NEONICOTINOIDS

Country-specific effects of neonicotinoid pesticides on honey bees and wild bees

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Neonicotinoid seed dressings have caused concern world-wide. We use large field experiments to assess the effects of neonicotinoid-treated crops on three bee species across three countries (Hungary, Germany, and the United Kingdom). Winter-sown oilseed rape was grown commercially with either seed coatings containing neonicotinoids (clothianidin or thiamethoxam) or no seed treatment (control). For honey bees, we found both negative (Hungary and United Kingdom) and positive (Germany) effects during crop flowering. In Hungary, negative effects on honey bees (associated with clothianidin) persisted over winter and resulted in smaller colonies in the following spring (24% declines). In wild bees (*Bombus terrestris* and *Osmia bicornis*), reproduction was negatively correlated with neonicotinoid residues. These findings point to neonicotinoids causing a reduced capacity of bee species to establish new populations in the year following exposure.

Global declines in honey bees and wild bees have been linked to pathogens, climate change, habitat fragmentation, and pesticide use (*1*–*3*). The potential threat from neonicotinoid seed coatings applied to flowering crops has been the subject of considerable debate (*4*–*9*). Neonicotinoids have been shown to increase mortality in honey bees by impairing their homing ability (*4*) and to reduce the reproductive success of bumble bees (*5*, *8*, *10*) and solitary bees (*8*, *11*); other studies have identified no effects (*8*, *12*, *13*). There is limited information from replicated studies on longer-term survival of honey bee colonies following exposure [see (*12*)]. Landscape-scale experiments under real-world agricultural conditions are needed to integrate spatial, temporal, and species-specific variation in order to understand the impacts of neonicotinoids on bees (*8*, *12*, *14*–*16*). Such studies should explore the impacts of different neonicotinoid formulations, land use, and regional climate. In a large-scale experiment spanning three European countries, we tested the hypotheses that (i) exposure to seed treatments containing neonicotinoids affected the reproductive potential of managed and wild bee species and (ii) whether such effects differ between countries.

At each of 33 sites (Germany, 9; Hungary, 12; and United Kingdom, 12) an average of 63.1 ha (SE of ±2.8 ha) of winter-sown oilseed rape (OSR) was established in 2014 (Fig. 1, fig. S1, and table S1). We clustered sites into triplets (>3.2 km between sites) and randomly allocated sites to one of three treatments: (i) clothianidin applied at 11.86 to 18.05 grams of active ingredient per hectare (g a.i. ha^{-1}) with a fungicide (thriam and prochloraz) and nonsystemic pyrethroid (beta-cyfluthrin) (trade name Modesto); (ii) thiamethoxam applied at 10.07 to 11.14 g a.i. ha^{-1} and combined with the fungicides fludioxonil and metalaxyl-M (trade name Cruiser); and (iii) control OSR receiving a commercial fungicide (thriam and dimethomorph in Germany and Hungary and thriam and prochloraz in the United Kingdom) but no neonicotinoid seed treatment. All treatments received typical commercial inputs of pesticide (e.g., lambda-cyhalothrin) and fertilizer, with these standardized across a triplet. Standardized colonies of honey bees (*Apis mellifera*) and wild bees (bumble bee *Bombus terrestris* and solitary bee *Osmia bicornis*) were introduced to each site. For honey bees, we quantified the impacts of the treatments on colony viability during the crop flowering period and in the year following exposure (hive survival and overwintering worker, brood, and storage cell numbers). Overwintering fitness defines the multiyear persistence of honey bees. For *B. terrestris*, we measured impacts on within-year reproductive output (colony weight gain and worker, queen, and drone production) and for *O. bicornis* the number of reproductive cells produced (table S2). Neonicotinoids can be persistent and widespread in agroecosystems (*17*, *18*), so we quantified residues both in the nests of bee species and those expressed in the crop.

We found that neonicotinoid seed treatment affected the interannual viability of honey bee colonies following the winter period in a country-specific manner. In Hungary, worker numbers were 24% lower where clothianidin was compared with the control [treatment × country: $\chi^2(6) = 1.47$, $P = 0.01$, explained variance = 59.4%] (Fig. 2), with no significant effect of thiamethoxam. Clothianidin was more likely to be expressed in the crop where it was applied as a seed treatment, which identified a mechanism of exposure to the bees [$\chi^2(2) = 6.46$, $P = 0.04$], but this was not so for thiamethoxam (table S3). In the United Kingdom, high hive mortality precluded a formal statistical analysis of overwintering worker numbers. However, median worker numbers were zero for all four clothianidin-treated sites but above zero for two of the control and one of the thiamethoxam sites (table S2 and Fig. 2). Worker numbers following the winter in Germany showed no treatment effect (table S4). Overwintering honeybee brood, stored hive products (pollen and nectar), and the likelihood of hives surviving the winter were not affected by seed treatments (table S3).

Neither *B. terrestris* queen nor *O. bicornis* egg cell production was directly affected by the seed treatments or its interaction with country (table S5). However, they were negatively correlated with peak [$\chi^2(1) = 2.09$, $P = 0.03$, explained variance = 13.5%] (Fig. 3A) and median [$\chi^2(1) = 4.34$, $P = 0.04$, explained variance = 0.8%] (Fig. 3B) neonicotinoid nest residues (combined clothianidin, thiamethoxam, and imidacloprid). Imidacloprid was not applied as part of the study, and its presence is most likely a result of environmental contamination from previous widespread agronomic use (*17*, *18*). Residues of neonicotinoids detected in stored hive products did not differ in response to seed treatments for any bee species (table S6). This may be due to the amalgamation of stored hive products at the site level for residue analysis, which may have obscured within-site heterogeneity in residues. The negative correlation

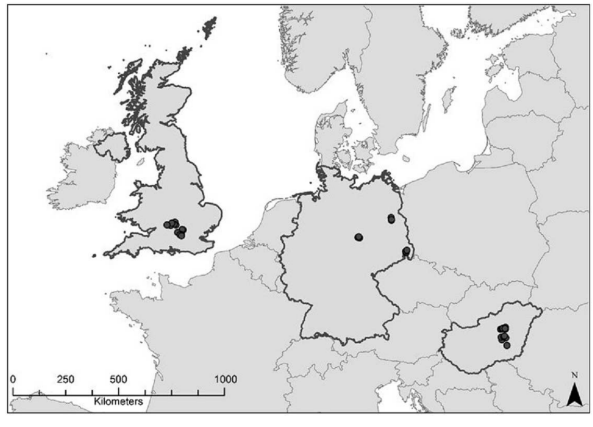

Fig. 1. Location of the 33 experimental sites in the United Kingdom, Hungary, and Germany. See fig. S2 for a diagrammatic representation of the experimental setup.

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for *B. terrestris* queen production remained significant when we excluded sites with imidacloprid residues [$\chi^2(1) = 2.14$, $P = 0.02$], although this was not the case for *O. bicornis* [$\chi^2(1) = 0.05$, $P = 0.81$]. Country-specific responses to neonicotinoid seed treatment were found for *B. terrestris* drone production, with positive and negative effects from exposure to thiamethoxam in Germany and the United Kingdom, respectively [treatment × country: $\chi^2(6) = 13.1$, $P = 0.04$, explained variance = 13.6%] (Fig. 2).

We also found seed treatment effects during the crop flowering period that lasted between 3 and 6 weeks (tables S4 and S5). Significant interactions between seed treatment and country were identified for peak worker [$\chi^2(6) = 16.6$, $P < 0.01$, explained variance = 45.3%], egg cell [$\chi^2(6) = 4.13$, $P = 0.01$, explained variance = 49.9%], and combined pollen and nectar storage cell [$\chi^2(6) = 40.5$, $P < 0.001$, explained variance = 53.6%] numbers. These responses describe within-year colony performance. Neonicotinoid exposure resulted in both negative (Hungary and United Kingdom) and positive (Germany) effects on colony size (see Fig. 2; pairwise treatment comparison given in tables S4 and S5). *Bombus terrestris* worker and peak colony weight showed no seed treatment response.

Our quantification of neonicotinoid effects on the interannual viability of honey bees and wild bee populations represents a fundamental advance in our understanding of the impacts of these pesticides. For solitary bees and bumble bees (queen production), neonicotinoid impacts were associated with the residues found in nests rather than the experimental seed treatments. For *B. terrestris*, the few treatment effects and the presence of imidacloprid in stored pollen and nectar (tables S7 to S9) suggests that negative impacts of neonicotinoids may be driven by the persistence of residues in the wider landscape rather than current management alone (*18*, *19*). The European Union (EU) moratorium meant that no neonicotinoids were applied to oilseed in the surrounding landscapes during the experiment, so such residues may originate from previous agricultural use leading to expression in nontarget plants (*17*–*19*), guttation fluids, or contaminated water (*19*, *20*). Although the reproductive potential of *O. bicornis* was also negatively affected by neonicotinoid residues in nests, the explained variation of these effects was small. However, a failure to detect small population changes may be due to limited experimental replication restricting statistical power. Our results suggest that even if their use were to be restricted, as in the recent EU moratorium, continued exposure to neonicotinoid residues resulting from their previous widespread use has the potential to impact negatively wild bee persistence in agricultural landscapes (*14*, *18*, *19*).

Taken together, our results suggest that exposure to neonicotinoid seed treatments can have negative effects on the interannual reproductive potential of both wild and managed bees, but that these effects are not consistent across countries. The country-specific responses of honey bees and bumble bees strongly suggest that the effects of neonicotinoids are a product of interacting factors (*20*–*23*). This study has identified between-country differences in the use of oilseed rape crop as a forage resource for bees (affecting exposure to crop residues) and incidence of disease within hives. Both factors were higher for Hungarian and U.K. honey bees (tables S10 and S11). Overall neonicotinoid residues were detected infrequently and rarely exceeded 1.5 ng g^{-1} (w/w). As such, direct mortality effects caused by exposure to high concentrations of neonicotinoids are likely to be rare (table S12). However, our results suggest that exposure to low levels of neonicotinoids may cause reductions in hive fitness that are influenced by a number of interacting environmental factors. Such interacting environmental factors can amplify the impact of honey bee worker losses (e.g., through sublethal

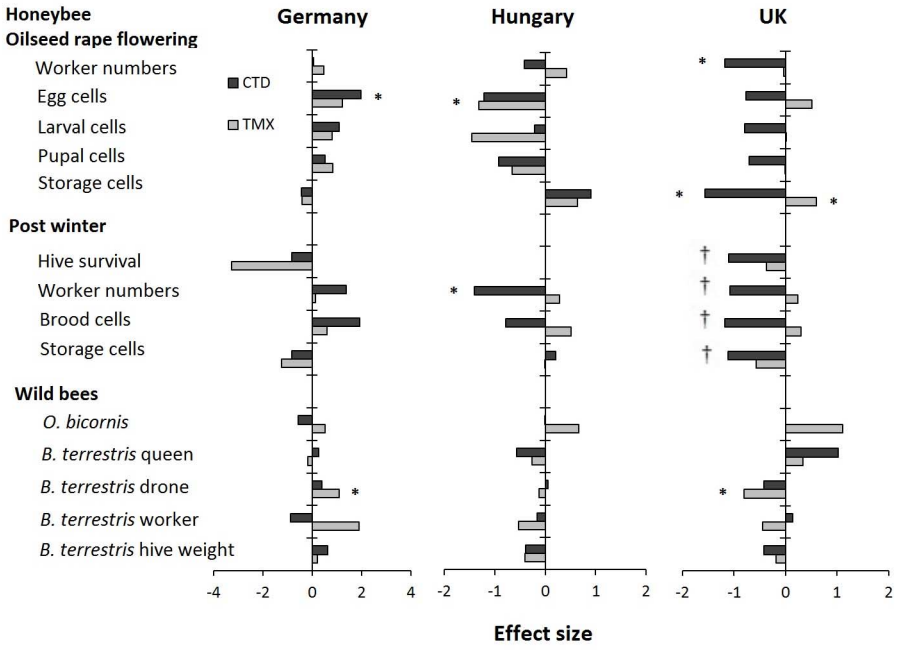

Fig. 2. Summary effect sizes for the response of honey bees and wild bees to the neonicotinoid seed treatments. An effect size represents the difference between the mean population response for a given seed treatment and the control within a country, with this difference divided by the pooled standard deviation, where asterisk (*) indicates a significant difference between the control and seed treatment [either TMX (thiamethoxam) or CTD (clothianidin)] determined from the predicted marginal means of the model "*y ~ seed treatment × country + block/country*." Dagger (†) indicates where U.K. colony survival was too low for a formal analysis. Note that effect sizes differ between countries.

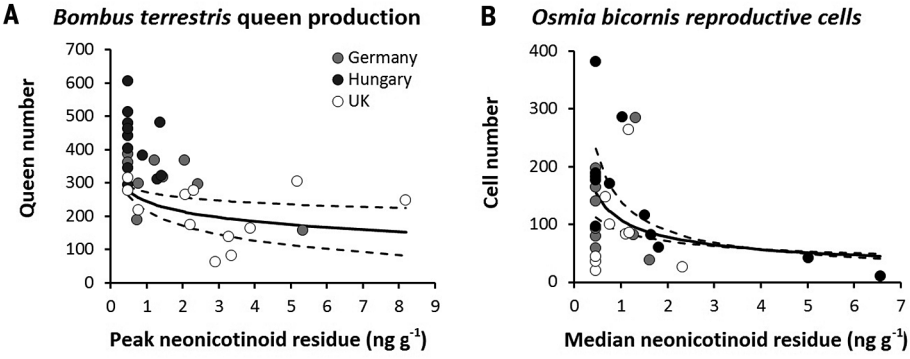

Fig. 3. Wild bee reproductive success in response to neonicotinoid nest residues. Separate graphs are shown for the response of *B. terrestris* queen production and *O. bicornis* reproductive cell production to neonicotinoid residues found in nests. The significance of these relationships is based on a likelihood ratio test comparison of H0: "*y ~ country*" and H1: "*y ~ neonicotinoid + country*." Neonicotinoid residues are based on summed concentrations of clothianidin, thiamethoxam, and imidacloprid.

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toxicity effects) and reduce longer-term colony viability (*4*, *16*). Note that our common experimental approach applied across three countries revealed varying impacts and may explain the inconsistent results of previous studies conducted in single countries or at few sites (*4*, *5*, *8*, *12*, *13*, *15*).

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ACKNOWLEDGMENTS

Data are in supplementary materials. Funded by Syngenta Ltd. and Bayer CropScience (P. Campbell, M. Miles, C. Maus, D. Holah, M. Coulson). Wild pollinator work supported by NERC CEH National Capability funding (NEC05829). Thanks to K. Jaekel, P. Fisher, M. Nowakowski, R. Hails, P. Scrimshaw, N. Mitschunas, P. Nuttall, M. McCracken, S. Ball, J. Webb, B. Sutherland, R. Freckleton, T. Tscharntke, J. Memmott, K. Norris, B. Raffa, and D. Vaskor.

