Fitness costs and incomplete resistance associated with delayed evolution of practical resistance to Bt crops

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Supplementary material

File S1: Statistical Analyses

Fitness Costs

We used multiple regression to compare the relative fitness of the resistant strain or F_1 progeny relative to the susceptible strain (i.e., $W_{R/S}$ or $W_{RS/S}$) between cases of pests with and without practical resistance. The response variable was $W_{R/S}$ (square root [X + 0.5] transformed) or $W_{RS/S}$ (log transformed). We used different transformations of these response variables based on their capacity to improve assumptions of normality and homogeneity of variance. Explanatory variables in the basic model were strain relatedness (susceptible and resistant strains related or not), food type (artificial diet, corn or cotton), and species and country (e.g., *Helicoverpa armigera* from Australia) nested within food type. Strains were considered related if the resistant strain was selected from the susceptible strain (n = 34 cases, 35% of cases), ≥ 4 backcrosses followed by selection were used to homogenize the genetic background of the susceptible and resistant strains (n = 12 cases, 12% of cases), or costs were estimated from genotypes in hybrid strains identified with PCR (n = 7 cases, 7% of cases).

We tested for potential influence of two additional factors on $W_{R/S}$ or $W_{RS/S}$: the magnitude of resistance to the Bt toxin (estimated by the resistance ratio [RR] obtained from diet bioassays, log transformed) and the type of traits used to estimate costs (Ro or fitness components). When entered one at a time in the basic model, neither of these variables were significantly associate with $W_{R/S}$ (log RR: slope = -0.009, df = 1, 38, t = -0.27, P = 0.79; type of fitness measures: df = 1, 75, F = 0.070, P = 0.79) or $W_{RS/S}$ (log RR: slope = 0.0016, df = 1, 23, t = 0.13, P = 0.90; type of fitness measures: df = 1, 46, F = 2.40, P = 0.13). Thus, these explanatory variables were not included in analyses to compare $W_{R/S}$ or $W_{RS/S}$ between cases with and without practical resistance.

Least squares means for species from particular countries obtained from the basic models are adjusted statistically for effects of strain relatedness and food type. We used contrasts between these least squares means to test the hypotheses that $W_{R/S}$ or $W_{RS/S}$ differed significantly between cases with and without practical resistance. Back-transformed least squares means were used to estimate the average costs and associated 95% confidence interval for cases with and without practical resistance.

Incomplete Resistance

We used multiple regression to evaluate whether IR (square root [X + 0.5] transformed) differed significantly between cases with and without practical resistance. Explanatory variables included in the basic model were food type (corn or cotton) and species and country nested within food type. The magnitude of costs could affect IR because costs affect survival of resistant strains on the non-Bt crop. We thus assessed whether the magnitude of costs (i.e., $W_{R/S}$) or the extent of resistance (i.e., the resistance ratio, log transformed) were associated with IR. When entered one at a time in the basic model, these variables were not significantly associate with IR (log RR: slope = - 0.0082, df = 1, 9, $F = 0.83$, $P = 0.84$; $W_{R/S}$: df = 1, 21, $F = 1.33$, $P = 0.26$). These variables were not included in the model used to test whether IR differed significantly between cases with and without practical resistance with least squares means contrasts.

Table S1. Estimates of relative fitness of resistant strains or F_1 progeny relative to susceptible strains ($W_{R/S}$ and $W_{RS/S}$) from literature review (attached excel file)

Table S2. Estimates of incomplete resistance (IR) from literature review (attached Excel file)

Table S3. Fitness of the genotypes on the non-Bt and Bt crop used in simulations. Recessive fitness costs on the non-Bt crop were 0, 14 or 30%. Incomplete resistance on the Bt crop was 1 (i.e., 100% survival and no incomplete resistance), 0.76 or 0.43. With non-recessive resistance (h = 0.26), fitness of *rs* was adjusted to keep the dominance of resistance constant across levels of incomplete resistance.

Crop	**Cost (%)**	**Fitness**		
		Rr	***rs***	***ss***
Non-Bt	0	1	1	1
	14	0.86	1	1
	30	0.70	1	1

Crop	**Dominance of resistance (h)**	**Incomplete resistance**	**Fitness**		
			rr	***rs***	***ss***
Bt	0	1	1	0.01	0.01
		0.76	0.76	0.01	0.01
		0.43	0.43	0.01	0.01
	0.26	1	1	0.26	0.01
		0.76	0.76	0.21	0.01
		0.43	0.43	0.12	0.01

References for Tables S1 and S2

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