Reactie van Bayer CropScience B.V. n.a.v. het bezwaar (2010-19) van de Bijenstichting tegen de toelating door het Ctgb van Merit Turf 13321

De nummering van het bezwaar wordt gevolgd.

1. Petitie stop de bijensterfte, wordt aangehaald. Reactie BCS is hier niet relevant, tenzij Ctgb nadere informatie noodzakelijk acht.

2. Antwoorden Minister Verburg op Kamervragen van mevr. Thieme worden aangehaald. Reactie BCS is hier niet relevant, tenzij Ctgb nadere informatie noodzakelijk acht.

3. Van Dijk: “Effects of neonicotinoid pesticide pollution of Dutch surface water on non-target species abundance”. De relevantie van de conclusies is beperkt, gezien de passage op pagina 27 in de discussie van het betreffende rapport*: “During data analysis it became clear that one of the sub-questions drafted for this study, “Has the distribution and number of different non-target species changed significantly since the application of neonicotinoid began?” could not be answered, since continuous species abundance date over a time span of several decades did not appear to be available for any species or order of species.”*

3. Verwijzing naar duurzame gewasbescherming rapportages MNP 500126001 & RIVM 607016001
   Imidacloprid staat niet op de lijst probleemstoffen drinkwater, gepubliceerd op Ctgb site 11-03-2010.

   Betr. de relatie : vóórkomen van imidacloprid in oppervlakte water en effect op bijen ontvingen wij via het Ctgb de studie van Adindah Visser:
   “Invloed van imidaclopridresiduen in oppervlaktewater op bijensterfte in Nederland”
   met onder meer de conclusie :
   Een negatief effect van imidacloprid in het milieu op de bijensterfte in Nederland is in dit onderzoek niet aangetoond.

4. Wereldbijencongres Apimondia 2009. BCS kan de genoemde conclusies van het congres niet onderschrijven. Volgens BCS waren de belangrijkste conclusies dat de oorzaak van de bijensterfte multifunctioneel is en verder onderzoek noodzakelijk. Varroa is nog steeds de belangrijkste factor. Bijgaand een Zwitsers artikel (in Duits) dat de uitkomsten van het congres op een goede manier weergeeft.

   Zie bijlage I

   De "Pesticide Round tables" waarnaar verwezen wordt in het bezwaarschrift maken geen onderdeel uit van het officiële programma van de Apimondia.

   Dr. T. Blacquiere (WUR) heeft deelgenomen aan Apimondia 2009. Zijn conclusies?

5. Vanuit BCS is het volgende document beschikbaar als reactie op artikel Tennekes:

   Zie bijlage II

6. Vanuit BCS is het volgende document beschikbaar als reactie op artikel van Alaux:

   Zie bijlage III

7. Mommaerts et al, 2010. Er bestaan geen gevalideerde test methoden voor hommels. De huidige opzet van de studie staat ver van de praktijk (microkolonie van 5 hommels zonder koningin). Ter onderbouwing van de resultaten is wel een vergelijking gemaakt met kooitesten bestaande uit een kolonie van 25 werkers + koningin; deze kolonies zijn echter

slechts 2 weken gevolgd. Zonder vastgestelde testmethode is het lastig om effecten op hommels op een juiste manier te beoordelen. In het artikel van Mommaerts staat ook vermeld*: "before making relevant conclusions, a good knowledge of environmentally relevant concentrations of these pesticides as well as combinations of pesticides should be evaluated in more realistic field situations for the assessment of potentially deleterious effects on foraging behavior using whole bee colonies"* . Op basis van deze studie kunnen geen uitspraken gedaan worden over de gevoeligheid van hommels in vergelijking met de gevoeligheid van bijen. Wel is duidelijk dat in tier 1 toxiciteits experimenten met eenvoudige opzet hommels (evenals bijen) gevoelig zijn voor imidacloprid.

9. Directive 2010/21/EU gaat over zaadbehandelingen. Aangezien Merit Turf geen zaadbehandeling is, is deze richtlijn niet van toepassing.

10. Onderzoek uitgevoerd door de industrie wordt als niet betrouwbaar/onafhankelijk gezien. Een reactie van BCS lijkt ons contra-productief.

11. Aantal onderwerpen besproken:
    a. Beoordelingsmethode voor systemische insecticiden worden als onvoldoende beoordeeld. *In NL hebben zich voor zover ons bekend met imidacloprid geen duidelijke negatieve effecten op bijen voorgedaan. Voortschrijdend wetenschappelijk inzicht kan evt. leiden tot nieuwe vraagstelling.*
    Informatie over toelating in Duitsland is incorrect. *Merit Turf heeft geen toelating in Duitsland.*
    b. Onvoldoende aandacht voor overschrijding MTR. *Toepassing van Merit Turf zal niet leiden tot belasting van oppervlaktewater. Bij een dosering van 150 gram a.i./ha spoelt imidacloprid niet uit. Er is dus ook geen belasting via drainage te verwachten.*
    c. Onvoldoende aandacht voor drinkwater. *Imidacloprid staat niet op de VEWIN-lijst probleemstoffen drinkwater, gepubliceerd op Ctgb site 11-03-2010. Bovendien is blootstelling oppervlaktewater ten gevolge van gebruik Merit Turf niet te verwachten.*
    d. Blootstellingsroutes bijen en hommels.
        i. Voor guttatie kunnen we de volgende reactie geven: *Merit Turf is applied at 150 g as/ha in grass or turf between May and September. Studies performed in 2009 / 2010 with winter barley, winter wheat, and maize show that guttation in monocots regularly occurs. After CNI seed dressing, excreted guttation droplets contain active substances. Particularly in maize (high seed dressing loading per plant, ca. 10 plants / m²) residues in droplets can be in a ppm range for some weeks. Residues in guttation droplets excreted by wheat or barley (lower seed dressing loading per plant, 200 - 400 plants / m²) are lower. A longterm exposure of beehives over several weeks (maize) or even a month (cereals) in direct vicinity to the field margins however showed that the potential exposure to residues in guttation droplets did not result in any effect on the development of the monitored hives. As in terms of the exposure scenario, applications of Merit Turf on grass or turf is comparable to a cereal seed treatment but the likelihood of beehives being exposed on or aside such treated areas is even lower if compared to the situation in agricultural landscapes, no indication for any unacceptable effects on honeybee colonies is given.*

        ii. Het is bekend dat de afbraaksnelheid van stoffen in compost vele malen hoger is dan in bodem in verband met hoge microbiële activiteit en de hogere temperatuur. Imidacloprid kan in de bodem volledig worden afgebroken door microbiële processen. We hebben een residuproef in grasland beschikbaar, waaruit blijkt dat direct na toepassing de residuen *in gras 5.5-8.8 mg/kg zijn en na 21 dagen is het residu 0.02-0.2 mg/kg. Mocht er al residu aanwezig zijn in compost, zal de opname door bloeiende planten minimaal zijn. Anders zou ook residu in volggewassen verwacht kunnen worden.*

iii. Rode klaver; We hebben een artikel over witte klaver (Gels et al, 2002), waaruit blijkt dat bij het huidig gebruik (inclusief naregenen) geen effecten te verwachten zijn.