SUPPLEMENTARY MATERIALS

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Materials and Methods
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7 December 2016; accepted 22 May 2017
10.1126/science.aaa1190

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www.sciencemag.org/content/356/6345/1393/suppl/DC1

Supplementary Materials for

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Published 30 June 2017, *Science* **356**, 1393 (2017)
DOI: 10.1126/science.aaa1190

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Materials and Methods
Figs. S1 and S2
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Materials and Methods

In August-September 2014, large continuous blocks of winter sown oilseed rape (mean=63.1 ha, SE=2.8; range 31.3 – 95.6 ha) were established on 33 commercial sites split between the UK (12 sites), Hungary (12 sites) and Germany (9 sites) (Table S1). These countries represent a gradient in climate and environmental characteristics resulting from historical land (e.g. collectivization, field size and landscape diversity) and agri-management practices (pesticide use and cropping rotations). By using a common experimental framework this study will test whether the impact of neonicotinoid seed treatments is consistent among the wide range of environmental conditions represented by the three studied countries. Winter sown oilseed rape was chosen as it represents a key element of the cropping system in Europe (24). The far less widely sown spring oilseed rape (as tested in Rundlöf et al (8)) has higher expression of neonicotinoids (> 10 ng g^{-1}) than winter sown varieties (> 3.5 ng g^{-1} (13)). The area of sown oilseed rape at each site reflects typical block cropping patterns of commercial farming systems. In each country the variety of oilseed rape was chosen from popular hybrid varieties (UK – *var.* Harper; Germany – *var.* Flyer; Hungary – *var.* Hybrirock). Sites were clustered into blocks of three sites located in similar landscapes and on similar soils within each country. Sites were separated on average by 5.47 km (SE=0.54, minimum = 3.2 km), with blocks separated by > 10 km.

Within each block (containing three sites, see Fig. S1) one site was randomly allocated to each of the following oilseed rape neonicotinoid seed treatments: 1) Clothianidin (Modesto®, Bayer Cropscience Ltd.) achieving a within field application rate of 11.86 g ha^{-1} a.i. (UK), 18.05 g ha^{-1} a.i. (Germany) and 17.71 g ha^{-1} a.i. (Hungary). Modesto® is combined with a fungicide (Thriam and prochloraz) and non-systemic pyrethroid (beta-cyfluthrin) used to protect seeds against immediate pest damage on sowing; 2) Thiamethoxam (Cruiser®, Syngenta Ltd.) achieving an application rate of 10.07 g ha^{-1} a.i. (UK), 10.61 g ha^{-1} a.i. (Germany) and 11.14 g ha^{-1} a.i. (Hungary). Cruiser® is combined with a fungicide (fludioxonil and metalaxyl-M; 3) Control oilseed rape where seeds received only a commercial fungicide (Thriam and Dimethomorph (Germany & Hungary) or Thriam and prochloraz (UK)), but no neonicotinoid seed treatment. All treatments received typical commercial inputs of pesticide (e.g. Lambda-cyhalothrin or Tau-fluvalinate) and fertiliser which were standardized within a block. Sites were chosen so that there was no other oilseed rape crop except for that established as part of the experiment within 1.5 km of the hives. Due to the EU moratorium any oilseed rape outside of this radius would not have been treated with neonicotinoids.

Honey bees

The domesticated honey bee represent one of the principal pollinators of oilseed rape (4, 12, 15). At each site six honey bee hives were located centrally to the oilseed rape crop. In the majority of cases where multiple fields of oilseed rape were sown, hives were placed as close to the field centers as possible along an existing field boundary. Where a single large field of oilseed rape was sown, a 50 x 100 m area was cleared in the center of the crop and the hives were placed there. Hives were established at the BBCH 61 developmental stage for each block (5-11/5/2015 in Germany, 14-21/4/2015 in Hungary and 9-23/4/2015 in the UK). Within a country honey bees originated from the

same genetic stock. For Germany and Hungary hives were 1 year old colonies of the *carnica* sub species (average pre-exposure colony size: Germany=10683 workers, SE=405; Hungary= 8993, SE=248). In the UK it was not possible to source sufficient full size colonies with the same provenance and so new (6 frame) nuclei colonies were produced from young queens (1 year old) of the '*Buckfast*' strain (average of 3294 workers, SE±126). Following the end of the oilseed rape flowering period, hives were removed to a single overwintering site within each country in a landscape that provided non-crop flowering resources (Germany: Lat. 50.763802, Long. 9.099248; Hungary: Lat. 47.335223, Long. 20.311399; UK: Lat. 51.888052, long. -1.4344352). As all honey bees within a country were exposed to a common set of conditions at these sites (e.g. foraging resources, landscape and weather) their population sizes as monitored the following year were the result of the experimental treatments during the previous oilseed rape flowering period. Bees were supplementary fed with fondant or sugar solution depending on typical practice in each country. Hives were treated for *Varroa* using either formic acid (Germany and Hungary) or oxalic acid (UK). However, country specific differences in disease rates were observed, with the UK having higher levels of *Varroa* mite infection (8.05 % of worker bees ±SE 1.34) than those of either Germany (1.04 % ±SE 1.00) or Hungary (2.12 % ±SE 1.34) (χ^2_2=16.6, p<0.001; Table S11). In the UK, honey bees had a narrower diet breadth (fewer plant species present in pollen samples) than those of either Germany or Hungary (χ^2_2=9.81, p= 0.001; Table S10). Honey bees in the UK and Hungary also foraged on higher proportions of pollen originating from oilseed rape than Germany (χ^2_2=12.2, p<0.001; Table S10).

The impact of honey bee exposure to neonicotinoid seed treatments was assessed using standard Liebefeld (25) counts of worker, egg cell, larvae, pupae, male brood and combined storage cells (pollen and nectar) within each hive. Male brood numbers were too infrequent for a valid statistical analysis. Assessments were undertaken during the oilseed rape flowering period (April-June 2015) and again during the post-winter period (March 2016). In the oilseed rape flowering period assessments were made at 4-7 days after deployment at sites and then again at weekly intervals until the end of flowering. The flowering period differed between countries lasting from 3 (Hungary) to 6 weeks (Germany and UK). Over this period the peak numbers of bees and brood developmental stages were assessed. However, to ensure that peak counts reflected responses to the oilseed rape crop the first sampling round (undertaken at 4-7 days) was ignored. Hive weight was adjusted so that the first colony weight measured during the flowering period was set to zero. The final colony assessment in the oilseed rape flowering period was undertaken on 21/5/2015 in the UK, 12/5/2016 in Hungary and 8/6/2016 in Germany. Overwintering survival and colony strength was also assessed using the Liebefeld method. This was undertaken on single date in March 2016 (UK: 30/3/2016; Hungary: 8/3/2016; Germany: 15/3/2016). Following the overwintering period individual life stages of egg, larvae, pupae and male brood were infrequent and so were summed to provide a measure of total brood. In all cases median site values from the six hives at a site were used in subsequent analyses.

During the oilseed rape exposure period samples of pollen and nectar collected by the honey bees were analysed for residues of clothianidin, thiamethoxam and imidacloprid (a third widely used neonicotinoid product). While this latter neonicotinoid was not applied as part of the study, its residues have been reported both in arable soils

(17, 18). At each site residues of these three products were determined from: 1) pollen stored in combs within the hives (sampled from 10 cells from each of six hives at a site and then homogenized); 2) nectar stored in combs (sampled as for stored pollen); 3) nectar collected by honey bees and dissected from their honey stomachs on two occasions during the flowering period (300 bees from six hives at a site); 4) Pollen collected by worker bees using pollen traps and sampled on three occasions (taken from six hives at a site and homogenized). Prior to overwintering (November 2015) pollen and nectar stored in combs within the hives were again analysed for residues using the same method. These approaches provide information on residues from a range of sources of pollen and nectar at a site level, but do not attempt to quantify within hive spatial variability of neonicotinoid residues in stored hive products. By amalgamating samples originating from multiple hives within a site it is possible that detection rates of neonicotinoids may be reduced where high levels of within and between hive spatial variability in the distribution of residues exists.

Bumblebees (*Bombus terrestris*)

This bumblebee regularly visits flowers of oilseed rape and is an important crop pollinator worldwide (26). At each study site 12 commercial *B. terrestris* colonies (Biobest Ltd.) of either *audax* (UK) or *terrestris* sub-species (Hungary and Germany) were established reflecting distributional ranges and regulatory issues. The 12 colonies were clustered into four multi-hives (a multihive is a cluster of three colonies housed in the same protective polystyrene box) and were placed central to the sown oilseed rape crop. As for the honey bees, this was either along a field boundary where multiple fields were sown with oilseed rape, or in a cleared area in the center of crop with only a single large field sown per site. The entrance to individual colonies was restricted to prevent parasitism by *B. psythirus* s.g.. This also prevented the escape of new queens produced by the colonies. *Bombus* colonies were places in fields at the same time as honey bee hives. The pre-exposure colony size was a mean of 102.2 workers (SE=1.9) in Germany, 81.2 (SE=1.06) in Hungary and 93.6 (SE=1.36) in the UK.

Bumblebee colonies do not produce reproductive stages (queens and drones) until after the end of oilseed rape flowering. At this stage they have typically consumed all stored hive products. For this reason colonies were collected in two phases. The first 6 colonies (2 multihives) were collected at the end of the oilseed rape flowering period (UK: 20/5/2015; Hungary: 18-19/5/2016; Germany: 30/5/2015 – 1/6/2016) in order to measure neonicotinoid residues in stored hive products (pollen and nectar). In addition, pollen was collected from the pollen baskets of workers returning to multihives.

The remaining six colonies were collected after 51-60 days following their exposure to the treated crop (UK: 9-11/6/2015; Hungary: 17-18/6/2016; Germany: 20-21/6/2016) in order to measure effects on reproductive success. Each colony was dissected and the total number of workers, queens and drones were counted. Queen number was defined as the combined number of emerged queens and un-emerged queen cells which could be distinguished on the basis of their larger size (>12 mm) (8). As the aperture entrance to colonies was too small to allow newly emerged queens from leaving counts of queens are likely to be very accurate. It was not possible to prevent drones from leaving the hives as they are similar in size to workers. As larval worker and drone cells were equivalent in size it was not possible to incorporate pupal cell numbers in the

estimation of either of these two castes. As there was typically considerable spill-over between colonies within a multihive counts of all castes were summed within a single multihive. Median numbers of developmental stages (queens, workers and drones) per site were used as a response. In addition to the dissections of hives, individual multihives were weighted at the same time at the honey bees at weekly intervals during the oilseed rape flowering period.

Solitary bees (*Osmia bicornis*)

This solitary bee has been identified as an important contributor to the worldwide value of crop production and frequently feeds on oilseed rape (11, 26). At each site 50 *Osmia bicornis* cocoons containing an equal ratio of males to females were placed in protected release cage. These were located next to two artificial trap nests (standardized wooden blocks (11 × 11 × 28 cm) drilled with equal number of 4, 6, 8 and 10mm diameter holes) attached to 2 m poles to provide nesting locations. *Osmia* species naturally nest along field edges so cocoons and trap nests were always situated at the edge of each fields. At the end of the oilseed rape flowering period (June 2015) the two trap nests were dissected and counts of the number of *O. bicornis* cells were made. A median count of the number of cells per site was used in subsequent analyses. Pollen and nectar samples were removed from individual cells to test for residues of neonicotinoids. Note, that as no *O. bicornis* reproductive cells were produced at three sites no pollen and nectar could be collected for analysis of neonicotinoid residues.

Neonicotinoid expression in the oilseed rape crop

To quantify the expression of neonicotinoids found within the treated and untreated crops a single honey bee hive was placed within a fine mesh cage (20m long × 5m wide × 3m tall) over the flowering crop. Honey bees were thus used as vectors to collect pollen and nectar from a large number of flowers at each site. This method has the advantage that it simultaneously collects pollen and nectar samples from a large number of oilseed rape plants. However, should there be spatial variation in the expression of neonicotinoids between plants some of this variation may be averaged out as the pollen and nectar collected from all plants were amalgamated. Pollen was collected from honey bees using pollen traps placed on the front of the hive. To collect nectar 300 bees returning to hives were collected and nectar was removed from their honey stomachs by dissection. Nectar and pollen was collected on two occasions (day 2 and day 9 of crop flowering). There was evidence of unexpected expression of neonicotinoids in the crop that did not correspond with the seed treatments (Table S12). Imidacloprid was detected in three sites. Clothianidin residues were found in one control and two thiamethoxam sites, although as clothianidin is a metabolite of thiamethoxam this does not reflect contamination (21). Thiamethoxam was found in one of the control sites and a clothianidin treated site. Although infrequent, unexpected expression in the crop was linked to historic patterns of pesticide application on these sites (17).

Neonicotinoid residue analysis

All pollen and nectar samples were transported in insulated boxes with dry ice and stored long term at -80°C. Samples of pollen and nectar were analysed to quantify concentrations of clothianidin, thiamethoxam (UKAS accredited ISO17025:2005

standards) and imidacloprid. Analysis was performed using a liquid chromatography coupled to a triple quadrupole 'Quantum Ultra TSQ' mass spectrometer (Thermo Fisher Scientific, Hemel Hemsptead; UK) interfaced with an ion max electrospray ionisation (ESI) system (see http://www.ceh.ac.uk/sites/default/files/NNI%20Residue%20method%20technical%20protocol_0.pdf for full protocol). A Limit of Quantification (LoQ) for both pollen and nectar samples of 0.53 ng g^{-1} (Limit of Detection (LoD) = 0.38 ng g^{-1}) was obtained for samples from the honey bee and *B. terrestris.* For *O. bicornis* the LoQ was 0.52 ng g^{-1} (LoD = 0.37 ng g^{-1}). Residues below the LoQ were defined in the data set to be half LoD. The LOD was determined using 3 times the signal to noise ratio while the LOQ was calculated as the LOD plus the calculated expanded uncertainty using the method defined by Magnusson *et al* (27).

Median and maximum residues of clothianidin, thiamethoxam and imidacloprid were determined for each site based on the multiple pollen and nectar samples. As neonicotinoid residues were detected in sites where that product was not applied a combined metric of clothianidin, thiamethoxam and imidacloprid was derived (NNI_{median} and NNI_{Max}). While all three neonicotinoids have a similar mode of action (21, 28) they do differ slightly in toxicity (29, 30, 31). To account for this we provide a standard correction for the summed concentration of neonicotinoids based on acute oral LD_{50} values for honey bees (TMX=0.005 µg bee^{-1}; CTD= 0.00379 µg bee^{-1}; IMI=0.0037 µg bee^{-1} , or a ratio of their relative oral toxicity of 1: 0.758: 0.74) (29, 30, 31) so that $NNI = (TMX) + (CPD \times 0.758) + (IMI \times 0.74)$. This same correction was used for wild pollinators as comparable LD_{50} values were not available for these species.

Landscape structure

Landscape composition was recorded within a 1.5-km radius of the center of each site based on direct field observations of habitat types derived from onsite surveys undertaken during the oilseed rape flowering period. Each discrete land parcel (minimum size 25 × 25 m) was digitized using ARCGIS software and assigned to: crops (oilseed rape, cereals, legumes or vegetables), horticulture, grassland (improved, semi-Improved, unimproved), woodland (linear feature, broadleaf, coniferous or mixed), scrub, water or urban land use. We include as covariates in subsequent model percentage area of oilseed rape (to describe the potential resource on which bees could forage) and the percentage cover of all arable crops. The cover of arable crops acts as a measure of agricultural land use intensity while the cover of oilseed rape defines the availability of the crop foraging resource.

