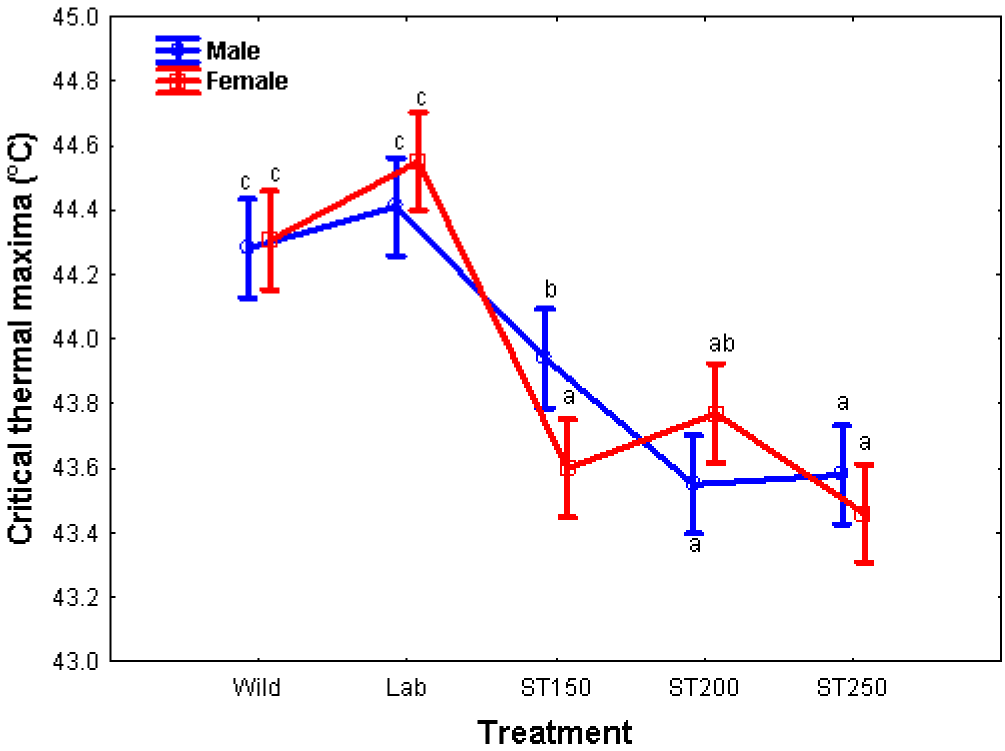

Figure 1. Effect of treatment on CTmax in adult *E. saccharina* moths (means ± 95% C.I). N = 10 per group.

Critical thermal minimum

There were significant differences between treatments in the case of critical thermal minima. Wild moths had the highest tolerance to low temperature exposure while those irradiated at 250Gy had the least tolerance (Figure 2). CTmin values did not differ significantly between genders in all treatments except in moths radiated at 150Gy. The results show that there were significant Gender x Treatment effects, $F_{(4, 90)}$ = 3.7101, P = 00767. The distinct difference in CTmin between males and females irradiated at 150Gy contributed to this interaction effect.

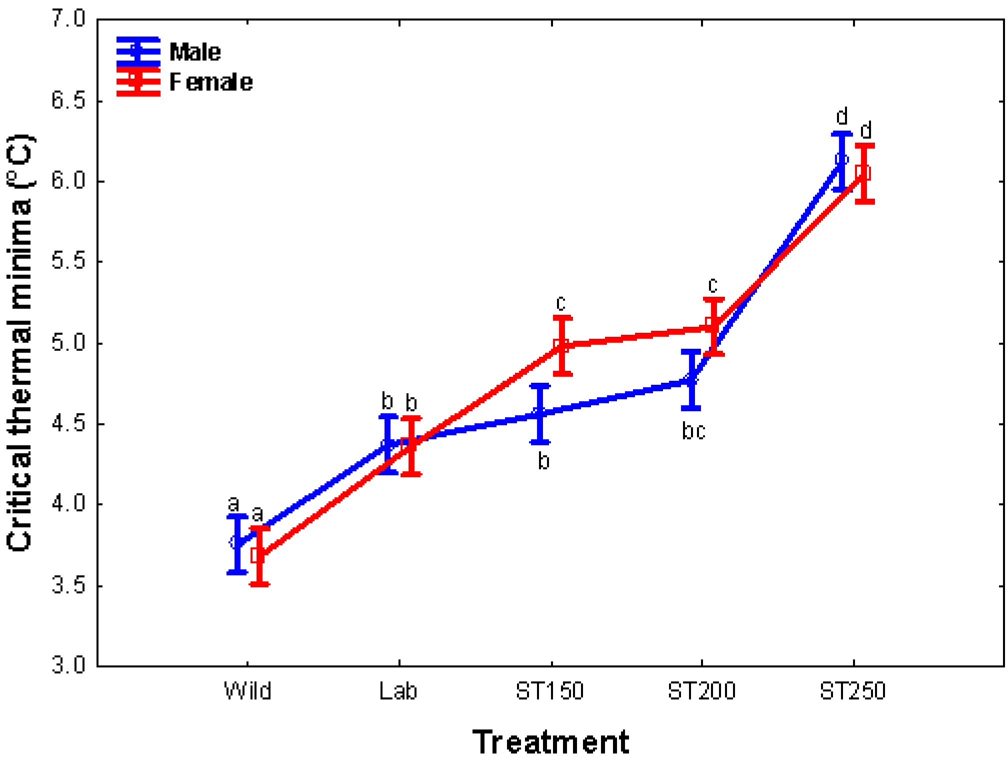

Figure 2. Effect of Treatment on CTmin in adult *E. saccharina* moths (means ± 95% C.I). *N* = 10 per group.

Discussion and Conclusion

The results above demonstrate that exposure of eldana moths to radiation negatively affects tolerance to temperature extremes (both cold and heat stress). Poor performance in laboratory reared moths compared to wild moths could be attributed to inbreeding depression in the former. Many aspects of mass rearing environments, such as rapid selection of individuals for laboratory adaptation and loss of heterozygosity, result in loss of fitness traits such as thermal tolerance (Jenson *et al*., 2010) mating competitiveness, compatibility, flight and adult longevity which in turn directly affect sterile insect quality (Lance and McInnis, 2005). Furthermore moths in the sterile strain originate from the mass reared population whose fitness characteristics are already compromised such that irradiation further compounds aspects of fitness (Shelley and Whittier, 1996; Lux *et al*., 2002).

Based on these findings, it can be concluded that radiation and mass rearing affect the fitness and competiveness of sterile moths against their wild counterparts in environments with extreme variable temperatures. This has implications for the implementation of the Sterile Insect Technique (SIT) as an area-wide integrated management strategy against the sugarcane borer. However, these data could be useful in guiding future mass releases given prevailing climatic conditions.

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