Zie bijlage IV

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Völkerverluste

Trotz grosser Anstrengungen werden die verschiedenen Ursachen und ihr Zusammenwirken für die weltweit auftretenden Verluste erst ansatzweise verstanden.

ROBERT SIEBER, MÜNCHENSTEIN

Die Suche nach den Ursachen der Völkerverluste beschäftigt Forschung und Imkergemeinde weltweit gleichermassen und mit unveränderter Priorität. In einer amerikanischen Studie wurden 280 Völker eines Grossimkers während eines Jahres in regelmässigen Abständen kontrolliert. Ende des Jahres waren nur noch etwa 40 % der Völker am Leben. Weitaus am meisten Völker gingen wegen Futtermangel verloren, gefolgt von ungenügenden Königinnen oder zu starkem Milbenbefall. Nur gerade bei 7 % konnten die klassischen Phänomene der Colony Colapse Disorder (CCD), das heisst Kahlfliegen bei noch vorhandener Brut und der Königin, gefunden werden. Allerdings ist auch bekannt, dass, wenn CCD in einer Grossimkerei auftritt, die Verluste sehr gross sein können. In den USA ist man über dieses Problem besonders besorgt, weil Grossimker ihren Job aufgeben könnten und damit die Bestäubung vieler Nutzpflanzen ernsthaft gefährdet wäre. Auf der anderen Seite der Grössenskala sind Kleinimker in Entwicklungsländern, welche zwar nur wenige Völker besitzen, wirtschaftlich von diesen aber genau so abhängig sind, wie der Grossimker in den USA. Fallbeispiele aus dem Mittleren Osten (Jordanien, Libanon, Irak und Palästina) mit Verlusten zwischen 40 und 80 % belegten dies auf eindrückliche Art und Weise.

Nosema?

Der Einfluss von *Nosema apis* und *Nosema cerana* auf Völkerverluste wird sehr unterschiedlich beurteilt. Während einige Referenten den Zusammenhang zwischen dem Pilz und Völkerverlusten als gegeben erachten, wurde in anderen Studien von Völkerverlusten berichtet, bei denen überhaupt keine *Nosema*-Infektion festgestellt werden konnte.

Varroa?

Der Zusammenhang zwischen der Varroa und den Völkerverlusten ist unbestritten. Daten aus England zeigen, dass Völkerverluste bereits vor der Einschleppung der Varroamilbe festgestellt worden waren. Seitdem die Milbe ihren Siegeszug auch in diesem Inselstaat angetreten hat, stiegen die Verluste aber kontinuierlich an. In der englischen Studie konnte auch gezeigt werden, dass der Befall der Bienen mit dem «Deformed Wing Virus» ein Indikator für schwache Bienenvölker darstellt. Nur ist damit noch nicht gezeigt, ob schwache Völker über ein schwächeres Abwehrsystem verfügen und deswegen vom Virus befallen werden oder ob der Befall des Virus zu einer Schwächung des Volkes führt.

Zurück zur Varroa: Der Traum einer Varroa resistenten Biene scheint zumindest in absehbarer Zeit unrealistisch. Bienenvölker, welche in ihrem natürlichen Habitat mit der Milbe gut zurechtkommen, brechen unter der Milbenlast zusammen, wenn sie in ein anderes Gebiet überführt werden. Über das Warum kann zurzeit nur gemutmasst werden. Die Wichtigkeit der rechtzeitigen Behandlung gegen die Varroa, das heisst, bevor Winterbienen gebildet werden, ist bekannt: In einer holländischen Studie wurde dies bestätigt, indem die Überlebensrate der Bienen am besten war, wenn die Varroabehandlung bereits im Juli vorgenommen wurde.

Gute imkerliche Praxis

Über den Imker als mögliche Ursache für Völkerverluste wurden keine Studiendaten präsentiert. Da wollte sich vermutlich auch kein Referent bei der Zuhörerschaft in die Nesseln setzen. Allerdings zeigen die oben erwähnten Verluste als Folge von Futtermangel oder ungenügender Königinnen, Resultate aus Frankreich über die Hygiene in der Imkerei sowie mangelhafte Varroabehandlung eindeutig, dass diese wichtige Ursache nicht unterschätzt werden darf. Verschiedene Referenten wiesen darauf hin, dass bis die Zusammenhänge besser verstanden werden, sich die Anstrengungen auf diejenigen Faktoren konzentrieren sollten, die unbestrittenermassen einen Einfluss auf Bienenverluste haben, nämlich Varroabehandlung und gute imkerliche Praxis.

APIMONDIA 2011

Wer die APIMONDIA 2011 besuchen will, muss eine etwas weitere Reise in Kauf nehmen. Diese wird in der argentinischen Hauptstadt Buenos Aires stattfinden.

Die argentinischen Bienenprodukte sehen jedenfalls schon mal vielversprechend aus.

FOTOS: ROBERT SIEBER

Problem Datenerfassung

Eine interessante Frage brachte Professor Crailsheim aus Graz ins Spiel: «Was genau meinen wir denn eigentlich, wenn wir von Völkerverlusten sprechen?» Und erstellte dazu gleich eine Anzahl weiterer Fragen: «Sind es die Verluste während der Wintermonate? Was meinen wir mit ‹Wintermonate›? Wie beurteilen wir die Verlustrate, wenn ein Imker im Frühling zwei schwache Völker vereinigt und dieses vereinigte Volk dann höchstwahrscheinlich die Trachtzeit nicht oder zumindest nicht als Wirtschaftsvolk erleben wird?» Fragen über Fragen. Es besteht dringender Handlungsbedarf, die Fragestellungen zu vereinheitlichen. Nur so können länder- und jahresübergreifende Vergleiche gezogen werden. Die Arbeitsgruppe COLOSS «Prevention of honey bee colony losses» unter der Leitung von Dr. Peter Neumann vom ALP Liebefeld nimmt sich dieser Problematik an (siehe auch Interview mit Dr. Neumann).

Nach wie vor sehr viele Fragen

In einem Übersichtsreferat fasste Dr. Peter Neumann den momentanen Kenntnisstand wie folgt zusammen: «Völkerverluste sind seit langer Zeit bekannt. In der letzten Zeit treffen sie aber ganz offensichtlich häufiger und heftiger auf. Die Varroa spielt zweifellos eine wichtige Rolle, kann aber nicht alleine für die Situation verantwortlich gemacht werden. Zu den weiteren Faktoren zählen höchstwahrscheinlich Viren, dann auch Bakterien oder Pilze. Dann aber auch Umwelteinflüsse, zu denen auch die imkerliche Praxis gezählt werden kann, und Gifte, die Vitalität der Bienenvölker und selbstverständlich die Kombination aller möglichen Faktoren.»