Statistical Analysis

The analysis aimed to test whether population metrics for honey bees, *B. terrestris* and *O. bicornis* differed in size relative to the control where clothianidin or thiamethoxam was used to treat oilseed rape. All analyses were undertaken using gerneralized linear models in R 3.3.1 (32). These models are specified in full in Tables S4 and S5. The analysis was a two-step process. Firstly we tested whether continuous covariates describing between site variations in environmental conditions (landscape structure) and neonicotinoid exposure risk explained additional variation over that seen

for a country only model. This was done separately for covariate describing neonicotinoid residues in the nests (natural logs of NNI_{median} and NNI_{Max}), neonicotinoid residues expressed in the oilseed rape crop (natural logs of NNI_{Max}) and landscape percentage cover of oilseed rape and arable crops. The significance of individual covariates was assessed using a likelihood ratio test comparing each covariate (*y ~ covariate + country*) to a simple country only model (*y ~ country*). Other potential covariates showed strong systematic variation with either country or seed treatment and as such could not be directly tested within this framework without violated underlying model assumptions (e.g. the proportion of oilseed rape making up the diet of pollen (Table S10), disease (Table S11) and starting colony size (Table S2)).

Following this, we then tested whether these same metrics showed either no response to the seed treatments, an overall seed treatment response common to all countries, or a seed treatment response that was country-specific. This was done by undertaking three likelihood ratio tests (LRT) for each population metric. These were: (i) a test to assess whether a simple overall seed treatment effect common to all countries explained more variance than a country only model (LRT comparing '*y ~ treatment + covariates + block/country*' to the null model '*y ~ covariates + block/country*'); (ii) a test to assess if there was an additive seed treatment effect that was unique to each country (LRT comparing '*y ~ treatment*country + covariates +block/country*' to the null model '*y ~ covariate + block/country*'); and (iii) a test to assess if the additive seed treatment effect describing country specific responses was a better fit to the data than a simple overall seed treatment effect (LRT comparing '*y ~ treatment*country + covariates + block/country*' to the simple seed treatment only model '*y ~ treatment + covariates + block/country*'). Covariates were included only where they were demonstrated to explain additional variance in the population metrics over a simple country only model as explained above. It should be noted that none of the significant responses to seed treatment were not dependent on the inclusion of these continuous covariates within the models. Count data were typically over-dispersed and were modelled using a negative binomial distribution and log link (glm.nb function in the MASS package in R). Where response variables were normally distributed (assessed using a Shapiro-Wilk normality test confirmed by QQ plots of theoretical and sample quantiles) a normal distribution with identify link was used. Honey bee colony survival was modelled using an events / trials approach with binomial errors and logit link. Individual model-predicted marginal means were used to assess the significance of differences between the control and seed treatments within country (Tables S4 and S5). To confirm models met underlying assumptions visual checks of standard residual diagnostic plots were undertaken. We did not apply Bonferroni corrections as the lack of independence for the majority of the response variables (e.g. different life stages of honey bee) meant that there was no valid level for the correction. Note that honey bee overwintering survival in the UK was considered too low for valid statistical testing. As such the analysis of overwintering honey bee colony strength was restricted to Germany and Hungary data sets only.

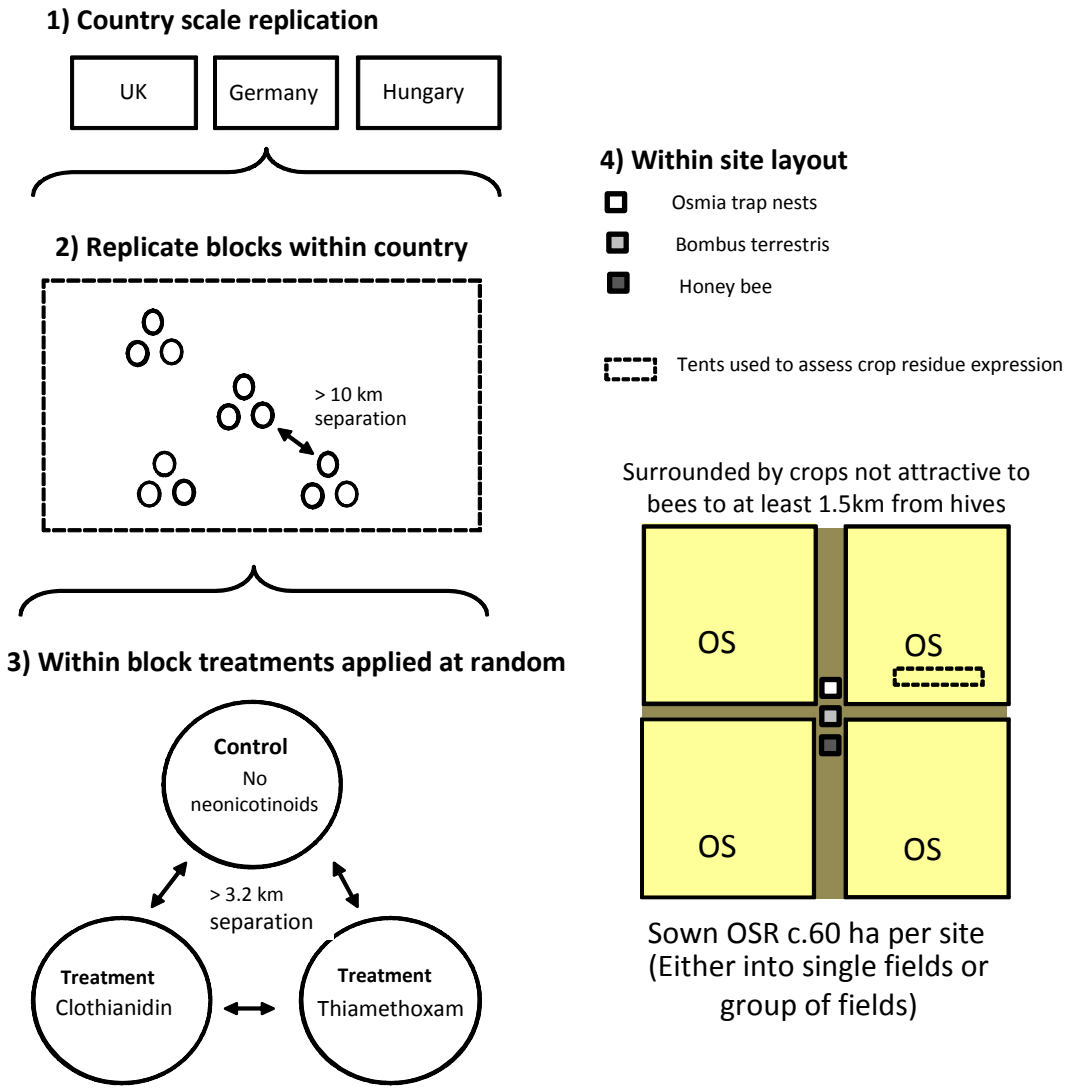
A further analysis was undertaken to assess if the occurrence of neonicotinoid residues in stored hive products (pollen and nectar) varied in response to seed treatment. This analysis followed the same structure described above with full models specified in Table S6. Individual clothianidin, thiamethoxam and imidacloprid residues were too

infrequent to provide a robust analysis of their individual responses (Table S7 to S9). We therefore assessed the response of the combined index (NNI_{Max}) of neonicotinoid residues to the additive seed treatment and country specific seed treatment effects models as described above. In addition to this, we also tested using the same approach whether the expression of neonicotinoid pesticides within the oilseed rape crop could be predicted by seed treatment (see Table S3 for individual models). Site median and peak residues of clothianidin and thiamethoxam (based on the four combined samples per site of pollen and nectar) had a large number of non-detect values making a direct analysis of these not possible (Table S12). To account for this we undertook an events (number of pollen and nectar samples with residues > LoQ): trials (total number of pollen and nectar samples) analysis using binomial errors (logit link). This assessed the proportion of pollen and nectar samples from the crop that had residues above the LoQ of 0.53 ng g^{-1} w/w. We note that while this approach is suitable for identifying broad patterns in the expression of neonicotinoids in the crop it does not take into account different levels of expression of these compounds in pollen and nectar. However, given the paucity of residue data the same analyses treating pollen and nectar residues separately would be too data poor to allow robust inferences (individual pollen and nectar residues are given in Tables S7, S8, S9 and S12).

Power analysis

Figures S2A-C presents a power analysis used to assess the capacity of the experimental design to detect overall additive neonicotinoid seed treatment effects that were consistent across all countries (i.e. $y \sim$ seed treatment + block/country). Figure A (honey bee response metrics recorded during the oilseed rape flowering period), B (honey bee population metrics following the overwinter period) and C (wild bee population metrics) provides the power (1-β) of the experimental design to detect effect size reductions from 7 – 50 % under different levels of replication (3, 4, 5, 10 or 20 replicate blocks within each country). To perform the power analysis we simulated data to determine how the number of replicate blocks within each country (where a block represents a control, clothianidin and thiamethoxam treated site) affects the power (1-β) of the study to detect a given effect size difference between the control and a single neonicotinoid seed treatment. This reflects the key experimental goal of identifying consistent cross-country effects of neonicotinoid seed treatments. To perform the power analysis we used a simple country only null model to derived estimates for univariate distributions, e.g. mean and standard deviation for normal distribution or theta for Negative binomial. From this we simulated data sets where effect size difference was altered between the control and a single neonicotinoid seed treatment. This was done by generating random outcomes from either a negative binomial, normal or binomial distribution depending on the response variable (Table S4 and S5). For each combination of effect size and number of blocks 10,000 simulations were run. Power (1-β) was defined to be the proportion of these simulations (for each effect size and block number combination) that had a probability of detecting an additive seed treatment effect.

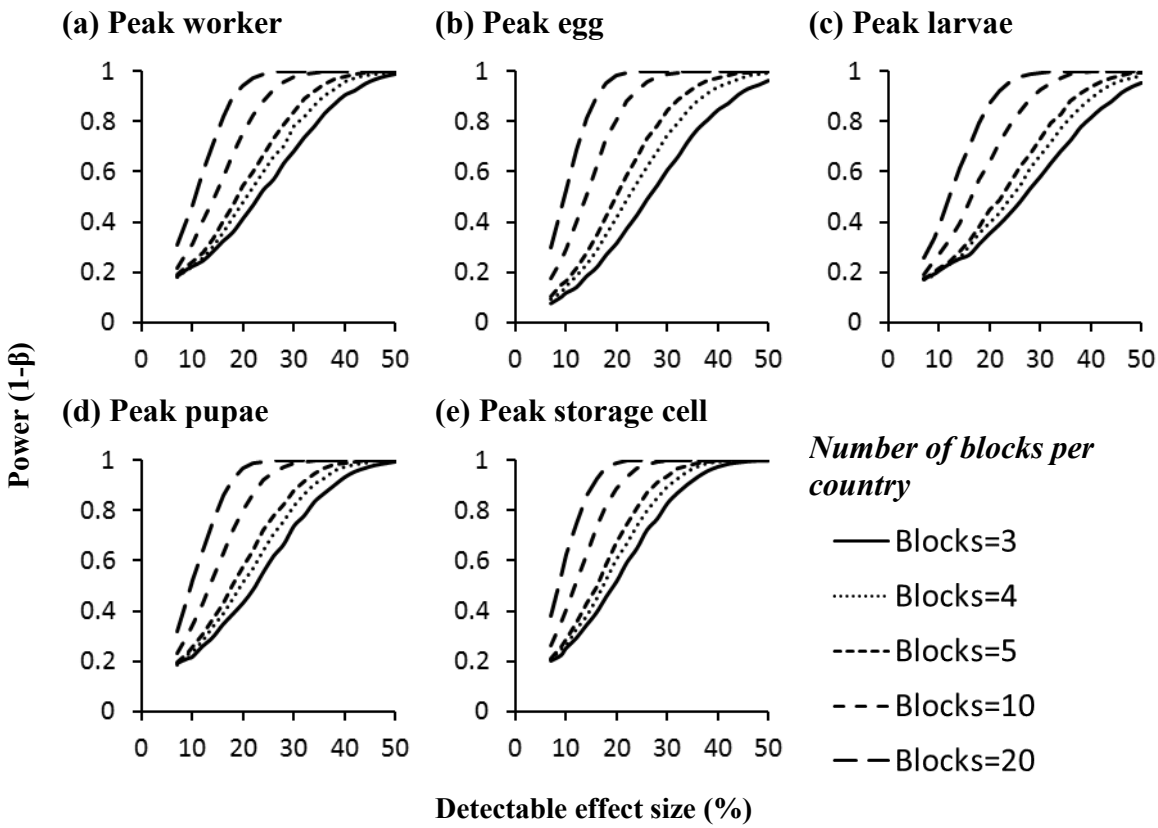
Fig S1.


1) Country scale replication
UK
Germany
Hungary
2) Replicate blocks within country
> 10 km separation
3) Within block treatments applied at random
Control
No neonicotinoids
> 3.2 km separation
Treatment
Clothianidin
Treatment
Thiamethoxam
4) Within site layout
Osmia trap nests
Bombus terrestris
Honey bee
Tents used to assess crop residue expression
Surrounded by crops not attractive to bees to at least 1.5km from hives
OS
OS
OS
OS
Sown OSR c.60 ha per site
(Either into single fields or group of fields)

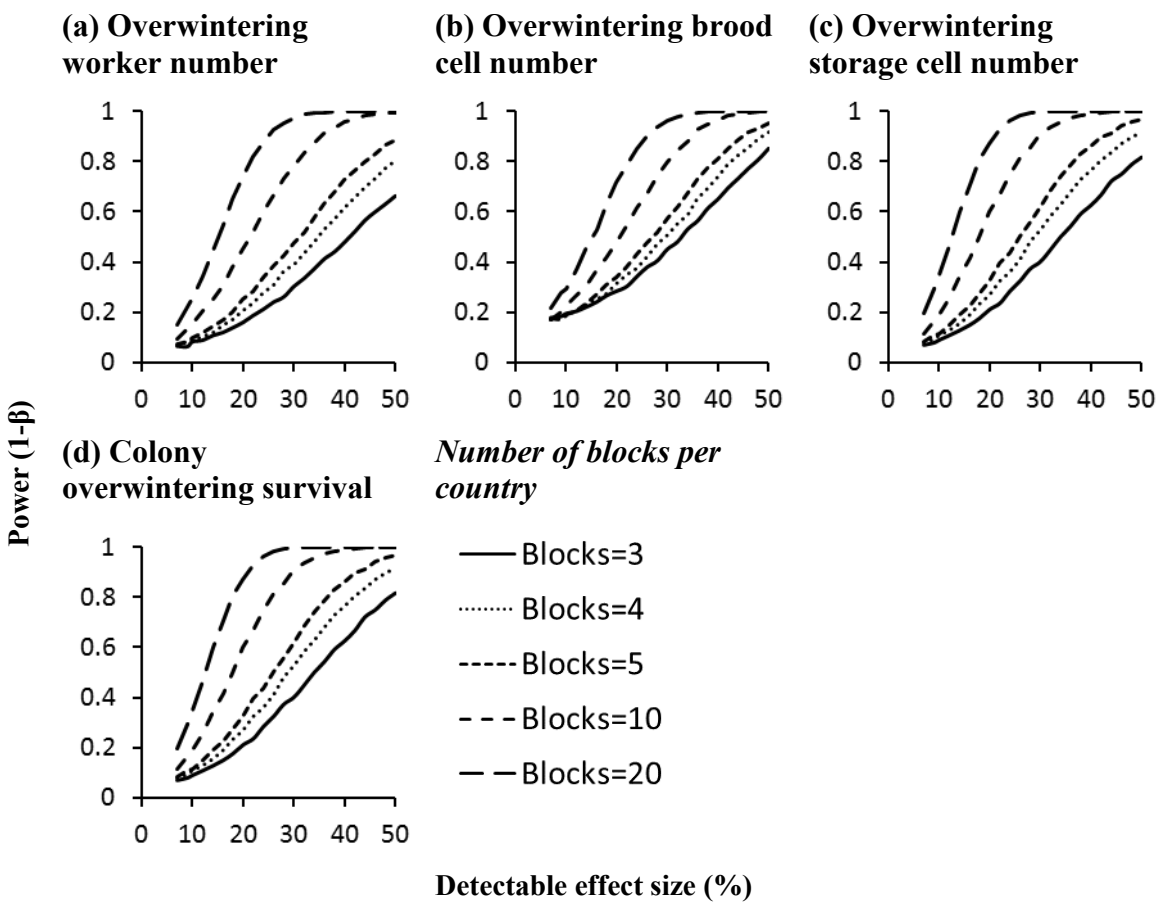
A simple diagrammatic representation of the experimental set-up. This shows the three seed treatments applied to winter oilseed rape (clothianidin, thiamethoxam and control). Each seed treatment was sown at the scale of an individual site (e.g. a farm), which represents our experimental unit. Triplets of sites were nested within blocks, with these blocks replicated within each of the three countries (UK and Hungary = 4 blocks, Germany = 3). Within each site honey bee hives, *B. terrestris* colonies and *O. bicornis* populations were established as close to the center of the sown oilseed rape as possible (although the three species were always separated by 50 m to limit direct interference). For some sites multiple fields of oilseed rape were needed to achieve the target coverage of crop. At these sites all three species were placed on a field boundary close to the centroid of the sown crop. At some sites only a single large field was sown. At these sites an area in the center of the field was cleared of the crop and the honey bee and *B. terrestris* colonies were placed here. For *O. bicornis* trap nests were always located on boundaries as the behavior of these species would prevent them colonizing trap nests in the center of a large field. The cages used to assess the expression of neonicotinoid residues in the crop were also established on one of the sown oilseed rape fields at each site.

