

Supplementary Information for:

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I. RATIONALE FOR IMIDACLOPRID EXPOSURE LEVEL USED IN EXPERIMENT

The imidacloprid exposure level used in this experiment was based on a survey of available literature of neonicotinoid levels used in lab and field experiments or estimated from environmental screening. Table S1 (below) is a summary of the surveyed literature on field- and laboratory-based neonicotinoid levels (bb = bumblebee, hb = honeybee).

Citation	Type of experiment: field (with country in parentheses) or laboratory study	Levels of imidacloprid found in field or tested in laboratory
David et al., 2016 (1)	Field (England; bb)	pollen in urban area: <0.36 - <20 ppb
Botias et al., 2017 (2)	Field (England; bb)	urban area – late spring : <0.72 - <2.2 ng/g urban area - early summer: <0.72 - <10 ng/g arable area – midsummer: <0.72 - <2.2 ng/g
Mullin et al., 2010 (3)	Field (USA; hb)	wax samples: 13.6 - 2.4ppb pollen samples: 206.0 - 6.2 ppb
Stewart et al., 2014 (4)	Field (USA)	Preseason: 4.0±5.5 ng/g Wildflowers (adjacent to cotton): 1.1±6.0 ng/g
Lambert et al., 2013 (5)	Field (France; hb)	Limit of detection (LOD): 0.4ng/g Limit of quantification (LOQ): 9.6ng/g Honey-LOD: 0.2 ng/g Honey-LOQ: 3.9 ng/g Pollen-LOD: 2.6 ng/g Pollen-LOQ: 12.0 ng/g
Genersch et al., 2010 (6)	Field (Germany)	3 ppb in one pollen sample (of 215 total samples)
Whitehorn et al., 2012 (7)	Laboratory (bb)	pollen treated with 6 ng/g imidacloprid, plus 0.7 ng/g in nectar
Feltham et al., 2014 (8)	Laboratory (bb)	pollen treated with 6 ppb imidacloprid, plus 0.7 ppb in sugar syrup

Gill <i>et al.</i> , 2012 (9)	Laboratory (bb)	10 ppb imidacloprid in sugar syrup plus a synthetic pyrethroid insecticide
Williamson <i>et al.</i> , 2014 (10)	Laboratory (hb)	Pilot study with the concentrations 10 and 100 nM, to identify that all pesticides being used at a sublethal dose (as defined by Desneux <i>et al.</i> 2007); a 10 nM dose of all pesticides was selected for use and was in the range of the reported values from field collected nectar and pollen (Blacquiere <i>et al.</i> 2012; Sanchez-Bayo and Goka 2014)
Powner <i>et al.</i> , 2016 (11)	Laboratory (bb)	10 nM in 50% sucrose (with and without 670 nm light)
Moffat <i>et al.</i> , 2016 (12)	Laboratory (bb)	2.5 ppb, field relevant levels: 10 nM
Creswell <i>et al.</i> , 2012 (13)	Laboratory (bb)	125, 50, 20, 8, 3.2, 1.28, 0.51, 0.2 and 0.08 µg/g
Tasei <i>et al.</i> , 2000 (14)	Laboratory (bb)	10µg/kg/ and 25 µg/kg in syrup and 6µg/kg/ 16 µg/kg in pollen
Gill <i>et al.</i> , 2012 (9)	Semifield experiment (bb)	10 ppb sucrose solution
Mommaerts <i>et al.</i> , 2010 (15)	Laboratory (bb)	Use the maximum field recommended concentration (MFRC): 200 ppb

II. NUTRITIONAL CONTENT OF POLLENS USED IN EXPERIMENT

Table S2 (below) shows the crude nutrient content of rockrose (*Cistus*) and heather (*Erica*) pollen used in experiment, with the nutrient content of the 50/50 mixed diet group estimated by averaging the two. Data from Di Pasquale et al. 2013.