Etwas mag aber schon erstaunen: Trotz dieser enormen Problematik der Völkerverluste werden nach wie vor riesigen Mengen an Bienenmaterial um den Erdball verschifft. Einerseits Kleinvölker und Königinnen und andererseits Pollen oder Wachs aus zum Teil zweifelhafter Herkunft. Und dies, obwohl eine genügende Anzahl von Untersuchungen zeigen, dass diese Transporte zum Problem der Völkerverluste beitragen.

Sind wir in der Schweiz in dieser Beziehung etwas gescheiter? ○

Herr Neumann, was ist COLOSS?

Dr. Peter Neumann war an der APIMONDIA ein gefragter Mann. Trotzdem stellte er sich der Schweizerischen Bienen-Zeitung zu einem Interview zur Verfügung.

SBZ: *Herr Neumann, Sie und Ihre Kollegen aus andern Ländern haben sich bereits zwei Tage vor der APIMONDIA zusammengesetzt. Worum ging es?*

Peter Neumann: Das Rahmenprogramm unseres Treffens war ein Überblick über die Verluste des letzten Winters sowie der Aktivitäten der anderen Gruppen in unserem Netzwerk. Primäres Ziel der 5. COLOSS Konferenz war es jedoch, die Planung für das kommende Jahr möglichst detailliert zu organisieren. Diese Aufgabe ist nicht leicht, da momentan in unserem Netzwerk über 150 Bienenwissenschafter und Imker aus 39 Ländern kooperieren. Eine COLOSSale Hauptaufgabe in den nächsten Monaten muss daher sein, die nationalen Ansätze zum Monitoring und zur Forschung präzise zu standardisieren. Nur so wird es möglich sein, unsere Völkerverluste in der Schweiz mit denen in den USA und anderen Ländern zu vergleichen. Dies ist auch unentbehrlich für die Forschung zu den Völkerverlusten. Zum momentanen Zeitpunkt ist es zum Beispiel sehr schwierig, Nosema Ergebnisse aus Spanien mit unseren Daten vom ZBF oder anderen Bieneninstituten zu vergleichen.


FOTO: ROBERT SIEBER

Dr. Peter Neumann beim Interview mit der Schweizerischen Bienen-Zeitung vor dem Konferenzzentrum der APIMONDIA in Montpellier: «Es müssen noch viele offene Fragen geklärt werden.»

Was haben Sie konkret beschlossen?

Wir haben eine ganze Reihe von Veranstaltungen geplant. So werden sich zum Beispiel Anfang 2010 führende Vertreter aus den USA und Europa im Rahmen eines COLOSS Workshops treffen, um die Monitoring Programme im Detail abzusprechen, bevor diese an die imkerliche Praxis weitergeleitet werden. Ich möchte hier die Schweizer Imkerinnen und Imker ermuntern, uns dabei bitte zu helfen. Nur so können wir herausfinden, warum Völker sterben. Ebenfalls wird es zwei Workshops am ZBF geben. In einem werden sich international führende Experten der Varroamilbe treffen, um endlich weiter in der Bekämpfung dieser Gefahr Nr. 1 zu kommen. In einem weiteren Workshop werden wir das Bienen Buch angehen. In diesem vom ZBF initiierten Buch möchten wir die dringend notwendigen internationalen Standards zur Bienenforschung und zum Monitoring anpacken.

Was bringt dies für den Imker, die Imkerin in der Schweiz? Wann dürfen wir in Sachen Völkersterben aufatmen?

Mithilfe des vom ZBF geleiteten globalen COLOSS Netzwerkes stehen wir in sehr engem internationalem Kontakt mit Imkern und Bienenwissenschaftern. Nur so ist es möglich, rechtzeitig neue Gefahren für die Bienengesundheit zu erkennen, bevor sie in der Schweiz auftreten (Frühwarnsystem) und das Problem Völkerverluste vernünftig anzugehen, wovon die Schweizer Imkerinnen und Imker ebenfalls profitieren werden. Einzelne Länder haben keine Chance, da das Problem zu vielschichtig ist. Ich bin aus diesem Grund leider nur wenig optimistisch, was die Völkerverluste angeht. Ich vermute, dass es noch einige Jahre dauern wird, bis wir die Verluste gut verstehen und in den Griff kriegen werden. Wir haben am ZBF daher unser Hauptaugenmerk auf den einzigen Faktor gelegt, von dem wir jetzt schon ganz sicher sein können, das er eine zentrale Rolle spielt: die Varroamilbe.

Vielen Dank, Herr Neumann, für die interessanten Informationen. ○

Statement on the publication:

TENNEKES, H.A. (2010): The significance of the Druckrey–Küpfmüller equation for risk assessment -The toxicity of neonicotinoid insecticides to arthropods is reinforced by exposure time. Toxicology: doi:10.1016/j.tox.2010.07.005

In his paper, the author refers to the Druckrey–Küpfmüller equation that was established to explain the chronic effect of low concentration levels of chemical carcinogens. It says that for these substances the total dose required to produce the same effect decreases with decreasing exposure levels, even though the exposure times required to produce the same effect increase with decreasing exposure levels. Therefore, if both receptor binding and the effect are irreversible, exposure time would reinforce the effect. The author claims likewise that recently, similar dose-response characteristics have been established for the toxicity neonicotinoid insecticides to arthropods. His conclusion is that the equation would explain patterns of chronic effects of Imidacloprid to honeybees and other arthropods and that this phenomenon would so far not have been sufficiently considered in the risk assessment.

The approach to extrapolate the effect patterns of long-term effects of carcinogenic substances to the effects of pesticides to arthropods is certainly an interesting one. However, the concerns of the author are unfounded as the approach chosen cannot be applied by implication to evaluate neonicotinoid chronic toxicity to insects, and, moreover, as the risk assessment of Imidacloprid for honey bees is based on data in which a chronic exposure of bees to Imidacloprid is already sufficiently considered. This is outlined in detail in the following.

1.) All commercial neonicotinoid insecticides bind to insect nicotinic acetylcholine receptors and evoke the same effect as the natural neurotransmitter acetylcholine, i.e. agonistically activating the receptors causing a transient inward-current leading to the generation of action potentials. Similar to acetylcholine neonicotinoid binding to nicotinic acetylcholine receptors, the binding of neonicotinoid insecticides is reversible as shown by their rapid desensitization/recovery during short-term exposure in electrophysiological whole-cell voltage clamp assays on isolated insect neurons (Nauen et al., 2001; Jeschke & Nauen, 2005). The synaptic action of acetylcholine under normal physiological conditions is terminated by acetycholinesterase, which hydrolyzes the transmitter. Neonicotinoids cannot be hydrolyzed by the enzyme, i.e. they persist at the binding sites leading to over-stimulation of cholinergic synapses, resulting in hyperexcitation and paralysis of the insect (Yu, 2008). Due to the reversible nature of binding of neonicotinoids, their toxic action strongly depends on the pharmacokinetics as shown in aphids recovering from imidacloprid intoxication under discontinuous exposure conditions (Nauen, 1995). Therefore, the basic conditions for the applicability of the Druckrey–Küpfmüller equation (i.e. both receptor binding and the effect are irreversible) are not given in this case.
2.) There are extensive data available on the chronic toxicity of Imidacloprid under laboratory conditions. These data are summarized in SCHMUCK (2004). In the underlying studies, chronic effects of Imidacloprid were directly measured over

longer times (e.g. in 10 day feeding studies) and not extrapolated from short-time exposure studies, which excludes an underestimation of chronic toxicity based on the phenomena described by the author.