Fig. S2.

(A)


(a) Peak worker
(b) Peak egg
(c) Peak larvae
(d) Peak pupae
(e) Peak storage cell
Power (1-β)
Detectable effect size (%)
Number of blocks per country
Blocks=3
Blocks=4
Blocks=5
Blocks=10
Blocks=20

(B)


(a) Overwintering worker number
(b) Overwintering brood cell number
(c) Overwintering storage cell number
(d) Colony overwintering survival
Power (1-β)
0
0.2
0.4
0.6
0.8
1
0 10 20 30 40 50
Number of blocks per country
Blocks=3
Blocks=4
Blocks=5
Blocks=10
Blocks=20
Detectable effect size (%)

(**C**)

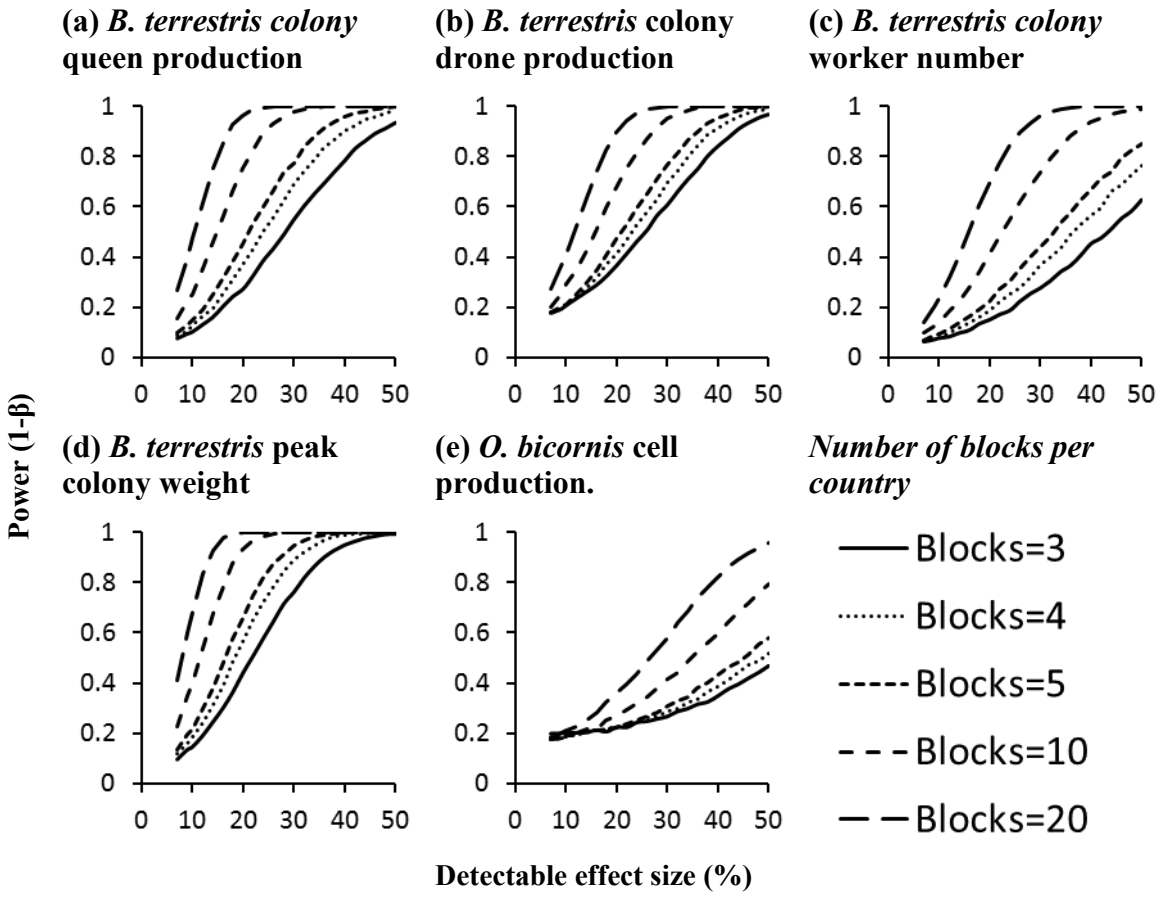


Fig. S2. Summary power analysis for individual population metrics. Summary graphs from a power analysis used to assess the capacity of the experimental design to detect overall additive neonicotinoid seed treatment effects that were consistent across all countries (i.e. y ~ seed treatment + block/country). (**A**) Honey bee response metrics recorded during the oilseed rape flowering period. (**B**) Honey bee population metrics following the overwinter period. (**C**) Wild bee population metrics. These data provide the power (1-β) of the experimental design to detect effect size reductions from 7 – 50 % under different levels of replication (3, 4, 5, 10 or 20 replicate blocks within each country).

Table S1. Site characteristics. A description of individual site characteristics including allocation of sites to neonicotinoid seed treatments (where CTD = clothianidin, TMX= thiamethoxam) and separation from the next closest site. Cover of oilseed rape and all arable crops within 1.5-km radii of hives is provided.

Country	Site / block	Treat.	Nearest site (km)	Sown area (ha) (Percentage cover OSR)	Cover of arable crops (%)	Shannon habitat diversity
Germany	1 (Bl.1)	Control	9.3	66.7 (9.7)	34.4	1.37
Germany	2 (Bl.1)	CTD	4.1	95.7 (17.2)	33.6	1.67
Germany	3 (Bl.1)	TMX	4.1	74.3 (15.3)	65.3	1.44
Germany	4 (Bl.2)	Control	7.7	72.5 (11.7)	21.3	1.40
Germany	5 (Bl.2)	CTD	7.0	37.4 (5.7)	50.8	1.66
Germany	6 (Bl.2)	TMX	7.0	31.4 (10.4)	74.7	1.20
Germany	7 (Bl.3)	Control	4.8	74.2 (15.8)	86.8	1.45
Germany	8 (Bl.3)	CTD	5.9	54.6 (12.9)	93.6	0.73
Germany	9 (Bl.3)	TMX	4.8	74.3 (16.0)	46.6	1.57
Hungary	10 (Bl.1)	Control	3.3	47.5 (7.0)	93.8	1.32
Hungary	11 (Bl.1)	TMX	3.3	55.7 (12.1)	90.7	1.47
Hungary	12 (Bl.1)	CTD	11.6	43.7 (17)	87.5	1.53
Hungary	13 (Bl.2)	Control	6.1	79.4 (13.6)	74.3	1.54
Hungary	14 (Bl.2)	TMX	4.5	46.1 (15.3)	66.5	1.68
Hungary	15 (Bl.2)	CTD	4.5	50.6 (9.8)	42.5	1.65
Hungary	16 (Bl.3)	Control	6.6	65.6 (20.1)	70.2	1.55
Hungary	17 (Bl.3)	TMX	3.7	77.4 (11.1)	65.5	1.63
Hungary	18 (Bl.3)	CTD	3.7	76.7 (14.5)	58	1.28
Hungary	19 (Bl.4)	CTD	10.8	64.8 (12.6)	98.7	1.4
Hungary	20 (Bl.4)	Control	4.7	45.4 (8.9)	52.6	1.68
Hungary	21 (Bl.4)	TMX	4.7	53.6 (9.3)	61.3	1.59
UK	22 (Bl.1)	TMX	4.6	85.8 (12.6)	35.7	1.72
UK	23 (Bl.1)	Control	4.6	75.1 (14.1)	35.5	1.75
UK	24 (Bl.1)	CTD	6	56.7 (9.4)	75.9	1.9
UK	25 (Bl.2)	Control	8.2	56.9 (33.2)	72.6	1.8
UK	26 (Bl.2)	TMX	10.5	70.6 (8.7)	44.8	2.06
UK	27 (Bl.2)	CTD	8.2	71.2 (15.9)	63.5	1.79
UK	28 (Bl.3)	CTD	12	91.0 (10.2)	45.8	1.98
UK	29 (Bl.3)	Control	12	56.7 (12.8)	61.6	1.77
UK	30 (Bl.3)	TMX	17.3	73.1 (8.0)	51.3	1.81
UK	31 (Bl.4)	Control	4.7	59.6 (10.7)	25.3	1.88
UK	32 (Bl.4)	TMX	7.5	61.4 (8.6)	37.1	1.79
UK	33 (Bl.4)	CTD	4.7	36.9 (9.0)	47.6	2.31

Table S2. Peak honey bee population metrics derived during the flowering (S2A) and overwintering (S2B) periods. Reproductive success of *B. terrestris* and *O. bicornis* (S2C). Presented values are based on site medians across hives and colonies for honey bees and *B. terrestris.* For this reason the number of hives (out of six) surviving the winter period can be above zero while median population sizes for that site can be zero. Peak hive / colony weights for honey bees are given relative to the first weight measurement when hives were placed out on experimental sites.

Table S2A

Site (treatment)	Workers (pre-exposure to crop)	Peak worker	Peak egg	Peak larvae	Peak pupae	Peak male brood	Peak storage cell
G1 (Cont.)	11737	21850	4960	7920	23040	1120	122480
G2 (CTD)	10050	21975	6080	8400	23680	1120	88480
G3 (TMX)	12150	22350	4080	5920	23040	480	125760
G4 (Cont.)	12375	16550	2960	2560	15040	240	108160
G5 (CTD)	13350	23025	5440	8320	20080	880	119040
G6 (TMX)	7987	22000	9120	8800	23040	640	79600
G7 (Cont.)	9975	22250	3280	6720	23680	1680	88160
G8 (CTD)	9487	16325	4880	7200	24080	1280	89360
G9 (TMX)	7275	19800	5360	8080	24240	1200	86960
H10 (Cont.)	8712	19380	3672	9112	30328	0	37672
H11 (TMX)	7905	19508	2856	8296	25160	0	53040
H12 (CTD)	7990	17723	3264	11560	24480	0	52904
H13 (Cont.)	8585	23037	6800	10472	30192	0	51620
H14 (TMX)	11517	27507	5576	10336	31824	136	57528
H15 (CTD)	7947	20995	5712	10744	28696	0	50592
H16 (Cont.)	8925	25683	6120	12104	34272	0	50320
H17 (TMX)	10285	29745	4216	8568	30736	0	53176
H18 (CTD)	8627	24609	4216	10064	30328	0	59964
H19 (CTD)	7947	17425	2584	8432	24616	0	40664
H20 (Cont.)	9945	18190	5712	10200	25432	0	34000
H21 (TMX)	8585	17723	2176	8024	20808	0	34544
UK22 (TMX)	3550	5050	1280	2080	7920	96	8080
UK23 (Cont.)	2855	2330	1280	1440	4240	0	3600
UK24 (CTD)	3940	1025	160	0	4160	0	1840
UK25 (Cont.)	3675	5525	1600	3280	8640	80	5760
UK26 (TMX)	3600	2200	1680	1760	4080	0	4720
UK27 (CTD)	3500	920	1280	208	3520	0	3008
UK28 (CTD)	2500	3500	1040	2000	5840	0	4320
UK29 (Cont.)	2370	6450	1680	2560	11200	0	8000
UK30 (TMX)	1405	6800	2880	3520	12320	0	9040

UK31 (Cont.)	2245	2375	960	640	2240	0	8480
UK32 (TMX)	2025	2375	976	640	1760	0	9200
UK33 (CTD)	1800	2885	1552	2080	4480	160	4960

Table S2B

Site (treatment)	Worker (overwinter)	Combined brood (overwinter)	Storage cells (overwinter)	Number of surviving hives (out of 6) following winter
G1 (Cont.)	3926	400	12880	6
G2 (CTD)	3796	960	15440	6
G3 (TMX)	2314	880	11200	5
G4 (Cont.)	3588	240	16640	6
G5 (CTD)	4784	800	14640	6
G6 (TMX)	3432	80	14640	4
G7 (Cont.)	4030	720	19520	6
G8 (CTD)	4810	720	12800	5
G9 (TMX)	6474	1200	13440	5
H10 (Cont.)	8840	1360	38760	5
H11 (TMX)	10625	5440	30328	6
H12 (CTD)	5398	952	40256	6
H13 (Cont.)	6545	2312	25568	6
H14 (TMX)	6035	1224	25160	6
H15 (CTD)	5653	1224	24888	6
H16 (Cont.)	10710	3400	33728	6
H17 (TMX)	10073	2584	39440	6
H18 (CTD)	7863	2312	33728	5
H19 (CTD)	5270	2312	27880	6
H20 (Cont.)	7055	2176	22712	6
H21 (TMX)	8628	2856	25568	5
UK22 (TMX)	0	0	0	1
UK23 (Cont.)	375	480	6480	3
UK24 (CTD)	0	0	0	0
UK25 (Cont.)	0	0	0	1
UK26 (TMX)	0	0	0	2
UK27 (CTD)	0	0	0	1
UK28 (CTD)	0	0	0	2
UK29 (Cont.)	850	320	12560	4
UK30 (TMX)	1925	1440	7520	4
UK31 (Cont.)	0	0	0	2
UK32 (TMX)	0	0	0	1
UK33 (CTD)	0	0	0	2

Table S2C

Site (treatment)	*Bombus* workers pre-exposure (based on multihives of 3 colonies)	*Bombus* Queen production	*Bombus* drone production	*Bombus* worker number	*Bombus* peak multihive weight (kg)	*Osmia* reproductive cell number
G1 (Cont.)	275	387	138	133	1.962	80
G2 (CTD)	321	299	253	141	2.461	164
G3 (TMX)	270	368	228	281	2.297	82
G4 (Cont.)	315	157	122	217	1.551	93
G5 (CTD)	349	318	129	129	1.355	59
G6 (TMX)	309	189	149	256	1.268	140
G7 (Cont.)	323	363	178	240	1.95	197
G8 (CTD)	298	368	123	197	2.611	38
G9 (TMX)	332	296	519	292	2.177	284
H10 (Cont.)	240	441	168	223	2.161	116
H11 (TMX)	248	483	163	225	1.693	82
H12 (CTD)	230	294	178	107	1.788	42
H13 (Cont.)	278	404	166	370	2.085	189
H14 (TMX)	268	513	150	230	1.986	286
H15 (CTD)	248	480	214	301	1.301	381
H16 (Cont.)	213	606	167	204	1.779	171
H17 (TMX)	230	312	104	122	1.731	177
H18 (CTD)	300	463	188	295	2.088	97
H19 (CTD)	230	322	94	131	2.091	11
H20 (Cont.)	243	345	164	105	1.72	60
H21 (TMX)	238	382	230	142	2.024	183
UK22 (TMX)	267	219	146	96	2.639	0 †
UK23 (Cont.)	238	165	505	394	2.934	0 †
UK24 (CTD)	276	278	257	210	2.192	20
UK25 (Cont.)	232	82	245	154	1.636	36
UK26 (TMX)	280	277	315	299	1.865	264
UK27 (CTD)	287	315	344	384	2.083	0 †
UK28 (CTD)	295	174	369	301	1.774	45
UK29 (Cont.)	300	305	522	422	2.612	86
UK30 (TMX)	282	63	295	305	1.916	147
UK31 (Cont.)	304	139	109	116	1.251	26
UK32 (TMX)	270	265	105	144	1.549	100
UK33 (CTD)	287	249	144	258	1.326	83

†As no *O. bicornis* cells were found at these sites no residue analysis for neonicotinoids was possible.

