Bee Better Certified™

Background to the Production Standards

BEE BETTER
CERTIFIED
XERCES SOCIETY

BEE BETTER CERTIFIED™

Xerces Society for Invertebrate Conservation

Bee Better Certified™ works to give bees a healthy place to live.

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Cover photo: Leafcutter bee foraging on rayless gaillardia in Arizona (The Xerces Society/Mace Vaughan).

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Background to the Production Standards

Contents

The Bee Better Certified Production Standards draw on research and best practice to establish criteria for successfully integrating pollinator habitat such as hedgerows into working farms. (Photograph: The Xerces Society/Sarah Foltz Jordan.)

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Introduction

Bee Better Certified™ Production Standards combine current scientific understanding with best management practices to develop measures that best support wild, native pollinators on working farms. This document presents the reasoning behind the production standards. Each standard is presented with a summary of the research supporting the standard, accompanied by a selection of resources that offer relevant information that can help with its implementation. We also point you towards forms and documents that the Bee Better Certified™ program has developed to assist with the implementation of each standard.

1 Pollinator Habitat

1.1 Habitat Minimums

Standard 1.1.a

a. *All certified operations are required to have at least 5% of their total acreage requested for certification in pollinator habitat.*
    i. *At least one-fifth of the required habitat (i.e., 1% of the parcel acreage) must be permanent habitat; the reminder may be in temporary habitat.*
    ii. *If mass-flowering, pollinator-attractive crops are identified as part of the temporary habitat, they may not account for more than one-fifth of the required habitat (i.e., no more than 1% of the parcel acreage).*
    iii. *Habitat measurements must follow the Habitat Measurement Guidelines in Appendix B.*
    iv. *The land where habitat is created must be owned and/or controlled by the certifying farm or operator and available for habitat management and inspection.*
    v. *Pollinator habitat must be on or adjacent to or within 1 mile of certified crop fields.*
    vi. *If certified acreage is comprised of disconnected parcels, pollinator habitat should be distributed throughout the parcels, and the sum of the habitat established on all parcels must meet the 5% minimum.*
    vii. *Do not plant pollinator habitat in locations where nitroguanidine neonicotinoids were applied in the previous two years. Application includes the planting of seeds treated with nitroguanidine neonicotinoids.*

Rationale

The amount of natural habitat in the surrounding landscape is often an important factor affecting native bee populations on farms (Kremen et al. 2004; Ricketts et al. 2008). While most farmers don't have control of the surrounding landscape, they can create patches of habitat on their farms (Morandin and Kremen 2013). On-farm, flower-rich pollinator habitat supports higher bee diversity and abundance than bare or weedy field margins (M'Gonigle et al. 2015; Ponisio et al. 2016; Williams et al. 2015). Small habitat strips can bolster pollinator populations within crop fields, augmenting crop yields (Blaauw and Isaacs 2014). It is important that patches of habitat are located within 1 mile of the field(s) to be certified because bees are only able to utilize resources located within their foraging range. Bee foraging range correlates with their body size and varies from less than 500 feet for small-bodied bees to several miles for large bees, including bumble bees (Greenleaf et al. 2007; Ricketts et al. 2008).

Bee Better Certified set a target of 5% of a farm being pollinator-friendly habitat because farmers need to balance food production with their conservation efforts. Converting 5% of a farm to pollinator habitat presents a challenge, and might not be feasible for all farmers, but it is likely to make a big difference for pollinators in agricultural areas. If 5% of farmers in the U.S. incorporated pollinator habitat into 5% of their farms, approximately 2 million acres of farmland would become more habitable for wild pollinators.

While mass-flowering, bee-attractive crops can provide foraging resources for bees, their effects on pollinator populations are mixed and may depend on the availability of natural habitat, the timing of bloom, and floral resources at other times of the season (Westphal et al. 2009; Kovács-Hostyánszki et al. 2013; Rundlöf et al. 2014). Recent evidence suggests that when mass-flowering crops dominate the landscape they dilute pollinator populations (Holzschuh et al. 2011), leading to less than optimal crop yields (Holzschuh et al. 2016). It is likely, therefore, that patches of habitat adjacent to mass-flowering crop fields are still important for bee populations because they provide nesting sites, and continuity and diversity of resources throughout the season (Holzschuh et al. 2016).

Pollinator habitat is defined as areas containing flowering plants and/or nesting sites. Remnant natural habitat and newly created habitat are both considered pollinator habitat. All habitat areas must be protected from chemical drift. Pollinator habitat cannot be planted in areas where systemic pesticides have been used in the past 2 years. Pollinator habitat must be on the farm in or adjacent to crop fields, or within 1 mile of field(s) to be certified. The land where habitat is created must be owned and/or controlled by the certifying farm or operator and available for habitat management and inspection. If farms are comprised of disconnected parcels, pollinator habitat should be distributed throughout the properties, and the sum of the habitat established on all properties must meet the Bee Better Certified habitat requirements.

