

Rapid evolution of a cold stress cline in Mediterranean fruit fly

Georgia D. Papadogiorgou¹, Cleopatra A. Moraiti¹, David Nestel², John S. Terblanche³ and Nikos T. Papadopoulos¹

¹Laboratory of Entomology & Agricultural Zoology, Department of Agriculture Crop Production and Rural Environment, School of Agricultural Sciences, University of Thessaly, Volos, Greece,

²Department of Entomology, Institute of Plant Protection, Agricultural Research Organization,

Israel ³Department of Conservation Ecology & Entomology, Faculty of AgriSciences, Stellenbosch University, South Africa.

Background: The Mediterranean fruit fly, *Ceratitidis capitata* (Diptera: Tephritidae), holds an impressive record of successful invasion events promoted by globalization in fruit trade and human mobility. In recent years the species is frequently detected in cooler temperate areas of the Northern Hemisphere. Cold tolerance of *C. capitata* seems to be a crucial feature that promotes population establishment and hence invasion success. The importance of rapid evolution of traits and their phenotypic plasticity, or alternative processes, in facilitating this invasion is however poorly determined.

Methods: We determined: (a) the supercooling capacity (SCP) of immature stages and adults as a measure of cold tolerance, and (b) the acute cold stress survival of adults of *C. capitata* from populations originated from a wide geographical range in the Northern Hemisphere: Austria (Vienna), Croatia (Zaton), Greece (Thessaloniki, Volos, Chania, Heraklion), and Israel (South Arava). To assess the phenotypic plastic capacity in these populations, (c) the effect of acclimation to low temperatures on acute cold stress survival in adults was also examined.

Results: There was marked geographical variation in the SCP of larvae with those originated from Thessaloniki (Greece) and Zaton (Croatia) expressing the highest and the lowest SCP values, respectively. Population and age had significant effects on the SCP of pupae. Young pupae expressed higher SCP compared to old ones, regardless of the population origin. Finally, the SCP of adults was not affected by either population or sex. Acclimation at low temperatures was positively related with survival to acute cold stress. Adults from the warmer environment of South Arava (Israel) were less tolerant of acute cold stress compared with those from Heraklion and Thessaloniki. Plastic responses to cold acclimation were population specific with S. Arava population expressing lower levels compared to the two Greek populations.

Conclusion: Northward range expansions have resulted in the rapid evolution of a cold tolerance cline, even among closely-related populations or nearby localities, or despite high gene flow among populations, that correlate with low temperatures in the region. These results set the stage for asking questions regarding the evolutionary adaptive processes that facilitate range expansions of *C. capitata* into cooler temperate areas of Europe.

Keywords: *Ceratitidis capitata*, supercooling, cold response, cold treatment