Table S3. Statistical tests and analysis of pollen and nectar samples. Summary of statistical tests (**A**) and results from statistical analyses testing the probability that pollen and nectar samples collected from the oilseed rape crop will express clothianidin, thiamethoxam and imidacloprid above the LoQ (0.53 ng g^{-1} w/w) in response to seed treatment (**B**). Due to the relatively infrequent recovery of residues from the crop, separate analyses for pollen and nectar were not undertaken as nonzero data was too scarce for a robust analysis. In these analyses, we used likelihood ratio tests to assess whether (i) there was an overall seed treatment effect common to all countries (TEST 1), (ii) if there was an additive seed treatment effect that was unique to each country (TEST 2), and (iii) if there was an additive seed treatment effect was that a better fit to the data that a simple overall seed treatment effect (TEST 3). TEST 1 compares a seed treatments only model (*y ~ treatment + block/country*) to the null model ('*y ~ block/country*'); TEST 2 compares an additive seed treatment model (*y ~ treatment*country + block/country*) to the same null model (*y ~ block/country*); and TEST 3 compares the additive seed treatment model (*y ~ treatment*country + block/country*) to the simple seed treatment only model (*y ~ treatment + block/country*). This final comparison is only pertinent when the additive seed treatment model explains more variation than the null model. For both thiamethoxam and imidacloprid only three sites were identified where residues were found in the crop (Table S12).

Table S3A

Test	Description of models compared using likelihood ratio tests
TEST 1: 'Seed treatment only model' > null	H0: y ~ block/country H1: y ~ treatment + block/country
TEST 2: 'Seed treatment × country model' > null	H0: y ~ block/country H1: y ~ treatment*country + block/country
TEST 3: 'Seed treatment × country model' > 'Seed treatment only model'	H0: y ~ treatment + block/country H1: y ~ treatment*country + block/country

Table S3B

Analysis	Proportion of pollen and nectar samples with neonicotinoid residues above the LoQ (>0.53 ng g^{-1} w/w)		
	Clothianidin	**Thiamethoxam**	**Imidacloprid**
Error distribution	Binomial (logit Link)	Binomial (logit Link)	Binomial (logit Link)
TEST 1: 'Seed treatment only model' > null	**χ^2_2=6.46, p=0.04**	χ^2_2=2.98, p=0.22	χ^2_2=0.19, p=0.90
TEST 2: 'Seed treatment × country model' > null	**χ^2_6=12.4, p=0.05**	χ^2_6=2.98, p=0.81	χ^2_6=0.19, p=0.99
TEST 3: 'Seed treatment × country model' > 'Seed treatment only model'	χ^2_4=5.92, p=0.20	χ^2_4<0.001, p=0.999	χ^2_4<0.001, p=0.999

Table S4. Statistical tests and analysis of honey bees for seed treatment effects. Summary of statistical tests (**A**) and results from statistical analyses for honey bees during the oilseed rape flowering (**B**) and overwintering periods (**C**). In these analyses we used likelihood ratio test to assess whether (i) there was an overall seed treatment effect common to all countries (TEST 1), (ii) if there was an additive seed treatment effect that was unique to each country (TEST 2), and (iii) if there was an additive seed treatment effect was that a better fit to the data that a simple overall seed treatment effect (TEST 3). TEST 1 compares a seed treatments only model (*y ~ treatment + covariates + block/country*) to the null model ('y ~ *covariates + block/country*'); TEST 2 compares an additive seed treatment model (*y ~ treatment*country + covariates +block/country*) to the same null model (*y ~ covariates + block/country*); and TEST 3 compares the additive seed treatment model (*y ~ treatment*country + covariates + block/country*) to the simple seed treatment only model (*y ~ treatment + covariates + block/country*). The inclusion of covariates in models for TESTS 1 to 3 occurred only where they were demonstrated to explain additional variance in the population metrics over that explained by underlying between country variation. This was assessed using likelihood ratio tests to compare the effect of individual covariate (*y~ covariates + country*) to a simple country only model (*y ~ country*). Continuous covariates were percentage cover of oilseed rape, percentage arable cover and the natural logs of maximum (NNI_{Max}) concentrations of neonicotinoid residues (combined clothianidin, thiamethoxam and imidacloprid) in hives and detected from the oilseed rape crop. Note the median values of neonicotinoid expression were not used as they were too data poor to provide viable covariates (Table S12). Also as the UK honey bee colonies were so different in size from those of Germany and Hungary their inclusion in one model violated distributional assumptions and so UK sites were tested separately using a simple additive model (*y ~ treatment + block*) compared to a null model (*y ~ block*). Honey bee male brood data was too data poor for a valid statistical analysis and so this is not presented. Individual life stages of overwintering brood were infrequent following the overwintering period and so were summed to provide total overwintering brood (eggs + larvae + pupae + male brood). For count data the underlying distributions were sometimes more optimally modelled using a normal distribution with identify link. We provide a measure of explained variance where a fixed effect was found to improve model fit relative to the null model based on how much of the variation in the residuals had been removed (Expl. Var.). Where significant seed treatment differences were identified predicted marginal means were used to compare within treatment differences between the control and thiamethoxam (C-TMX) and control and clothianidin (C-CTD) seed treatments. Note that for the UK overwintering mortality was very high across all seed treatments. Too few data were therefore present in the UK for a valid statistical analysis.

Table S4A

Test	**Description of models compared using likelihood ratio tests.**
TEST 1: 'Seed treatment only model' > null	H0: y ~ covariates† + block/country H1: y ~ treatment + covariates† + block/country
TEST 2: 'Seed treatment × country model' > null	H0: y ~ covariates† + block/country H1: y ~ treatment*country + covariates† + block/country
TEST 3: 'Seed treatment × country model' > 'Seed treatment only model'	H0: y ~ treatment + covariates† + block/country H1: y ~ treatment*country + covariates† + block/country
Oilseed rape % cover	H0: y ~ country H1: y ~ arable_cover + country
Arable crop % cover	H0: y ~ country H1: y ~ oilseed_cover + country
Log_e (NNI_{Max} *hives*)	H0: y ~ country H1: y ~ NNI_{Max} *hives* + country
Log_e (NNI_{Max} *Crop*)	H0: y ~ country H1: y ~ NNI_{Max} *Crop* + country

† Covariates are only included in these models where they are identifies as explaining a significant increase in mode variance above that of a simple country only model.

Table S4B

Honey bee oilseed rape flowering period analysis	**Worker (max. flowering period)**	**Eggs (max. flowering period)**	**Larvae (max. flowering period)†**	**Pupae (max. flowering period)**	**Stored hive products (max. summed nectar and pollen cells)**
Germany & Hungary analysis					
Error distribution	Neg. Bin. (link-Log)	Normal (Link=Ident.)	Neg. Bin. (link-Log)	Neg. Bin. (link-Log)	Neg. Bin. (link-Log)
Shapiro-Wilk normality test	W=0.87, p=0.001	W=0.94, p=0.11	W=0.90, p<0.01	W=0.88, p<0.01	W=0.89, p<0.01
TEST 1: 'Seed treatment only model' > null	**χ^2_2=6.24, p=0.04**	χ^2_2=0.16, p=0.81	χ^2_2=0.06, p=0.96	χ^2_2=0.62, p=0.73	**χ^2_2=6.46, p=0.04**
TEST 2: 'Seed treatment × country model' > null	**χ^2_6=16.6, p=0.01 (Expl.Var. = 45.3 %)** **Ger**: C-TMX *z*=-0.27, *p*=0.95; C-CTD *z*=-0.03, *p*=0.99. **Hun**: C-TMX *z*=-0.45, *p*=0.89; C-CTD *z*=0.39, *p*=0.91. **UK**: C-TMX *z*=0.19, *p*=0.97; C-CTD *z*=4.38, *p*<0.01;	**χ^2_6=4.13, p=0.01 (Expl.Var. = 49.9 %)** **Ger**: C-TMX *z*=-2.77, *p*=0.01; C-CTD *z*=-1.96, *p*=0.12. **Hun**: C-TMX *z*=2.43, *p*=0.04; C-CTD *z*=2.12, *p*=0.08. **UK**: C-TMX *z*=-0.42, *p*=0.90; C-CTD *z*=0.48, *p*=0.87.	χ^2_6=2.31, p=0.88	χ^2_6=5.73, p=0.45	**χ^2_6=40.5, p<0.001 (Expl.Var. = 53.6%)** **Ger**: C-TMX *z*=0.79, *p*=0.70; C-CTD *z*=0.54, *p*=0.85. **Hun**: C-TMX *z*=-1.36, *p*=0.36; C-CTD *z*=-1.76, *p*=0.18. **UK**: C-TMX *z*=-2.35, *p*=0.05; C-CTD *z*=6.41, *p*<0.01.
TEST 3: 'Seed treatment × country model' > 'Seed treatment only model'	**χ^2_4=10.3, p=0.04**	**χ^2_4=3.97, p=0.004**	χ^2_4=2.25, p=0.68	χ^2_4=5.11, p=0.27	**χ^2_4=34.1, p<0.001**
Oilseed rape % cover	χ^2_1=1.42, p=0.23	χ^2_1=0.01, p=0.84	χ^2_1=1.11, p=0.29	χ^2_1=1.78, p=0.18	χ^2_1=0.02, p=0.87
Arable crop % cover	χ^2_1=0.01, p=0.93	χ^2_1=0.21, p=0.48	χ^2_1=1.08, p=0.29	χ^2_1=1.64, p=0.19	χ^2_1=2.987, p=0.09
Log_e (NNI_{Max} hives)	χ^2_1=0.04, p=0.83	χ^2_1=0.47, p=0.28	χ^2_1=0.23, p=0.62	χ^2_1=0.06, p=0.79	χ^2_1=0.31, p=0.57
Log_e (NNI_{Max} Crop)	χ^2_1=0.19, p=0.65	χ^2_1=0.03, p=0.78	χ^2_1=0.56, p=0.45	χ^2_1=0.12, p=0.91	χ^2_1=0.37, p=0.54

†Model convergence for larval data could not be achieved where an outlier zero count value was included in a clothianidin seed treatment in the UK. This data point was excluded.

Table S4C

Honey bee overwintering period analysis	**Overwintering hive survival**	**Overwintering Worker numbers**	**Overwintering total brood (eggs + larvae + pupae + male brood)**	**Overwintering stored hive products.**
Germany & Hungary analysis				
Error distribution	Binomial (Link=Logit.)	Normal (link=Ident.)	Neg. Bin. (link-Log)	Normal (link=Ident.)
Shapiro-Wilk normality test	NA	W=0.94, p=0.24	W=0.87, p=0.01	W=0.91, p=0.08
TEST 1: 'Seed treatment only model' > null	χ^2_2=3.39, p=0.18	χ^2_2=0.61, p=0.13	χ^2_2=0.93, p=0.62	χ^2_2=0.05, p=0.63
TEST 2: 'Seed treatment × country model' > null	χ^2_6=9.31, p=0.15	**χ^2_6=1.47, p<0.01 (Expl.Var. = 59.4 %)** **Ger**.:C-CTD z=-0.67, p=0.77; C-TMX=-0.25, p=0.99. **Hun**: C-CTD z=2.85, p=0.01; C-TMX-0.70, p=0.76. **UK**: NA	χ^2_6=7.59, p=0.10	χ^2_6=0.12, p=0.72
TEST 3: 'Seed treatment × country model' > 'Seed treatment only model'	χ^2_4=5.91, p=0.21	**χ^2_4=0.85, p=0.01**	**χ^2_4=6.65, p=0.03**	χ^2_4=0.07, p=0.55
Oilseed rape % cover	χ^2_1=0.29, p=0.58	χ^2_1=0.001, p=0.99	χ^2_1=1.22, p=0.26	χ^2_1=0.08, p=0.44
Arable % cover	χ^2_1=2.11, p=0.14	χ^2_1=0.01, p=0.89	χ^2_1=0.27, p=0.60	χ^2_1=0.20, p=0.23
Log_e (NNI_{Max} *Hives*)	χ^2_1=1.00, p=0.31	χ^2_1=0.10, p=0.51	χ^2_1=0.02, p=0.88	χ^2_1=0.37, p=0.10
Log_e (NNI_{Max} *Crop*)	χ^2_1=3.27, p=0.08	χ^2_1=0.001, p=0.96	χ^2_1=0.34, p=0.55	χ^2_1=0.24, p=0.18

Table S5. Statistical tests and analysis of wild bee seed treatment effects. Summary of statistical tests (**A**) and results from statistical analyses for wild bees (*B. terrestris* and *O. bicornis*) during the oilseed rape flowering (**B**). In these analyses we used likelihood ratio test to assess whether (i) there was an overall seed treatment effect common to all countries (TEST 1), (ii) if there was an additive seed treatment effect that was unique to each country (TEST 2), and (iii) if there was an additive seed treatment effect was that a better fit to the data that a simple overall seed treatment effect (TEST 3). TEST 1 compares a seed treatments only model (*y ~ treatment + covariates + block/country*) to the null model ('*y ~ covariates + block/country*'); TEST 2 compares an additive seed treatment model (y ~ *treatment*country + covariates + block/country*) to the same null model (*y ~ covariates + block/country*); and TEST 3 compares the additive seed treatment model (*y ~ treatment*country + covariates + block/country*) to the simple seed treatment only model (*y ~ treatment + covariates + block/country*). The inclusion of covariates in models for TESTS 1 to 3 occurred only where they were demonstrated to explain additional variance in the population metrics over that explained by underlying between country variations. This was assessed using likelihood ratio tests to compare the effect of individual covariate (*y~ covariates + country*) to a simple country only model (*y~ country*). Continuous covariates were percentage cover of oilseed rape, percentage arable cover and the natural logs of median (NNI_{median}) and maximum (NNI_{Max}) concentrations of neonicotinoid residues (combined clothianidin, thiamethoxam and imidacloprid) in nests and detected from the oilseed rape crop. Note the median values of neonicotinoid expression in the crop were not used as there were too few data to provide viable covariates (Table S12). For *O. bicornis* reproductive cell production neonicotinoid residues could only be collected from sites where cells were found and so there was no data for sites UK22, UK23 and UK27. Although significant effects of NNI_{median} were identified for *O. bicornis* reproductive cell production the inclusion of these covariates in the additive treatment and country specific treatment models caused the loss of zero count data from three sites. Both seed treatment models were therefore tested without the inclusion of NNI_{median} so that zero count data was not lost. We provide a measure of explained variance where a fixed effect was found to improve model fit relative to the null model based on how much of the variation in the residuals had been removed (Expl. Var.). Where significant seed treatment differences were identified predicted marginal means to compare within treatment differences between the control and thiamethoxam (C-TMX) and control and clothianidin (C-CTD) seed treatments.