3.) There are studies available where bee colonies have been chronically fed with Imidacloprid-spiked diet under practically relevant conditions (e.g. the study of FAUCON (2004), where bee hive were exposed to field-relevant concentrations of Imidacloprid over 34 days (longer than the normal lifespan of an adult bees) and monitored for several months. No adverse effects on mortality or other endpoints were seen.
4.) There were numerous higher-tier (tunnel and field) studies conducted where honeybee colonies were exposed to Imidacloprid-treated crops under realistic conditions (see for instance SCHMUCK 1999, CURÉ et al. 2001, MAUS et al. 2003, SCHMUCK et al. 2005). Of course, these studies include the observation of chronic effects, as their duration is normally covering several generation cycles of the bees. In none of these studies, increased chronic or acute mortalities were seen.
5.) As evidence for his hypothesis, the author cites the study of SUCHAIL et al. (2001) which claimed to have found a chronic toxicity of Imidacloprid to bees which is by far in excess to the measured acute toxicity. The results of this study, however, were found to be flawed, and could not be reproduced by several independent research institutions (SCHMUCK 2004).

Therefore it can be concluded that potential chronic effects of Imidacloprid to honeybees are fully covered by appropriate studies and that there is no concern that effects like described by the Druckrey–Küpfmüller equation might entail a higher chronic toxicity than assumed. In contrast, recent studies provide evidence that there is under realistic conditions no correlation between exposure of honey bees to Imidacloprid-treated crops and increased colony mortality (e.g. NGUYEN et al. 2009, CHAUZAT et al. 2009, GENERSCH et al. 2010).

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Dr. Christian Maus & Dr. Ralf Nauen, Bayer CropScience

Statement on the finding of the study:

ALAUX et al. 2009: Interactions between *Nosema* microspores and a neonicotinoid weaken honeybees (*Apis mellifera*)

In the recently issued publication of Alaux et al. (2009), the interactions of an oral exposure to different sublethal doses of Imidacloprid and a challenge with *Nosema* infestation were investigated under laboratory conditions. Measured endpoints were mortality over a 10-day period, food consumption, and the activity of three enzyme and other markers involved in the immune defense reaction of insects.
In the groups simultaneously exposed to Imidacloprid and *Nosema*, mortality rates were approximately additive in comparison to the test groups where bees were exposed only to *Nosema* or to Imidacloprid alone. Only in the highest dose group (70 µg/kg) effects were more than additive. The activity of two of the three immune system markers (total hematocyte count and phenoloxidase activity) were not influenced by neither Imidacloprid exposure nor by *Nosema* infestation, nor by a combination of both, the third (glucose oxidase activity, as a marker of social immunity) was weaker in the group exposed to both, Imidacloprid and *Nosema*. From these findings, the authors conclude that a synergistic interaction between Imidacloprid and *Nosema* can weaken and thereby threaten bee colonies and that exposure to pesticides even at sublethal levels can affect bee colonies by making them more susceptible against diseases and weakening the bees' immune defense.

There is not too much known about the influence of multiple stressors to organisms under field conditions, and in how far laboratory data can be extrapolated to the situation in the field. In so far, there are some aspects to consider when drawing conclusions from laboratory results as the one reported here:

- There is no information available about the biological significance of the measured differences in the glucose oxidase activity. Apart from the fact that the differences are numerically rather small, there is no indicator value given, which level of enzyme activity represents normal physiological conditions, and which level of reduction would cause an adverse effect to the affected bee and the bee colony. Moreover, the role of the tested enzyme in the defense against *Nosema* is not proven, but just assumed on the basis of conclusions by analogy. And finally, the involvement of the tested glucose oxidase in the defense against *Nosema* via the social immune defense of a colony is of such indirect nature, that all conclusions about an adverse effect to the health of a colony by a reduced glucose oxidase activity remain highly speculative.
- The study was conducted under artificial laboratory conditions with individual worker bees out of the context of the colony and its complex interactions and compensation mechanisms. In such an artificial laboratory environment, bees may react quite different from a situation under realistic field conditions. There were already many cases where a sublethal stressor was shown to induce certain effects in the laboratory, which could then, however, not be recovered under field conditions, or where sublethal effects that were seen in the laboratory proved not to be biologically relevant under realistic conditions. Therefore, the results of the study referred to here do not provide a proof of an adverse effect to bee colonies by the exposure to sublethal doses of a neonicotinoid (although this is implied in the paper), but at the utmost indicates an intrinsic effect potential. There is no evidence that this could cause a hazard to bee colonies under realistic conditions.
- Before concluding on any synergistic effect, the reproducibility of the reported findings has to be demonstrated. The reported findings of a higher sensitivity of honeybees exposed to sublethal concentrations of Imidacloprid to *Nosema* infestation is apparently specific to this study since results of the Bee Institute of Celle/Germany, did not find interactions between sublethal exposure to Imidacloprid and a challenge with *Nosema* infestation (WEHLING et al. 2006: Intoxication of honeybees – Interactions of plant protection products and other factors. Proceedings of the Second European Congress of Apidology EurBee, Prague 10.-16. September 2006: 79). Likewise, the observation that the treatment group exposed to Imidacloprid only was, in contrast to the control group, not infested with *Nosema*, and the conclusion drawn from this finding, that Imidacloprid may have a slight suppressing effect to *Nosema*, is in contrast to the observations with a recent US study in which higher *Nosema* spore counts were found in Neonicotinoid-exposed hived than in control hives (DIVELY & PETTIS, unpublished data). These inconsistencies suggest that the test designs applied may not yet be fully technically mature.
- At residue levels encountered by bees under agronomic use conditions, i.e. < 20 µg/kg, mortality was only increased in an additive manner in this study; only in the highest combined *Nosema* and Imidacloprid exposure group (70 µg/kg Imidacloprid), effects were over-additive. Therefore the scenario where synergistic effects were seen is of no relevance in practice.

In summary, it can be stated that the study of ALAUX et al. (2009) does not convincingly substantiate the conclusion of any adverse effects of the exposure of bees to sublethal doses of Imidacloprid alone or in combination with other stressors like diseases or pathogens under realistic exposure conditions in the field.

