Genetic redundancy resolves invasion paradox in Colorado potato beetle

Fangyuan Yang[1], Michael Crossley[1], Lukas Schrader[1], Ivan Dubovskiy[2], and Runzhi Zhang[1]

[1]Affiliation not available
[2] Institute of Systematics and Ecology of Animals Siberian Branch, Russian Academy of Sciences

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Abstract

The paradox of how invasive species cope with novel selective pressures with limited genetic variation is a fundamental question in molecular ecology. Several mechanisms have been proposed, but they can lack generality and predictive power. Here, we introduce an alternative mechanism, genetic redundancy, wherein changes in multiple combinations of loci can achieve a fitness optimum for polygenic traits, and thus the variations left after the founder effect may be sufficient for adaptation. We tested the potential importance of genetic redundancy in environmental adaptation of Colorado potato beetle (CPB) in introduced Eurasia. Population genomic analyses showed substantial genetic depletion following a single introduction event, which supports invasive CPB as a classic system for the paradox study. Genome-environment association analyses revealed a suite of loci and gene functions plausibly related to cold stress. Notably, a substantial portion of loci showed different contributions to similar or identical environments. Such non-parallel evolution indicates their potential redundancy to overall fitness. Furthermore, one important adaptive gene function, "phospholipid production", was represented by more than one independent linkage cluster, suggesting some gene functional redundancy in cold resistance. Taken together, these results support the hypothesis that genetic redundancy can promote the adaptability of polygenic traits despite strong genetic depletion, thus providing a general mechanism for resolving the genetic paradox of invasion. More broadly, genetic redundancy, as an inherent feature of the genome, may have contributed to the evolutionary success of invasive species in many aspects.

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