Table S5A

Test	Description of models compared using likelihood ratio tests.
TEST 1: 'Seed treatment only model' > null	H0: y ~ covariates† + block/country H1: y ~ treatment + covariates† + block/country
TEST 2: 'Seed treatment × country model' > null	H0: y ~ covariates† + block/country H1: y ~ treatment*country + covariates† + block/country
TEST 3: 'Seed treatment × country model' > 'Seed treatment only model'	H0: y ~ treatment + covariates† + block/country H1: y ~ treatment*country + covariates† + block/country
Oilseed rape % cover	H0: y ~ country H1: y ~ arable_cover + country
Arable crop % cover	H0: y ~ country H1: y ~ oilseed_cover + country
Log_e (NNI_{Median} *hives*)	H0: y ~ country H1: y ~ NNI_{Median} *hives* + country
Log_e (NNI_{Max} *hives*)	H0: y ~ country H1: y ~ NNI_{Max} *hives* + country
Log_e (NNI_{Max} *Crop*)	H0: y ~ country H1: y ~ NNI_{Max} *Crop* + country

†Covariates are only included in these models where they are identified as explaining a significant increase in mode variance above that of a simple country only model.

Table S5B

Wild pollinator responses	***B. terrestris* worker number**	***B. terrestris* queen number**	***B. terrestris* drone number**	**Max. *B. terrestris* colony weight gain**	***O. bicornis* reproductive cell number**
Error distribution	Normal (Ident. Link)	Normal (Ident. Link)	Neg. Bin. (link-Log)	Normal (Ident. link)	Neg. Bin. (link-Log)
Shapiro-Wilk normality test	W=0.98, p=0.94	W=0.93, p=0.96	W=0.81, p<0.001	W=0.96, p=0.45	W=0.90, p=0.01
TEST 1: 'Seed treatment only model' > null	χ^2_2=0.19, p=0.89	χ^2_2=0.04, p=0.96	χ^2_2=0.06, p=0.96	χ^2_2=0.09, p=0.91	χ^2_2=4.12, p=0.12
TEST 2: 'Seed treatment × country model' > null	χ^2_6=4.69, p=0.46	χ^2_6=0.97, p=0.95	**χ^2_6=13.1, p=0.04 (Expl.Var. = 13.6 %)** **Ger**: C-TMX *z*=-0.-3.11, *p*=0.01; C-CTD *z*=-0.74, *p*=0.73. **Hun**: C-TMX *z*=0.18, *p*=0.98; C-CTD *z*=-0.05, *p*=0.99. **UK**: C-TMX *z*=2.41, *p*=0.04; C-CTD *z*=0.87, *p*=0.65.	χ^2_6=1.86, p=0.74	χ^2_6=7.42, p=0.28
TEST 3: 'Seed treatment × country model' > 'Seed treatment only model'	χ^2_4=4.50, p=0.25	χ^2_4=0.94, p=0.81	**χ^2_4=13.1, p=0.01**	χ^2_4=1.76, p=0.50	χ^2_4=3.30, p=0.50
Oilseed rape % cover	χ^2_1=0.25, p=0.61	χ^2_1=0.14, p=0.59	χ^2_1=0.24, p=0.62	χ^2_1=1.34, p=0.25	χ^2_1=0.60, p=0.43
Arable % cover	χ^2_1=0.39 p=0.53	χ^2_1=0.14, p=0.60	χ^2_1=0.14, p=0.70	**χ^2_1=1.32, p=0.26**	**χ^2_1=1.34, p=0.24**
Log$_e$ (NNI$_{median}$ Nests)	χ^2_1=1.53, p=0.21	χ^2_1=0.15, p=0.59	χ^2_1=1.92, p=0.16	χ^2_1=0.80, p=0.38	**χ^2_1=4.33, p=0.04‡ (Expl.Var. = 0.8 %)**
Log$_e$ (NNI$_{Max}$ Nests)	χ^2_1=0.08, p=0.77	**χ_1=2.09, p=0.03† (Expl.Var. = 13.5 %)**	χ^2_1=0.15, p=0.69	χ^2_1=0.71, p=0.41	χ^2_1=0.45, p=0.49
Log$_e$ (NNI$_{Max}$ Crop)	χ^2_1=1.50, p=0.21	χ^2_1=0.01, p=0.91	χ^2_1=0.90, p=0.34	χ^2_1=0.81, p=0.37	χ^2_1=0.06, p=0.79

†If sites where the imidacloprid contaminant are excluded this correlation remains significant (χ^2_1=2.14, p=0.02).
‡If sites where the imidacloprid contaminant are excluded this correlation is not significant (χ^2_1=0.05, p=0.81).
††This marginal (p=0.07) response of drone production to combined neonicotinoid concentrations in expressed I the oilseed rape crop had a correlation coefficient of –3.14.

Table S6. Statistical test and analysis of the exposure of bees to neonicotinoids. Summary of statistical tests (**A**) and results from statistical analyses for honey bees and wild bees (*B. terrestris* and *O. bicornis*) describing the NNI_{Max} index (combining clothianidin, thiamethoxam and imidacloprid peak values) found in stored hive products (pollen and nectar) during the oilseed rape flowering (**B**). The NNI_{Max} index provides a measure of the exposure of bees to neonicotinoids originating from multiple sources (crop and non-crop plants). Note that assessment of separate neonicotinoid products was not viable due to paucity of data (Table S7 to S9). In these analyses we used likelihood ratio test to assess whether (i) there was an overall seed treatment effect common to all countries (TEST 1), (ii) if there was an additive seed treatment effect that was unique to each country (TEST 2), and (iii) if there was an additive seed treatment effect was that a better fit to the data that a simple overall seed treatment effect (TEST 3). TEST 1 compares a seed treatments only model (*y ~ treatment + block/country*) to the null model (*y ~ block/country*); TEST 2 compares an additive seed treatment model (*y ~ treatment*country + block/country*) to the same null model (*y ~ block/country*); and TEST 3 compares the additive seed treatment model (*y ~ treatment*country + block/country*) to the simple seed treatment only model (*y ~ treatment + block/country*). This final comparison is only pertinent when the additive seed treatment model explains more variation than the null model. For *O. bicornis* reproductive cell production neonicotinoid residues could only be collected from sites where cells were found and so there was no data for sites UK22, UK23 and UK27.

Table S6A

Test	**Description of models compared using likelihood ratio tests.**
TEST 1: 'Seed treatment only model' > null	H0: y ~ block/country H1: y ~ treatment + block/country
TEST 2: 'Seed treatment × country model' > null	H0: y ~ block/country H1: y ~ treatment*country + block/country
TEST 3: 'Seed treatment × country model' > 'Seed treatment only model'	H0: y ~ treatment + block/country H1: y ~ treatment*country + block/country

Table S6B

Expression of neonicotinoids in stored hive products	**Honey bee NNI_{MAX} for stored hive products**	***B. terrestris* NNI_{MAX} for stored hive products**	***O. bicornis* NNI_{MAX} for stored hive products**
Error distribution	Normal (Ident. Link)	Normal (Ident. Link)	Normal (Ident. Link)
TEST 1: 'Seed treatment only model' > null	χ^2_2=2.78, p=0.20	χ^2_2=0.83, p=0.58	χ^2_2=1.10, p=0.55
TEST 2: 'Seed treatment × country model' > null	χ^2_6=6.99, p=0.20	χ^2_6=2.74, p=0.79	χ^2_6=6.57, p=0.22
TEST 3: 'Seed treatment × country model' > 'Seed treatment only model'	χ^2_4=4.21, p=0.27	χ^2_4=1.90, p=0.70	χ^2_4=5.46, p=0.14

Table S7.

Concentration of clothianidin, thiamethoxam and imidacloprid residues found in combined pollen and nectar samples collected by honey bees (Table S7a) as well as the same values for residues originating from pollen only (Table S7b) and nectar only samples (Table S7c). Values below the limit of quantification (0.53 ng g^{-1} wet weight) were set to half the limit of detection (LoD=0.38 ng g^{-1}, Non-detect=0.19 ng g^{-1}). . The combined index of all neonicotinoid residues used as covariates in analyses is given for overall median (NNI_{median}) and maximum (NNI_{Max}) which account for differences in toxicity of the three neonicotinoid products by weighting them on the basis of acute honey bee oral LD_{50} values (TMX=0.005 µg bee^{-1}; CTD= 0.00379 µg bee^{-1}; IMI=0.0037 µg bee^{-1}) (29, 30, 31). The NNI_{median} and NNI_{Max} values were derived for two separate periods: 1) the oilseed rape flowering period used as covariates (pre.); 2) the entire year including pollen and nectar samples collected in the winter period (post). The latter of these was used as a covariate for the overwintering colony strength assessments. Note NNI_{Max} values were the same for both periods.

Table S7A: Combined pollen and nectar

Site (treat.)	Clothianidin (ng g^{-1} w/w)			Thiamethoxam (ng g^{-1} w/w)			Imidacloprid (ng g^{-1} w/w)			$NNI_{medinan}$ (ng g^{-1} w/w)		NNI_{Max} (ng g^{-1} w/w)
	Min.	Med	Max	Min	Med	Max	Min	Med	Max	Pre.	Post	
G1 (Cont.)	0.19	0.19	1.2	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	1.24
G2 (CTD)	0.19	0.19	0.59	0.19	0.19	0.19	0.19	0.19	0.87	0.48	0.48	1.28
G3 (TMX)	0.19	0.19	0.74	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.89
G4 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.58	0.19	0.19	0.19	0.48	0.48	0.86
G5 (CTD)	0.19	0.67	1.19	0.19	0.19	0.19	0.19	0.19	0.19	0.84	0.83	1.24
G6 (TMX)	0.19	0.19	0.70	0.19	0.19	0.65	0.19	0.19	0.19	0.48	0.48	1.32
G7 (Cont.)	0.19	0.19	0.77	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.92
G8 (CTD)	0.19	0.73	1.21	0.19	0.19	0.19	0.19	0.19	0.19	0.89	0.8	1.25
G9 (TMX)	0.19	0.19	0.68	0.19	0.46	1.41	0.19	0.19	1.00	0.74	0.48	2.65
H10 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	1.77	0.48	0.48	1.65
H11 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.48
H12 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.48
H13 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.73	0.19	0.19	0.19	0.48	0.48	1.01
H14 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.48
H15 (CTD)	0.19	0.19	1.05	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	1.13
H16 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.48
H17 (TMX)	0.19	0.19	0.19	0.19	0.19	0.79	0.19	0.19	0.19	0.48	0.48	1.07
H18 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.48
H19 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.48
H20 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	5.99	0.48	0.48	4.77
H21 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	3.10	0.48	0.48	2.63
UK22 (TMX)	0.19	0.19	0.19	0.19	0.19	0.86	0.19	0.19	0.19	0.48	0.48	1.14
UK23 (Cont.)	0.19	0.19	0.77	0.19	0.19	0.40	0.19	0.19	0.19	0.48	0.48	1.12

UK24 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.48
UK25 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.48
UK26 (TMX)	0.19	0.62	1.35	0.19	0.19	0.63	0.19	0.19	0.19	0.8	0.48	1.79
UK27 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.48
UK28 (CTD)	0.19	0.19	0.78	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.92
UK29 (Cont.)	0.19	0.56	0.96	0.19	0.19	0.19	0.19	0.19	0.19	0.75	0.48	1.06
UK30 (TMX)	0.19	0.19	1.48	0.19	0.19	0.58	0.19	0.19	0.19	0.48	0.48	1.83
UK31 (Cont.)	0.19	0.7	1.46	0.19	0.19	0.19	0.19	0.19	0.19	0.86	0.48	1.44
UK32 (TMX)	0.19	0.19	0.66	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	0.83
UK33 (CTD)	0.19	0.19	0.99	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48	1.08

Table S7B: Pollen only

Site (Treat.)	Clothianidin (ng g^{-1} w/w)			Thiamethoxam (ng g^{-1} w/w)			Imidacloprid (ng g^{-1} w/w)		
	Min.	Med	Max	Min.	Med	Max	Min	Med	Max
G1 (Cont.)	0.19	0.38	0.59	0.19	0.19	0.19	0.19	0.19	0.19
G2 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.87
G3 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G4 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.58	0.19	0.19	0.19
G5 (CTD)	0.6	0.78	1.08	0.19	0.19	0.19	0.19	0.19	0.19
G6 (TMX)	0.19	0.19	0.19	0.19	0.19	0.57	0.19	0.19	0.19
G7 (Cont.)	0.19	0.19	0.77	0.19	0.19	0.19	0.19	0.19	0.19
G8 (CTD)	0.19	0.5	0.73	0.19	0.19	0.19	0.19	0.19	0.19
G9 (TMX)	0.19	0.19	0.19	0.19	0.33	0.67	0.19	0.19	0.19
H10 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H11 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H12 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H13 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H14 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H15 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H16 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H17 (TMX)	0.19	0.19	0.19	0.19	0.19	0.71	0.19	0.19	0.19
H18 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H19 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H20 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	5.99
H21 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK22 (TMX)	0.19	0.19	0.19	0.19	0.19	0.86	0.19	0.19	0.19
UK23 (Cont.)	0.19	0.19	0.77	0.19	0.19	0.40	0.19	0.19	0.19
UK24 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK25 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK26 (TMX)	0.19	0.41	0.88	0.19	0.19	0.19	0.19	0.19	0.19
UK27 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK28 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK29 (Cont.)	0.19	0.19	0.56	0.19	0.19	0.19	0.19	0.19	0.19
UK30 (TMX)	0.19	0.19	0.19	0.19	0.37	0.58	0.19	0.19	0.19
UK31 (Cont.)	0.19	0.45	0.92	0.19	0.19	0.19	0.19	0.19	0.19
UK32 (TMX)	0.19	0.19	0.66	0.19	0.19	0.19	0.19	0.19	0.19
UK33 (CTD)	0.19	0.19	0.99	0.19	0.19	0.19	0.19	0.19	0.19

Table S7B: Nectar only

Site (Treat.)	Clothianidin (ng g^{-1} w/w)			Thiamethoxam (ng g^{-1} w/w)			Imidacloprid (ng g^{-1} w/w)		
	Min.	Med	Max	Min.	Med	Max	Min	Med	Max
G1 (Cont.)	0.19	0.19	1.2	0.19	0.19	0.19	0.19	0.19	0.19
G2 (CTD)	0.19	0.57	0.59	0.19	0.19	0.19	0.19	0.19	0.19
G3 (TMX)	0.19	0.19	0.74	0.19	0.19	0.19	0.19	0.19	0.19
G4 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G5 (CTD)	0.19	0.67	1.19	0.19	0.19	0.19	0.19	0.19	0.19
G6 (TMX)	0.19	0.19	0.7	0.19	0.19	0.65	0.19	0.19	0.19
G7 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G8 (CTD)	0.84	0.98	1.21	0.19	0.19	0.19	0.19	0.19	0.19
G9 (TMX)	0.19	0.19	0.68	0.19	0.65	1.41	0.19	0.74	1
H10 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	1.77
H11 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H12 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H13 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.73	0.19	0.19	0.19
H14 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H15 (CTD)	0.19	0.19	1.05	0.19	0.19	0.19	0.19	0.19	0.19
H16 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H17 (TMX)	0.19	0.19	0.19	0.19	0.67	0.79	0.19	0.19	0.19
H18 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H19 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H20 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H21 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	3.1
UK22 (TMX)	0.19	0.19	0.19	0.19	0.19	0.64	0.19	0.19	0.19
UK23 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK24 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK25 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK26 (TMX)	0.19	0.88	1.35	0.19	0.63	0.63	0.19	0.19	0.19
UK27 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK28 (CTD)	0.19	0.49	0.78	0.19	0.19	0.19	0.19	0.19	0.19
UK29 (Cont.)	0.69	0.83	0.96	0.19	0.19	0.19	0.19	0.19	0.19
UK30 (TMX)	0.75	1.19	1.48	0.19	0.19	0.19	0.19	0.19	0.19
UK31 (Cont.)	0.19	1.45	1.46	0.19	0.19	0.19	0.19	0.19	0.19
UK32 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK33 (CTD)	0.19	0.63	0.95	0.19	0.19	0.19	0.19	0.19	0.19

Table S8. Concentration of clothianidin, thiamethoxam and imidacloprid residues in pollen and nectar. Concentration of clothianidin, thiamethoxam and imidacloprid residues found in combined pollen and nectar samples collected by *B. terrestris* (**A**) as well as the same values for pollen only (**B**) and nectar only (**C**). Values below the limit of quantification (0.53 ng g^{-1} wet weight) were set to half the limit of detection (LoD=0.38 ng g^{-1}, Non-detect=0.19 ng g^{-1}). The combined index of all neonicotinoid residues used as covariates in analyses is given for overall median (NNI_{median}) and maximum (NNI_{Max}) which account for differences in toxicity of the three neonicotinoid products by weighting them on the basis of acute *Apis mellifera* oral LD_{50} values.