Hazards of Insecticides to the Bumble Bees *Bombus impatiens* (Hymenoptera: Apidae) Foraging on Flowering White Clover in Turf

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ABSTRACT Insecticides used on turf are sometimes applied to areas with flowering weeds that attract honey bees and native pollinators. We tested residual effects of such treatments on colony vitality and behavior of the bumble bees *Bombus impatiens* Cresson foraging on turf containing white clover, *Trifolium repens* L. Imidacloprid, a systemic chloronicotinyl used for preventive control of root-feeding grubs, was applied as granules, followed by irrigation, or sprayed as a wettable powder, with or without irrigation. Hives were confined on the plots in large field cages after residues had dried and colony vitality (i.e., numbers of brood, workers, and honey pots, and weights of queens, workers, and whole colonies with hives) was evaluated after 28–30 d. Workers' foraging activity and defensive response to an aggressive stimulus also were evaluated. In another test, weedy turf was sprayed with chlorpyrifos, carbaryl, or cyfluthrin at labeled rates for surface-feeding pests. Bee colonies were confined on the plots after residues had dried, with effects on colony vitality evaluated after 14 d. Finally, foraging activity of wild bumble bees was monitored on open plots to determine if insecticide-treated areas were avoided. Imidacloprid granules, and imidacloprid sprays applied with posttreatment irrigation, had no effect on colony vitality or workers' behavior, suggesting that such treatments pose little systemic or residual hazard to bumble bees. In contrast, exposure to dry nonirrigated residues of all of the aforementioned insecticides had severe impact on colony vitality. Foraging workers did not avoid insecticide-treated areas. Means by which turf managers can reduce hazards of insecticide applications to pollinators are discussed.

KEY WORDS *Bombus impatiens*, bumble bee, turfgrass, ecotoxicology, imidacloprid, cyfluthrin

HABITAT LOSS AND FRAGMENTATION, diseases and parasites, and exposure to broad-spectrum insecticides are factors contributing to declining populations of honey bees, native bee species, and other pollinators in the United States and worldwide (Watanabe 1994, Allen et al. 1998, Kearns et al. 1998). As urban areas grow, lawns, golf courses, and other managed landscapes continue to supplant natural bee habitat. Turfgrasses now cover >12 million hectares in the United States (Potter and Braman 1991). As pollinators adapt to their new urban environment, it is important their habitat include safe forage.

Lawns and out-of-play areas of golf courses commonly contain flowering weeds such as white clover (*Trifolium repens* L.), dandelions (*Taraxacum* spp.), plantain (*Plantago* spp.), and violets (*Viola* spp.). White clover, in particular, thrives on golf courses because it can flower and produce seed at mowing heights as low as 6 mm (Watschke et al. 1995). Sometimes it encroaches from roughs into fairways. When present, such weeds attract honey bees (Apidae), bumble bees (Bombinae), solitary bees (e.g., Andrenidae, Halictidae, Megachilidae), skippers (Hesperiidae), white and sulfur butterflies (Pieridae), and other pollinators (e.g., Shepherd and Tepedino 2000).

High esthetic standards for turf result in substantial insecticide usage on lawns and golf courses (Racke and Leslie 1993, Potter 1998, Racke 2000). Foliage-feeding pests typically are controlled with liquid applications of organophosphate, carbamate or pyrethroid insecticides, with residues allowed to dry on stems and leaves (Potter 1998). Root-feeding white grubs (Scarabaeidae) were traditionally controlled with organophosphates or carbamates applied after egg hatch and watered into the soil. During the 1990s, however, use patterns shifted to longer residual, less broadly toxic compounds, mainly imidacloprid and halofenozide (Potter 1998).

Imidacloprid, a chloronicotinyl, is now widely used for preventive control of white grubs, as well as billbug (*Sphenophorus* spp.) larvae, mole crickets (*Scapteriscus* spp), and other soil-inhabiting turf pests (Potter 1998). It is systemic, has relatively long residual effect when acting via soil, and has low mammalian toxicity (Elbert et al. 1991, Mullins 1993). In turf, it may be applied as a liquid spray, or as granules. The label recommends that for grub control, sufficient irrigation

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or rainfall be applied to move the residues into the soil. Although this usually is done on golf courses, in our experience, timely watering-in is less assured following treatments made by commercial lawn care firms or homeowners.

Exposure to organophosphate, carbamate, and pyrethroid insecticides has been associated with bee poisonings in food crops (Kevan 1975, Johansen 1977, Kearns et al. 1998). Such compounds could potentially intoxicate pollinators through direct contact, exposure to residues, or spray contamination of nectar and pollen (e.g., Burgett and Fisher 1980, Johansen et al. 1983). Certain systemic organophosphates and carbamates (e.g., dimethoate, aldicarb) also have the potential to contaminate nectar (Jaycox 1964, Waller et al. 1984, Johansen et al. 1983) and pollen (Ferguson 1987).

Imidacloprid, given direct exposure, also is inherently toxic to bees (Stark et al. 1995, Mayer and Lunden 1997, Schmuck et al. 2001). In some crops, the question has arisen whether soil-applied imidacloprid might be translocated into nectar and pollen at levels that pose a risk to pollinators or other insects that use floral resources. Schmuck et al. (2001) showed that residues of imidacloprid in nectar and pollen of seed-treated sunflower, *Helianthus annuus* L., plants in the field were negligible and that such treatments had no adverse effects on the development of exposed colonies of honey bees, *Apis mellifera* L. Imidacloprid seed coating of sunflowers also did not affect behavior or colony development of bumblebees, *Bombus terrestris* L. (Tasei et al. 2001). Smith and Krischik (1999), however, reported some adverse effects on mobility and fitness of the predatory coccinelid *Coleomegilla maculata* (DeGeer), which is a facultative pollen feeder, when beetles were confined with excised inflorescences from plants that had been treated with granular imidacloprid through the soil. Host foraging ability and longevity of the braconid *Microplitis croceipes* Cresson were reduced in wasps that had fed from extrafloral nectaries of imidacloprid-treated cotton (*Gossypium hirsutum* L.) plants (Stapel et al. 2000).

Lawn care professionals and homeowners often apply insecticides to lawns with flowering weeds, and many golf superintendents deliberately overlap the first cut of rough when treating fairways, aprons, putting greens, or tees. Potential hazards of such exposures to pollinators in weedy turf have not been evaluated. We applied imidacloprid to mixed stands of turf with flowering white clover, with or without posttreatment irrigation, and tested for residual and systemic effects on behavior and colony vitality of bumble bees, *Bombus impatiens* Cresson (Hymenoptera: Apidae) confined to foraging on the treated plots. Residual toxicity to the bees of three nonsystemic insecticides, carbaryl, chlorpyrifos, and cyfluthrin, also was examined. Finally, we tested whether or not foraging bumble bee workers avoid treated weedy turf in open field plots.

Materials and Methods

Exposure to Weedy Turf Treated with Granular Imidacloprid, Followed by Irrigation. This test was conducted on a mixed stand of tall fescue, *Festuca arundinacea* Schreber, with ≈25–50% flowering white clover cover at the University of Kentucky's Spindletop Research Farm, near Lexington. On 18 June 1999, 10 plots (3 by 5 m) were individually rated by three independent observers for percentage of surface area covered by clover. Plots were paired accordingly, and one of each pair was randomly selected for treatment the following day. Imidacloprid (Merit 0.5 G, Bayer, Kansas City, MO) was preweighed for application at the highest label rate for white grubs (0.4483 kg [AI]/ha). The granules were mixed with dry sand and evenly applied by gloved hand. The other plot of each pair was untreated. Shortly after treatment, all plots received 1.5 cm of irrigation from lawn sprinklers. Plots were then covered with pollination cages (4 by 2 by 1.3 m) consisting of a PVC frame draped with 1-mm mesh. The frames and screening were sealed at ground level using loose soil. The first rain (1.42 cm) was 24 June, 5 d after treatment. Total rainfall during the 30-d interval following treatment was 7.0 cm.