Pollen diet	Proteins (%)	Lipids (%)	Sugars (%)	Amino acids (g)	Antioxidants (μmol)
<i>Cistus</i>	12	6.9	5.2	11.9	103
<i>Erica</i>	14.8	7.4	4.8	16.27	196
Mixed (<i>Cistus</i> and <i>Erica</i>)	13.4	7.15	5	14.085	149.5

III. QUEEN MORTALITY AND BROOD PRODUCTION

Table S3 shows a summary of the numbers of queens that were originally used in the experiment (by treatment group), the numbers of surviving queens, and the numbers and proportions of queens with various stages of brood (eggs, larvae, pupae, and adults) in the nest when they were collected at the end of the experiment.

Group	No. Queens	No. died before laid eggs	No. which laid eggs	% with eggs	No. with larvae	% with larvae	No. with pupae	% with pupae	No. with adults	% with adults
Un-treated	90	28	62	68.9	52	57.8	26	28.9	1	1.1
IMD-A	45	16	29	64.4	21	46.7	3	6.7	1	2.2
IMD-B	45	35	10	22.2	7	15.6	1	2.2	0	0

IV. MODEL SELECTION

Model Selection

Fixed Factors	Loglik	AICc	Delta	Weight
Treatment + Pollen	-136.000	283.1	0.00	0.388
Treatment	-138.005	283.8	0.78	0.262
Treatment*Pollen	-132.492	284.6	1.59	0.175
Null	-152.570	306.7	23.63	0.000
Pollen	-150.886	307.1	24.00	0.000

Table S4. Candidate Cox mixed effects model selection for survival to the end of the experiment of queens exposed to one of three imidacloprid treatments and one of three pollen treatments. Bolded models are those within two AICc units of the best fitting model. Colony is included as random term in all analyses.

Fixed Factors	Loglik	AICc	Delta	Weight
Treatment	-67.661	145.7	0.00	0.978
Treatment+Pollen	-69.364	153.4	7.71	0.021
Treatment*Pollen	-68.000	159.6	13.90	0.001
Null	-80.321	166.8	21.11	0.000
Pollen	-82.248	174.8	29.17	0.000

Table S5. Candidate LMERs for the survival of queens exposed to one of three imidacloprid treatments and one of three pollen treatments. Colony is included as random term in all analyses.

Fixed Factors	Loglik	AICc	Delta	Weight
Treatment	-97.537	204.9	0.00	0.793
Null	-101.803	208.1	3.21	0.159
Treatment+Pollen	-97.440	211.1	6.19	0.036
Pollen	-101.732	213.3	8.39	0.012
Treatment*Pollen	-97.191	228.1	23.24	0.000

Table S6. Candidate LM for queen activity level when exposed to one of three imidacloprid treatments and one of three pollen treatments. Colony is included as random term in all analyses.

Fixed Factors	Loglik	AICc	Delta
Treatment	-369.110	748.220	0.00
#Treatment + Pollen	-367.299	748.598	0.38
Pollen	-380.692	771.384	23.16
null	-521.839	1057.567	309.35

Table S7. Candidate GAMLSS for total number of colony eggs when exposed to one of three imidacloprid treatments and one of three pollen treatments. Subsequent analysis was conducted using model marked with #, as it was more comprehensive and statistically comparable to the simpler model. Colony is included as random term in all analyses.

Fixed Factors	Loglik	AICc	Delta
#Treatment*Pollen	-338.377	704.884	0.00
Treatment + Pollen	-342.549	705.718	0.83
Treatment	-347.158	709.157	4.27
Null	-353.431	715.495	10.61
Pollen	-350.932	715.913	11.03

Table S8. Candidate GAMLSS for total number of colony larvae when exposed to one of three imidacloprid treatments and one of three pollen treatments. Subsequent analysis was conducted using model marked with #, as it was more comprehensive and statistically comparable to the simpler model. Colony is included as random term in all analyses.

Fixed Factors	Loglik	AICc	Delta
#Treatment*Pollen	-114.656	258.905	0.00
Treatment	-121.118	259.072	0.17
Treatment + Pollen	-120.568	262.021	3.12
Null	-133.358	272.728	13.82
Pollen	-132.215	274.431	15.53

Table S9. Candidate GAMLSS for total number of pupae and adults when exposed to one of three imidacloprid treatments and one of three pollen treatments. Subsequent analysis was conducted using model marked with #, as it was more comprehensive and statistically comparable to the simpler model. Colony is included as random term in all analyses.

V. REFERENCES

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