Table S8A: Pollen and nectar combined

	Clothianidin (ng g^{-1} w/w)			**Thiamethoxam (ng g^{-1} w/w)**			**Imidacloprid**			**NNI_{median} (ng g^{-1} w/w)**	**NNI_{Max} (ng g^{-1} w/w)**
	Min.	**Med**	**Max**	**Min.**	**Med**	**Max**	**Min**	**Med**	**Max**		
G1 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48
G2 (CTD)	0.19	0.19	0.58	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.77
G3 (TMX)	0.19	0.19	0.19	0.19	0.19	0.93	0.19	0.19	0.19	0.48	1.22
G4 (Cont.)	0.19	0.19	0.19	0.19	0.19	5.05	0.19	0.19	0.19	0.48	5.33
G5 (CTD)	0.19	0.19	0.19	0.19	0.19	1.16	0.19	0.19	0.19	0.48	1.44
G6 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.54	0.48	0.74
G7 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48
G8 (CTD)	0.19	1.77	2.27	0.19	0.19	0.19	0.19	0.19	0.19	1.68	2.06
G9 (TMX)	0.19	0.19	0.99	0.19	0.76	1.25	0.19	0.19	0.6	1.04	2.43
H10 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48
H11 (TMX)	0.19	0.19	1.38	0.19	0.19	0.19	0.19	0.19	0.19	0.48	1.38
H12 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48
H13 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48
H14 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48
H15 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48
H16 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48
H17 (TMX)	0.19	0.19	0.19	0.19	0.19	1.01	0.19	0.19	0.19	0.48	1.29
H18 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48
H19 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	1.45	0.48	1.41
H20 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48
H21 (TMX)	0.19	0.19	0.19	0.19	0.19	0.61	0.19	0.19	0.19	0.48	0.89
UK22 (TMX)	0.19	0.19	0.58	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.77
UK23 (Cont.)	0.19	1.12	4.69	0.19	0.19	22.2†	0.19	0.19	0.19	1.18	3.89
UK24 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48
UK25 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	4.07	0.48	3.35
UK26 (TMX)	0.19	1.3	1.85	0.19	0.19	0.76	0.19	0.19	0.19	1.32	2.3
UK27 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.48	0.48
UK28 (CTD)	0.19	0.19	1.54	0.19	0.19	0.19	0.19	0.19	1.16	0.48	2.22

UK29 (Cont.)	0.19	0.76	5.23	0.19	0.19	1.09	0.19	0.19	0.19	0.9	5.19
UK30 (TMX)	0.19	2.35	2.93	0.19	0.19	0.55	0.19	0.19	0.19	2.12	2.91
UK31 (Cont.)	0.19	1.25	3.05	0.19	0.19	0.82	0.19	0.19	0.19	1.28	3.27
UK32 (TMX)	0.19	0.19	1.71	0.19	0.19	0.64	0.19	0.19	0.19	0.48	2.08
UK33 (CTD)	0.19	0.85	2.07	0.19	0.19	0.19	0.19	0.19	8.70	0.98	8.19

†The identified thiamethoxam residue outlier was ignored in the derivation of the NNI_{Max}.

Table S8B Pollen only

Site (Treat.)	Clothianidin (ng g^{-1} w/w)			Thiamethoxam (ng g^{-1} w/w)			Imidacloprid (ng g^{-1} w/w)		
	Min.	Med	Max	Min.	Med	Max	Min	Med	Max
G1 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G2 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G3 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G4 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G5 (CTD)	0.19	0.19	0.19	0.19	0.19	1.16	0.19	0.19	0.19
G6 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.54
G7 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G8 (CTD)	0.19	0.19	2.00	0.19	0.19	0.19	0.19	0.19	0.19
G9 (TMX)	0.19	0.19	0.79	0.19	0.19	0.8	0.19	0.19	0.6
H10 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H11 (TMX)	0.19	0.19	1.38	0.19	0.19	0.19	0.19	0.19	0.19
H12 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H13 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H14 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H15 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H16 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H17 (TMX)	0.19	0.19	0.19	0.19	0.19	1.01	0.19	0.19	0.19
H18 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H19 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H20 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H21 (TMX)	0.19	0.19	0.19	0.19	0.19	0.61	0.19	0.19	0.19
UK22 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK23 (Cont.)	1.11	1.41	4.69	0.19	0.19	22.2†	0.19	0.19	0.19
UK24 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK25 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	4.07
UK26 (TMX)	0.19	0.72	1.85	0.19	0.19	0.19	0.19	0.19	0.19
UK27 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK28 (CTD)	0.19	0.19	1.54	0.19	0.19	0.19	0.19	0.19	1.16
UK29 (Cont.)	0.19	2.63	5.23	0.19	0.19	1.09	0.19	0.19	0.19
UK30 (TMX)	0.19	2.38	2.93	0.19	0.19	0.55	0.19	0.19	0.19
UK31 (Cont.)	0.19	2.87	3.05	0.19	0.19	0.82	0.19	0.19	0.19
UK32 (TMX)	0.19	0.19	1.71	0.19	0.19	0.64	0.19	0.19	0.19
UK33 (CTD)	0.19	0.19	2.07	0.19	0.19	0.19	0.19	0.19	8.69

†The identified thiamethoxam residue outlier was ignored in the derivation of the $NNI_{Max.}$.

Table S8C: Nectar only

Site (Treat.)	Clothianidin (ng g^{-1} w/w)			Thiamethoxam (ng g^{-1} w/w)			Imidacloprid (ng g^{-1} w/w)		
	Min.	Med	Max	Min.	Med	Max	Min	Med	Max
G1 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G2 (CTD)	0.58	0.58	0.58	0.19	0.19	0.19	0.19	0.19	0.19
G3 (TMX)	0.19	0.19	0.19	0.19	0.56	0.93	0.19	0.19	0.19
G4 (Cont.)	0.19	0.19	0.19	0.19	2.62	5.05	0.19	0.19	0.19
G5 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G6 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G7 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G8 (CTD)	1.77	2.02	2.27	0.19	0.19	0.19	0.19	0.19	0.19
G9 (TMX)	0.19	0.59	0.99	0.76	1.00	1.25	0.19	0.19	0.19
H10 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H11 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H12 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H13 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H14 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H15 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H16 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H17 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H18 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H19 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.82	1.45
H20 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H21 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK22 (TMX)	0.53	0.56	0.58	0.19	0.19	0.19	0.19	0.19	0.19
UK23 (Cont.)	0.19	0.19	0.19	0.19	0.43	0.67	0.19	0.19	0.19
UK24 (CTD)	0.12	0.16	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK25 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK26 (TMX)	1.3	1.34	1.37	0.73	0.74	0.76	0.19	0.19	0.19
UK27 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK28 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK29 (Cont.)	0.6	0.68	0.76	0.19	0.19	0.19	0.19	0.19	0.19
UK30 (TMX)	1.64	2.00	2.35	0.19	0.37	0.55	0.19	0.19	0.19
UK31 (Cont.)	0.96	1.11	1.25	0.19	0.19	0.19	0.19	0.19	0.19
UK32 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK33 (CTD)	0.85	0.91	0.96	0.19	0.19	0.19	0.19	0.19	0.19

Table S9. Concentration of clothianidin, thiamethoxam and imidacloprid residues found in pollen and nectar. Concentration of clothianidin, thiamethoxam and imidacloprid residues found in combined pollen and nectar samples collected by *O. bicornis* (**A**) as well as the same values for pollen only (**B**) and nectar only (**C**). Values below the limit of quantification (0.52 ng g^{-1} wet weight) were set to half the limit of detection (LoD=0.37 ng g^{-1}, Non-detect=0.185 ng g^{-1}). The combined index of all neonicotinoid residues used as covariates in analyses is given for overall median (NNI_{median}) and maximum (NNI_{Max}) which account for differences in toxicity of the three neonicotinoid products by weighting them on the basis of acute *Apis mellifera* oral LD_{50} values. For three sites (UK22, UK23 and UK27) no O. bicornis cells were found. As such it was not possible to determine residue concentrations in pollen and nectar collected by the bee for these sites.

Table S9A: Combined pollen and nectar

Site (treat.)	Clothianidin (ng g^{-1} w/w)			Thiamethoxam (ng g^{-1} w/w)			Imidacloprid (ng g^{-1} w/w)		
	Min.	Med	Max	Min	Med	Max	Med	Med	Max
G1 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G2 (CTD)	0.19	0.19	0.19	0.19	0.19	1.22	0.19	0.19	0.19
G3 (TMX)	0.19	0.19	1.97	0.19	1.26	3.22	0.19	0.19	0.19
G4 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G5 (CTD)	0.19	0.19	0.19	0.19	0.19	1.57	0.19	0.19	0.19
G6 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G7 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.65
G8 (CTD)	0.19	0.19	0.19	0.19	1.1	1.42	0.19	0.81	0.81
G9 (TMX)	0.19	0.19	1.07	0.19	0.85	0.96	0.19	0.66	0.70
H10 (Cont.)	0.19	0.49	0.8	0.19	1.17	2.15	0.19	0.19	0.19
H11 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	1.78	3.37
H12 (CTD)	0.19	0.19	0.19	0.19	2.47	2.47	0.54	4.01	4.01
H13 (Cont.)	0.19	0.19	0.73	0.19	0.19	0.19	0.19	0.19	2.45
H14 (TMX)	0.19	0.76	0.98	0.19	0.19	0.88	0.19	0.19	0.19
H15 (CTD)	0.19	0.19	0.19	0.19	0.19	0.61	0.19	0.19	0.87
H16 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.6	1.00
H17 (TMX)	0.19	0.19	1.25	0.19	0.19	0.19	0.19	0.19	0.56
H18 (CTD)	0.19	0.19	0.19	0.19	0.19	0.61	0.19	0.19	1.00
H19 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	8.42	8.43	8.43
H20 (Cont.)	0.19	1.54	1.54	0.19	0.19	0.19	0.19	0.19	0.19
H21 (TMX)	0.19	0.19	1.27	0.19	0.19	0.19	0.19	0.19	0.19
UK22 (TMX)	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†
UK23 (Cont.)	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†
UK24 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK25 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19

UK26 (TMX)	0.19	0.19	0.19	0.19	1.11	1.16	0.19	0.19	0.19
UK27 (CTD)	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†
UK28 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK29 (Cont.)	0.55	0.19	0.69	0.19	1.13	1.77	0.19	0.19	0.19
UK30 (TMX)	0.19	0.19	0.19	0.19	0.45	1.05	0.19	0.19	0.19
UK31 (Cont.)	1.60	0.72	1.24	0.19	1.74	1.87	0.19	0.39	0.59
UK32 (TMX)	0.19	0.48	1.2	0.19	0.19	1.53	0.19	0.19	0.19
UK33 (CTD)	0.98	0.19	0.19	0.19	1.03	1.9	0.19	0.19	0.19

†As no reproductive cells were found at this site it was not possible to collect pollen and nectar samples to assess for residues.

Table S9B: Pollen only

Site (treat.)	Clothianidin (ng g^{-1} w/w)			Thiamethoxam (ng g^{-1} w/w)			Imidacloprid (ng g^{-1} w/w)		
	Min.	Med	Max	Min.	Med	Max	Med	Med	Max
G1 (Cont.)	NA††	NA††	NA††	NA††	NA††	NA††	NA††	NA††	NA††
G2 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G3 (TMX)	1.26	1.26	3.22	0.19	0.19	1.97	0.19	0.19	0.19
G4 (Cont.)	NA††	NA††	NA††	NA††	NA††	NA††	NA††	NA††	NA††
G5 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G6 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G7 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G8 (CTD)	0.19	1.10	1.10	0.19	0.19	0.19	0.19	0.81	0.81
G9 (TMX)	0.96	0.96	0.96	0.19	0.19	0.19	0.7	0.7	0.7
H10 (Cont.)	2.15	2.15	2.15	0.8	0.8	0.8	0.19	0.19	0.19
H11 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	3.37	3.37	3.37
H12 (CTD)	2.47	2.47	2.47	0.19	0.19	0.19	4.01	4.01	4.01
H13 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H14 (TMX)	0.19	0.19	0.19	0.98	0.98	0.98	0.19	0.19	0.19
H15 (CTD)	0.61	0.61	0.61	0.19	0.19	0.19	0.19	0.19	0.19
H16 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	1.00	1.00	1.00
H17 (TMX)	0.19	0.19	0.19	0.19	1.25	1.25	0.19	0.19	0.19
H18 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H19 (CTD)	NA††	NA††	NA††	NA††	NA††	NA††	NA††	NA††	NA††
H20 (Cont.)	0.19	0.19	0.19	1.54	1.54	1.54	0.19	0.19	0.19
H21 (TMX)	0.19	0.19	0.19	0.19	0.73	1.26	0.19	0.19	0.19
UK22 (TMX)	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†
UK23 (Cont.)	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†
UK24 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK25 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK26 (TMX)	1.16	1.16	1.16	0.19	0.19	0.19	0.19	0.19	0.19
UK27 (CTD)	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†
UK28 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK29 (Cont.)	1	1.13	1.26	0.19	0.19	0.19	0.19	0.19	0.19
UK30 (TMX)	0.19	0.62	1.05	0.19	0.19	0.19	0.19	0.19	0.19
UK31 (Cont.)	1.87	1.87	1.87	1.24	1.24	1.24	0.58	0.58	0.58
UK32 (TMX)	0.19	0.86	1.53	0.19	0.69	1.2	0.19	0.19	0.19
UK33 (CTD)	1.03	1.03	1.03	0.19	0.19	0.19	0.19	0.19	0.19

†As no reproductive cells were found at this site it was not possible to collect pollen and nectar samples to assess for residues. †† There was insufficient pollen could be cleanly removed to undertake a viable residue analysis.