Similar-aged colonies of *B. impatiens* (Koppert Biological Supply, Romulus, MI) were paired according to their initial weights. Each colony was housed in a cardboard hive and contained a fertilized queen, 40–50 workers, and brood. Seven days after treatment (26 June), one randomly assigned hive was placed on a concrete block within each cage, facing west. A band of Tanglefoot (Tanglefoot, Grand Rapids, MI) was applied around the block to discourage invertebrate predators. Dry honey bee pollen, purchased from a health food store, was provided to ensure that the bees were not pollen-limited. The supplemental pollen (7 g, twice per week) was placed directly into the hive.

Bees were allowed to forage in the cages for 30 d. Foraging activity in each plot was monitored three times per week. Each time, the total number of bees foraging on each plot was counted for a 2-min interval between 1100 and 1300 hours. Counts were compared between treatments by multivariate analysis of variance (MANOVA for repeated measures using the Wilks lambda likelihood ratio test (SAS Institute 1997).

Observations early in the experiment suggested some bee colonies were more defensive than others. To test if imidacloprid was affecting colonies' defensive abilities, one person wearing a bee suit entered the cage and tapped the hive with a 30-cm wooden ruler three times from a striking distance of 20 cm. The time it took for the first three bees to leave the hive was recorded as the initial response time. A second measurement, the duration of response, was defined as the time elapsed from initial response until a 25-s lapse during which no more bees left the hive. In addition, the total number of bees that responded was recorded.

After dusk on the final day, each hive was closed and sealed within a dark plastic bag. Hives with colonies were brought back to the lab and frozen at −29°C.

Inspection of each cage the following day revealed no active bees, indicating that no workers had remained outside during the night and that the whole colony was accounted for.

Colonies were dissected to assess their relative vitality. Numbers of adult bees, honey pots (includes specialized wax cells filled with honey, together with smaller numbers of honey-filled, vacated adult cells), and brood chambers (i.e., individual cells containing one or more larvae) were counted, and weights of workers, queens, and whole colony plus hive were determined. Bees that had died on the ground could not be accounted for. Vacated cells were not a good indicator of number of adults that had emerged because such cells often were rebuilt and filled with honey, and were not distinctive unless the bee had just emerged.

Paired *t*-tests ($P = 0.05$) were used to compare colonies from treated versus untreated plots (Analytical Software 1996). All data are reported as means ± SE.

Exposure to Irrigated or NonIrrigated Spray Residues of Imidacloprid. Fifteen plots were established in a stand of tall fescue with ≈25–50% white clover coverage on a minimally maintained athletic field on the University of Kentucky campus, Lexington. Plots (3 by 5 m), marked and ranked as described earlier, were placed in five groups of three according to similar clover density. On 22 June 2000, two plots of each group were randomly selected for treatment with imidacloprid (Merit 75 WP, Bayer) at the label rate for grub control (0.336 kg [AI]/ha). Treatments were applied with a portable CO2 spray tank (R and D Sprayers, Opelousas, LA) with a spray volume of 468 liter/ha at pressure of 2,109 g/cm^2. The sprayer was equipped with a 1.8-m, hand-held boom with four Spraying System 8004 Tee Jet nozzles (Spraying Systems, Wheaton, IL). One sprayed plot within each group was randomly selected to receive 1.5 cm of irrigation immediately after treatment, as is recommended by the label. The third plot was left untreated. Plots were enclosed within individual pollination cages as before.

The following day, after residues had dried, a hive containing a *B. impatiens* colony was placed into each cage on a cement block, facing west. Each hive initially contained 20–25 workers, a fertile queen, and brood. The bees were fed 7 g of dry honey bee pollen once every 7 d. The first rainy period began 3 d after treatment (0.17, 0.15, and 3.45 cm on 25, 26, and 27 June, respectively) and total rainfall during the 4 wk following treatment was 10.1 cm.

Foraging activity and defensive response were assessed in the same manner as in 1999. Bees were allowed to forage inside the cages for 28 d. The hives and colonies were then collected and dissected as described for the previous test. Treatments were compared by a two-way analysis of variance (ANOVA) followed by the least significant difference test for mean separation (Analytical Software 1996).

Exposure to Nonirrigated Spray Residues of Nonsystemic Insecticides. On 24 May 2000, 16 plots were established on a different area of the same athletic field used in the previous imidacloprid experiment. Plot size and layout were the same as previously described. One plot of each replication was left untreated. The remaining plots were sprayed with either cyfluthrin (Tempo SC Ultra, Bayer) at 0.077 kg [(AI)]/ha, chlorpyrifos (Dursban 50W, Dow AgroSciences, Indianapolis, IN) at 1.12 kg [(AI)])/ha, or carbaryl (Sevin SL, Aventis, Montvale, NJ) at 6.10 kg [(AI)]/ha. Those rates are registered for control of foliage feeding turf pests. No posttreatment irrigation was applied.

The plots were caged as before, and hives with bumble bee colonies were placed on them 24 h after treatment. Observations on foraging activity were conducted as previously described. The first rain occurred 3 and 4 d after application (1.12 and 0.96 cm, respectively), followed by only a trace (0.2 cm) of additional rain through the remainder of the trial. The experiment ran for 14 d. The hives were then collected and their contents dissected as before. Colony vitality and behavioral parameters were compared between treatments by two-way ANOVA using Statistix for Windows, followed by the LSD means separation procedure ($P = 0.05$). Foraging activity was compared between treatments by MANOVA for repeated measures, as described before.

Test for Avoidance of Treated, Weedy Turf. To determine if bumble bees would avoid foraging in areas with irrigated residues of granular imidacloprid, another tall fescue stand with ≈25–50% clover cover on the University of Kentucky campus was used. Fourteen plots (3 by 6 m) were paired according to estimated percentage of the surface with flowering clover, as described before. On 7 July 1999, one plot of each pair was treated with imidacloprid (Merit 0.5 g) at 0.336 kg (AI)/ha, whereas the other plot was left untreated. Immediately thereafter, all plots received 1.5 cm of irrigation. Foraging activity was monitored 1 wk later (14 July), from 0800 to 1500 hours. The number of bees foraging on the clover within each plot was determined by walking the field and visually scanning the whole plot for 1 min, twice per hour, for 6 h. There was only a trace of rain (0.10 cm on 10 July) between the treatment and observation dates. Foraging activity was compared between treatments by MANOVA for repeated measures as described earlier.

To test for avoidance of nonirrigated spray residues of turf insecticides, four sets of five plots were established on a minimally maintained turf stand at the University Club golf course, near Lexington. Plots were blocked on the basis of similar clover cover, as before. Randomly selected plots were sprayed with carbaryl, chlorpyrifos, cyfluthrin, or imidacloprid, or left untreated. Formulations, rates, and application method were as described previously. Plots were treated on 17 August 2000. The following day, after residues had dried, the number of bees foraging on each plot was observed and recorded over 45-s intervals, twice per hour, as described above. Observations

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Table 1. Colony vitality and defensive response of bumble bees confined for 30 d on plots with turf and flowering white clover that were untreated, or had been treated with granular imidacloprid followed by irrigation

	Control	Imidacloprid	*t*-statistic	*P*
Weight (g)				
Colony (with hive)	2,540 ± 52.0	2,690 ± 52.5	−1.54	0.20
Workers	27.4 ± 5.6	30.3 ± 4.9	−0.31	0.77
Queen	0.79 ± 0.02	0.73 ± 0.05	−0.86	0.44
No. in colony				
Workers	157.2 ± 37.1	116.6 ± 33.8	−0.86	0.44
Brood chambers	43.6 ± 11.5	76.2 ± 27.4	−1.68	0.17
Honey pots	131.6 ± 20.0	148.8 ± 11.0	−0.82	0.46
Defensive response				
Time to initial response (s)	7.5 ± 2.6	1.8 ± 0.6	−1.9	0.13
Duration of response (s)	46.6 ± 14.4	44.0 ± 12.7	−0.1	0.92
No. of bees responding	15.0 ± 2.2	6.2 ± 3.6	−0.9	0.74

began at 0800 and ended at 1500 hours. No rain fell at the site between treatment and the end of the observation period. Counts were analyzed by MANOVA for repeated measures as before.

Results

Exposure to Weedy Turf Treated with Granular Imidacloprid, Followed by Irrigation. Granular imidacloprid applied with posttreatment irrigation had no effect on vitality of *B. impatiens* colonies or on workers' defensive response to an aggressive stimulus (Table 1). In addition, these treatments did not affect foraging activity (Fig. 1).

Exposure to Irrigated or NonIrrigated Spray Residues of Imidacloprid. Spray applications of imidacloprid that were followed by irrigation did not adversely affect colony vitality or workers' defensive response (Table 2). However, colonies foraging on nonirrigated imidacloprid treated plots had fewer brood chambers, honey pots, and workers. Total biomass of workers was reduced on these plots, as was total colony weight.

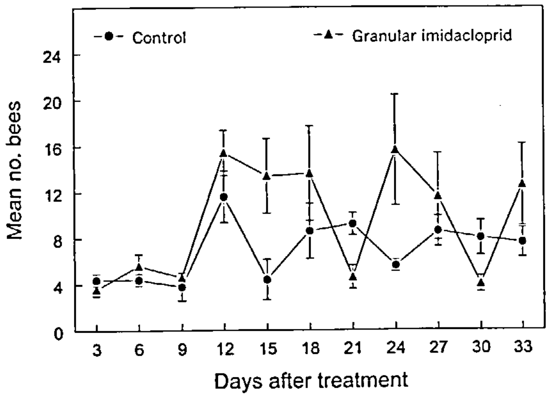

Fig. 1. Foraging activity of *B. impatiens* colonies confined on untreated plots of tall fescue mixed with flowering white clover, or similar plots that had been treated with granular imidacloprid followed by irrigation. Data are mean ± SE number of workers foraging within each cage based on 2-min counts taken every 3 d for 37 d. The overall treatment effect is not significant (MANOVA for repeated measures; $F = 1.91$; df = 1, 8; $P = 0.204$)

Queen weights were not affected, probably because queens already were mature. We observed a number of dead bees clinging to the sides of the cages on the nonirrigated, imidacloprid-treated plots, a phenomenon unique to this experiment. Colonies' defensive response to the aggressive stimulus also was reduced (Table 2). Colonies exposed to nonirrigated imidacloprid residues had reduced foraging activity (Fig. 2, MANOVA for repeated measures).

Exposure to Nonirrigated Spray Residues of Nonsystemic Insecticides. Exposure to dry spray residues of each of the surface-applied, nonsystemic insecticides adversely affected colony vitality of bumble bees (Table 3). Fewer worker bees, honey pots, and brood chambers were present in hives from treated plots. Worker biomass and colony weights were also reduced. For both carbaryl- and chlorpyrifos-treated plots, two of the four colonies had no live brood or adults. Colonies from chlorpyrifos-treated plots had significantly less brood than did plots from carbaryl- or cyfluthrin-treated plots (Table 3). Colonies from carbaryl-treated plots had less brood than those exposed to cyfluthrin. There also was reduced foraging activity on treated plots (Fig. 3).

Test for Avoidance of Treated, Weedy Turf. Endemic bumble bees neither avoided nor preferred plots that had been treated with granular imidacloprid relative to untreated control plots (MANOVA for repeated measures; $F = 0.89$, df = 1, 12; $P = 0.363$). Mean numbers of bee visits observed per plot, per 1-min observation period, were 5.5 ± 3.0 versus 5.1 ± 2.8, respectively. Likewise, bumble bees foraging on flowering white clover intermixed with turf did not avoid plots sprayed with imidacloprid, carbaryl, chlorpyrifos, or cyfluthrin, relative to untreated plots (MANOVA for repeated measures; $F = 1.62$; df = 4, 15; $P = 0.221$). Because there was relatively light foraging activity during this test, bee visits per plot were pooled across observation periods. Mean ± SE total numbers of workers observed per plot were 12.8 ± 1.3, 10.8 ± 0.9, 15.4 ± 1.5, 13.0 ± 1.3, and 12.1 ± 1.8, respectively.

Discussion

Our results suggest that regardless of formulation, imidacloprid applications that are followed by irriga-

Table 2. Colony vitality and defensive response of bumble bees confined for 28 d on untreated turf plots with flowering white clover versus plots with irrigated or non-irrigated imidacloprid residues

	Control	Irrigated	Non-irrigated	F	P
Weight (g)					
Colony (without hive)	86.4 ± 6.8a	80.6 ± 2.6a	39.6 ± 12.4b	11.81	0.004
Workers	7.2 ± 1.0a	7.9 ± 0.4a	3.2 ± 0.6b	18.63	0.001
Queen	0.7 ± 0.0a	0.7 ± 0.1a	0.7 ± 0.0a	0.00	0.999
No. in colony					
Adults	55.4 ± 7.0a	48.6 ± 4.4a	21.8 ± 2.3b	13.23	0.002
Brood chambers	28.6 ± 4.2a	25.0 ± 3.6a	3.6 ± 0.7b	18.65	0.001
Honey pots	24.0 ± 2.9a	24.2 ± 4.7a	6.8 ± 4.7b	6.37	0.022
Dead bees[a]	0.0 ± 0.0a	1.0 ± 0.7a	13.2 ± 2.3b	15.52	0.001
Defensive response					
Time to initial response (s)	9.8 ± 0.9a	9.2 ± 1.7a	3.2 ± 1.9b	14.24	0.002
Duration of response (s)	46.8 ± 1.0a	38.2 ± 7.0a	12.6 ± 7.2b	15.74	0.031
No. of bees responding	6.2 ± 1.9a	7.0 ± 0.7a	1.4 ± 0.8b	8.23	0.021