Table S9C: Nectar only

Site (treat.)	Clothianidin (ng g^{-1} w/w)			Thiamethoxam (ng g^{-1} w/w)			Imidacloprid (ng g^{-1} w/w)		
	Min.	Med	Max	Min	Med	Max	Med	Med	Max
G1 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G2 (CTD)	0.85	1.03	1.22	0.19	0.19	0.19	0.19	0.19	0.19
G3 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G4 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G5 (CTD)	0.19	0.88	1.57	0.19	0.19	0.19	0.19	0.19	0.19
G6 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
G7 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.42	0.65
G8 (CTD)	1.42	1.42	1.42	0.19	0.19	0.19	0.81	0.81	0.81
G9 (TMX)	0.19	0.47	0.74	0.19	0.19	1.07	0.19	0.19	0.61
H10 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H11 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H12 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.55	0.55	0.55
H13 (Cont.)	0.19	0.19	0.19	0.19	0.46	0.73	0.19	1.32	2.45
H14 (TMX)	0.19	0.19	0.88	0.19	0.19	0.53	0.19	0.19	0.19
H15 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.87
H16 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H17 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.56
H18 (CTD)	0.19	0.19	0.61	0.19	0.19	0.19	0.19	0.19	1.00
H19 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	8.43	8.43	8.43
H20 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
H21 (TMX)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK22 (TMX)	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†
UK23 (Cont.)	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†
UK24 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK25 (Cont.)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK26 (TMX)	0.19	0.95	1.07	0.19	0.19	0.19	0.19	0.19	0.19
UK27 (CTD)	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†	NA†
UK28 (CTD)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
UK29 (Cont.)	0.56	1.3	1.76	0.19	0.19	0.69	0.19	0.19	0.19
UK30 (TMX)	0.19	0.45	0.72	0.19	0.19	0.19	0.19	0.19	0.19
UK31 (Cont.)	1.61	1.61	1.61	0.19	0.19	0.19	0.19	0.19	0.19
UK32 (TMX)	0.19	0.19	0.59	0.19	0.48	1.08	0.19	0.19	0.19
UK33 (CTD)	0.99	1.71	1.9	0.19	0.19	0.19	0.19	0.19	0.19

†As no reproductive cells were found at this site it was not possible to collect pollen and nectar samples to assess for residues.

Table S10. Plant species in pollen. Foraging proportion of oilseed rape (OSR pollen) and other plant species (taxon richness) based on microscopy analysis of pollen collected during the oilseed rape flowering period for honey bees, *B. terrestris* and *O. bicornis*. Honey bee pollen was collected using pollen traps attached to the front of individual hives on a single sampling date 14 days after the initiation of exposure to the crop. The six samples per site were then amalgamated at the site level. For *B. terrestris* pollen was removed from returning workers at 14 days after exposure to the oilseed rape. For each *B. terrestris* multihive (four multihives per site, each containing three colonies) 10 pollen baskets were collected and then amalgamated at the site level. For returning to each hive or colony at a site and then amalgamated. Pollen from *O. bicornis* was removed from 10 dissected reproductive cells within trap nests. Frequency of oilseed rape in diets was scored along an index of 0-5 (0 = 0%; 0.1=trace amounts; 1 = 0.1-20%; 2=20-40%; 3=40-60%; 4=60-80%; 5= >80%). Pollen was stained using Fuschin and identified under compound light microscope where possible to generic or species level depending on the degree of homogeneity in pollen morphology. For all three species pollen was collected honey bees

Site (treat.)	Honey bees		*B. terrestris*		*O. bicornis*	
	OSR pollen	Taxon richness	OSR pollen	Taxon richness	OSR pollen	Taxon richness
G1 (Cont.)	0.1	6	0.1	4	0.1	3
G2 (CTD)	0.1	5	0.1	6	1.0	4
G3 (TMX)	1.5	4	0.1	6	2.0	4
G4 (Cont.)	1.0	4	0.1	5	0.1	4
G5 (CTD)	2.0	4	0.1	5	0.5	3
G6 (TMX)	0.5	5	0.5	4	2.0	3
G7 (Cont.)	0.1	4	5.0	1	0.1	5
G8 (CTD)	0.5	4	5.0	1	2.0	3
G9 (TMX)	1.0	5	4.5	2	1.0	2
H10 (Cont.)	2.0	5	3.0	2	1.0	3
H11 (TMX)	3.0	4	5.0	1	4.5	3
H12 (CTD)	3.0	3	4.5	2	0.1	2
H13 (Cont.)	1.0	7	5.0	1	2.0	3
H14 (TMX)	1.5	4	2.5	2	4.0	3
H15 (CTD)	5.0	2	5.0	1	0.1	2
H16 (Cont.)	1.5	8	3.0	2	3.5	3
H17 (TMX)	2.0	4	1.5	2	0.5	3
H18 (CTD)	1.0	8	2.0	1	1.0	3
H19 (CTD)	1.0	6	1.0	3	5.0	1
H20 (Cont.)	2.0	7	4.0	2	0.1	3
H21 (TMX)	2.0	6	4.5	1	0.1	3
UK22 (TMX)	1.0	5	2.0	2	NA†	NA†
UK23 (Cont.)	3.0	4	4.5	2	NA†	NA†

UK24 (CTD)	3.0	3	1.5	2	2.0	4
UK25 (Cont.)	2.5	4	2.0	2	0.1	3
UK26 (TMX)	3.0	5	5.0	1	0.5	2
UK27 (CTD)	2.0	3	5.0	1	NA†	NA†
UK28 (CTD)	4.0	2	5.0	1	1.0	2
UK29 (Cont.)	3.0	4	3.5	2	0.1	3
UK30 (TMX)	2.0	3	4.5	2	1.0	3
UK31 (Cont.)	3.0	3	2.0	2	0.0	1
UK32 (TMX)	1.0	2	1.5	2	0.1	4
UK33 (CTD)	2.5	3	0.1	4	1.0	3

†NA, not applicable.

Table S11. frequency of *Varroa* sp. and *Nosema* sp. infections in honey bees. Mean and ranges for the frequency of *Varroa* sp. and *Nosema* sp. infections in honey bee assessed at the end of the oilseed rape flowering period and pre-winter. The proportion of bees with *Varroa* mites on the body were assessed (based on 100 worker honey bees). For *Nosema* sp. surface sterilized bees (30 honey bees) were homogenized in 4 mL water and the homogenate was analyzed microscopically (400× magnification). The number of *Nosema* spp. spores within the visual field were classified on a 4 point semi-quantitative scale where: 0 = no *Nosema* spores in the field of view; 1 = <10 *Nosema* spores; 2 = 10-100 *Nosema* spores; 3 = > 100 spores).

Site (treat.)	Oilseed rape flowering period		Pre-winter assessment	
	Nosema sp.	*Varroa* sp. (%)	*Nosema* sp.	*Varroa* sp.
G1 (Cont.)	0.5	0.0	0.0	0.7
G2 (CTD)	0.0	0.0	0.0	1.0
G3 (TMX)	2.0	0.0	0.0	1.6
G4 (Cont.)	1.5	0.0	0.0	2.0
G5 (CTD)	0.5	0.4	0.0	1.7
G6 (TMX)	0.0	0.4	0.0	0.8
G7 (Cont.)	0.5	0.0	0.0	0.7
G8 (CTD)	0.5	0.0	0.0	0.7
G9 (TMX)	1.5	0.0	0.0	0.4
H10 (Cont.)	2.0	0.0	0.0	3.0
H11 (TMX)	1.0	0.0	0.5	0.4
H12 (CTD)	1.0	0.7	0.0	6.0
H13 (Cont.)	2.0	0.0	0.0	0.4
H14 (TMX)	1.0	0.0	0.0	0.7
H15 (CTD)	0.5	0.0	0.0	0.4
H16 (Cont.)	0.0	0.0	0.0	0.4
H17 (TMX)	0.0	0.4	0.0	6.4
H18 (CTD)	2.0	0.0	0.0	2.0
H19 (CTD)	2.0	0.0	0.0	2.0
H20 (Cont.)	2.0	0.0	0.0	1.0
H21 (TMX)	2.0	0.0	0.0	3.2
UK22 (TMX)	2.0	0.8	0.0	8.7
UK23 (Cont.)	1.0	2.0	0.0	12.0
UK24 (CTD)	0.0	2.7	NA†	NA†
UK25 (Cont.)	0.0	1.2	0.0	8.0
UK26 (TMX)	0.0	1.2	0.5	2.0
UK27 (CTD)	0.0	0.4	1.0	4.0
UK28 (CTD)	0.0	0.0	0.0	7.4
UK29 (Cont.)	2.0	0.0	0.0	5.5
UK30 (TMX)	0.0	1.0	0.0	7.2

UK31 (Cont.)	0.0	1.6	0.0	12.0
UK32 (TMX)	0.0	1.2	1.0	4.0
UK33 (CTD)	0.0	1.0	0.0	18.0

†NA, not applicable. All hives at site 24 had died by the pre-winter period and so no assessment of disease could be made.

Table S12. Concentrations of clothianidin, thiamethoxam and imidacloprid residues in pollen and nectar. Concentrations of clothianidin, thiamethoxam and imidacloprid residues in combined pollen and nectar collected from the oilseed rape crop (**A**) as well as the same values for pollen only (**B**) and nectar only (**C**). Values below the limit of quantification (LoQ= 0.53 ng g^{-1} wet weight) were set to half the limit of detection (LoD=0.38 ng g^{-1}, Non-detect=0.19 ng g^{-1}). Two pollen and two nectar samples were collected at day 2 and day 9 of crop flowering using honey bees caged over the crop. Pollen was removed from pollen baskets and nectar was dissected from the honey stomachs of worker bees. The median and maximum residues collected from the four pollen and nectar samples from the oilseed rape crop at each site are given, as well as the proportion of pollen and nectar samples above the LoQ (out of a maximum of 4).

Table S12A: Pollen and nectar.

Site (treat.)	Clothianidin (ng g^{-1} w/w)		Thiamethoxam (ng g^{-1} w/w)		Imidacloprid (ng g^{-1} w/w)	
	Median (max.)	Prop. Samples > LOQ	Median (max.)	Prop. Samples > LOQ	Median (max.)	Prop. Samples > LOQ
G1 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G2 (CTD)	0.19 (0.65)	0.25	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G3 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G4 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G5 (CTD)	0.50 (0.81)	0.50	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G6 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G7 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G8 (CTD)	0.19 (1.47)	0.25	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G9 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H10 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H11 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (1.20)	0.33
H12 (CTD)	0.19 (2.21)	0.25	0.19 (0.19)	0.00	0.19 (1.10)	0.25
H13 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H14 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H15 (CTD)	0.19 (0.19)	0.00	0.19 (0.58)	0.25	0.19 (0.19)	0.00
H16 (Cont.)	0.19 (0.19)	0.00	0.19 (0.61)	0.25	0.19 (1.23)	0.25
H17 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H18 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H19 (CTD)	0.19 (0.19)	0.00	0.19 (0.82)	0.25	0.19 (0.19)	0.00
H20 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H21 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK22 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK23 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00

UK24 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK25 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK26 (TMX)	0.44 (0.76)	0.50	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK27 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK28 (CTD)	0.37 (0.55)	0.50	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK29 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK30 (TMX)	0.4 (0.84)	0.25	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK31 (Cont.)	0.52 (0.87)	0.50	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK32 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK33 (CTD)	0.48 (0.79)	0.50	0.19 (0.19)	0.00	0.19 (0.19)	0.00

Table S12B: Pollen only

Site (treat.)	Clothianidin (ng g^{-1} w/w)		Thiamethoxam (ng g^{-1} w/w)		Imidacloprid (ng g^{-1} w/w)	
	Median (max.)	Prop. Samples > LOQ	Median (max.)	Prop. Samples > LOQ	Median (max.)	Prop. Samples > LOQ
G1 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G2 (CTD)	0.42 (0.65)	0.50	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G3 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G4 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G5 (CTD)	0.81 (0.81)	1.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G6 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G7 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G8 (CTD)	0.83 (1.47)	0.50	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G9 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H10 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H11 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.70 (1.2)	0.50
H12 (CTD)	1.20 (2.21)	0.50	0.19 (0.19)	0.00	0.65 (1.1)	0.50
H13 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H14 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H15 (CTD)	0.19 (0.19)	0.00	0.39 (0.58)	0.50	0.19 (0.19)	0.00
H16 (Cont.)	0.19 (0.19)	0.00	0.40 (0.61)	0.50	0.71 (1.23)	0.50
H17 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H18 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H19 (CTD)	0.19 (0.19)	0.00	0.51 (0.82)	0.50	0.19 (0.19)	0.00
H20 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H21 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK22 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK23 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK24 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK25 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK26 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK27 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK28 (CTD)	0.37 (0.55)	0.50	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK29 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK30 (TMX)	0.4 (0.6)	0.50	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK31 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK32 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK33 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00

Table S12C: Nectar only

Site (treat.)	Clothianidin (ng g^{-1} w/w)		Thiamethoxam (ng g^{-1} w/w)		Imidacloprid (ng g^{-1} w/w)	
	Median (max.)	Prop. Samples > LOQ	Median (max.)	Prop. Samples > LOQ	Median (max.)	Prop. Samples > LOQ
G1 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G2 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G3 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G4 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G5 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G6 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G7 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G8 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
G9 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H10* (Cont.)	NA	NA	NA	NA	NA	NA
H11 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H12 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H13 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H14 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H15 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H16 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H17 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H18 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H19 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H20 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
H21 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK22 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK23 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK24 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK25 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK26 (TMX)	0.73 (0.76)	1.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK27 (CTD)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK28 (CTD)	0.37 (0.54)	0.50	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK29 (Cont.)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK30 (TMX)	0.52 (0.84)	0.50	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK31 (Cont.)	0.86 (0.87)	1.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK32 (TMX)	0.19 (0.19)	0.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00
UK33 (CTD)	0.78 (0.79)	1.00	0.19 (0.19)	0.00	0.19 (0.19)	0.00

*For H10 insufficient nectar was dissected from bees for a viable analysis of residues.

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Country-specific effects of neonicotinoid pesticides on honey bees and wild bees

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Science **356** (6345), 1393-1395.
DOI: 10.1126/science.aaa1190

Damage confirmed

Early studies of the impacts of neonicotinoid insecticides on insect pollinators indicated considerable harm. However, lingering criticism was that the studies did not represent field-realistic levels of the chemicals or prevailing environmental conditions. Two studies, conducted on different crops and on two continents, now substantiate that neonicotinoids diminish bee health (see the Perspective by Kerr). Tsvetkov *et al.* find that bees near corn crops are exposed to neonicotinoids for 3 to 4 months via nontarget pollen, resulting in decreased survival and immune responses, especially when coexposed to a commonly used agrochemical fungicide. Woodcock *et al.*, in a multicounty experiment on rapeseed in Europe, find that neonicotinoid exposure from several nontarget sources reduces overwintering success and colony reproduction in both honeybees and wild bees. These field results confirm that neonicotinoids negatively affect pollinator health under realistic agricultural conditions.

Science, this issue p. 1395, p. 1393; see also p. 1331

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