Means within rows that are not followed with the same letter differ significantly (two-way ANOVA, LSD, $P < 0.05$).
[a] These were the dead bees were found clinging to sides of the cage (see text).

tion, as is recommended by the label for optimum soil insect control, pose little or no residual hazard to bumble bees foraging on flowering white clover in weedy turf. Importantly, they suggest absence of systemic effects of soil treatment on colony vitality, even with prolonged exposure from bees having been caged on the treated plots for 28–30 d. Nonirrigated granular applications were not evaluated but they, too, would likely be nonhazardous because bees would not encounter granules that settle into grass or thatch. Residues from the irrigated spray application apparently did not bind to pollen, petals, and leaves, or else were dislodged by watering.

In contrast, bee colonies that foraged on imidacloprid-sprayed plots not receiving posttreatment irrigation experienced loss of workers, brood, and honey pots, as well as reduced worker biomass and colony weight. Foraging activity and aggressiveness of those colonies were also reduced. This likely resulted from acute toxicity to workers rather than sublethal impairment of their behavior. Similarly, exposure to dry, nonirrigated spray residues of chlorpyrifos, carbaryl, or cyfluthrin adversely affected all colony vitality parameters of bumble bees foraging on weedy, treated turf.

Our results with nonirrigated spray residues are not surprising considering that all four of the insecticides tested are inherently toxic to bees (Hays and Laws 1991, Extoxnet 2001). These tests represent a worst-case scenario in that the workers were caged on the sprayed plots for 2 or 4 wk. Whole-colony consequences of a smaller proportion of the workers foraging on insecticide-contaminated weeds in an open system likely would be less severe. Nevertheless, the fact that *B. impatiens* workers did not avoid treated plots suggests that insecticide residues on blooming weeds could adversely affect local, native bee colo-

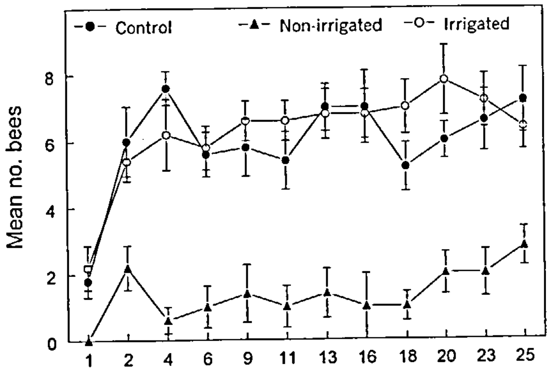

Fig. 2. Foraging activity of *B. impatiens* colonies confined on plots of tall fescue mixed with flowering white clover that were (1) untreated, (2) sprayed with a wettable powder formulation of imidacloprid with residues allowed to dry on the grass, or (3) sprayed with imidacloprid, with residues watered in. Data are mean ± SE number of workers foraging within each cage based on 2-min counts taken every 2–3 d. The overall treatment effect is significant (MANOVA for repeated measures; $F = 59.35$; df = 2, 12; $P < 0.0001$).

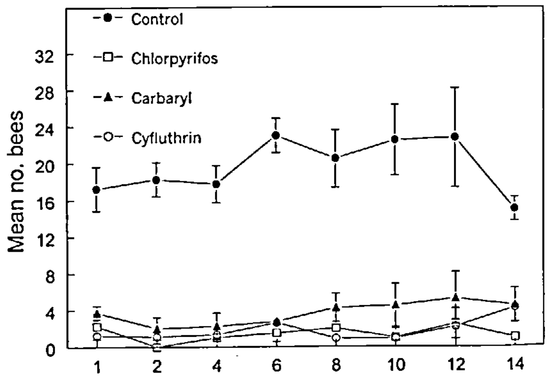

Fig. 3. Foraging activity of *B. impatiens* colonies confined on plots of tall fescue mixed with flowering white clover that had been treated with short-residual insecticides, with residues allowed to dry on the grass. Data are mean ± SE number of workers foraging within each cage based on 2-min counts taken every 3 d. The overall treatment effect is significant (MANOVA for repeated measures; $F = 40.34$; df = 3, 12; $P < 0.0001$)

Table 3. Colony vitality of bumble bees following 2-wk exposure to dry residues of surface insecticides on mixed stands of turf and flowering white clover

Colony parameters	Treatment				F	P
	Control	Chlorpyrifos	Carbaryl	Cyfluthrin		
Weight (g)						
Colony (without hive)	193.4 ± 26.3a	107.8 ± 7.2b	127.0 ± 11.4b	142.6 ± 13.6b	7.04	0.010
Workers	23.1 ± 4.9a	7.5 ± 1.1b	11.0 ± 2.5b	11.8 ± 2.3b	6.22	0.014
Queen	0.78 ± 0.05a	0.78 ± 0.08a	0.74 ± 0.06a	0.66 ± 0.03a	1.04	0.422
No. in colony						
Workers	132.8 ± 19.6a	56.8 ± 6.5b	67.3 ± 11.9b	76.8 ± 9.3b	9.07	0.004
Honey pots	41.8 ± 12.9a	5.5 ± 3.6c	29.7 ± 8.2b	38.5 ± 6.9a	6.05	0.015
Brood chambers	56.0 ± 5.1a	3.5 ± 1.3d	10.3 ± 2.4c	20.5 ± 2.7b	19.70	0.0003

Means within rows that are not followed with the same letter differ significantly (two-way ANOVA, LSD, $P < 0.05$)

nies. Honey bees, solitary bees, and other pollinators foraging in treated, weedy turf could similarly be at risk

The extent to which an insecticide is hazardous to pollinators is determined by its inherent toxicity as well as the formulation and manner in which it is applied (Stark et al. 1995). For example, pollen contamination, which can decimate honey bee colonies, may be exacerbated by wettable powder or microencapsulated formulations that have high affinity for binding to pollen (Johansen et al. 1983). Conversely, posttreatment irrigation may decrease exposure or dilute active ingredient concentration thereby reducing hazards to beneficial insects (e.g., Kunkel et al. 2001).

Our results suggest that, at least for imidacloprid, posttreatment irrigation will greatly reduce hazard to bees from liquid applications targeting soil pests. Other tactics likely to alleviate hazards of turf insecticides to pollinators include use of products with target-selective or low residual toxicity, granular formulations, mowing flower heads before treatment, weed management with herbicides, and avoiding treatment when weeds are in bloom. Although these tactics have long been advocated for agricultural crops (e.g., Kevan 1975, Johansen 1977, Kearns et al. 1998), increasing awareness of them among turf managers may help to conserve pollinators in urban and suburban landscapes.

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