Permanent habitat is present year-round, although the plants may be in a vegetative or dormant state during the winter.

> Examples of permanent habitat: hedgerows, perennial or re-seeding wildflower strips, riparian forests, and filter strips.

Temporary habitat may die back annually or be moved around the farm (as is the case with rotating cover crops). If mass-flowering, pollinator-attracting crops are to be considered part of temporary habitat, they may only account for 1% (out of the 4% required) temporary habitat and be used in combination with another temporary habitat type.

Examples of temporary habitat: cover crops, insectary strips, and mass-flowering crops.

For complete list of permanent and temporary habitat types see Appendix A: On-farm Habitat Practices that can be Managed to Support Pollinators, in Bee Better Certified Production Standards.

Forms
NA

Resources
Regional Habitat Installation Guides: http://www.xerces.org/pollinator-conservation/agriculture/pollinator-habitat-installation-guides/

Vaughan, M., J. Hopwood, E. Lee-Mader, M. Shepherd, C. Kremen, A. Stine, and S. Black. 2015. *Farming for Bees*. Portland, OR: The Xerces Society for Invertebrate Conservation.

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Blaauw, B. R., and R. Isaacs. 2014. Flower plantings increase wild bee abundance and the pollination services provided to a pollination-dependent crop. *Journal of Applied Ecology* 51:890–898.

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Holzschuh, A., M. Dainese, J. P. González-Varo, S. Mudri-Stojnić, V. Riedinger, M. Rundlöf, J. Scheper, J. B. Wickens, V. J. Wickens, R. Bommarco, D. Kleijn, S. G. Potts, S. P. M. Roberts, H. G. Smith, M. Vilà, A. Vujić, and I. Steffan-Dewenter. 2016. Mass-flowering crops dilute pollinator abundance in agricultural landscapes across Europe. *Ecology Letters* 19:1228–1236.

Kovács-Hostyánszki, A., S. Haenke, P. Batáry, B. Jauker, A. Báldi, T. Tscharntke, and A. Holzschuh. 2013. Contrasting effects of mass-flowering crops on bee pollination of hedge plants at different spatial and temporal scales. *Ecological Applications* 23(8):1938–1946.

Kremen, C., N. N. Williams, R. L. Bugg, J. P. Fay, and R. W. Thorp. 2004. The area requirements of an ecosystem service: crop pollination by native bee communities in California. *Ecology Letters* 7(11):1109–1119.

M'Gonigle, L. K., L. C. Ponisio, K. Cutler, and C. Kremen. 2015. Habitat restoration promotes pollinator persistence and colonization in intensively managed agriculture. *Ecological Applications* 25(6):1557–1565.

Morandin, L. A., and C. Kremen. 2013. Hedgerow restoration promotes pollinator populations and exports native bees to adjacent fields. *Ecological Applications* 23(4):829–839.

Ponisio, L., L. K. M'Gonigle, and C. Kremen. 2016. On-farm habitat restoration counters biotic homogenization in intensively managed agriculture. *Global Change Biology* 22(2):704–715.

Ricketts, T. H., J. Regetz, I. Steffan-Dewenter, S. A. Cunningham, C. Kremen, A. Bogdanski, B. Gemmill-Herren, S. S. Greenleaf, A.-M. Klein, M. M. Mayfield, and L. A. Morandin. 2008. Landscape effects on crop pollination services: are there general patterns? *Ecology Letters* 11(5):499–515.

Rundlöf, M., A. S. Persson, H. G. Smith, and R. Bommarco. 2014. Late-season mass-flowering red clover increases bumble bee queen and male densities. *Biological Conservation* 172:138–145.

Westphal, C., I. Steffan-Dewenter, and T. Tscharntke. 2009. Mass flowering oilseed rape improves early colony growth but not sexual reproduction of bumblebees. *Journal of Applied Ecology* 46(1):187–193.

Williams, N. M., K. L. Ward, N. Pope, R. Isaacs, J. Wilson, E. A. May, J. Ellis, J. Daniels, A. Pence, K. Ullmann, and J. Peters. 2015. Native wildflower plantings support wild bee abundance and diversity in agricultural landscapes across the United States. *Ecological Applications* 25(8):2119–2131.

1.2 Bloom

Standard 1.2.a

a. *Permanent habitats must have a minimum of 3 flowering species present during each season (spring, summer, and fall).*

Rationale

Consistent floral bloom that is available throughout the year best supports bee populations (Williams et al. 2015). Providing consistent floral bloom throughout the growing season can increase native bee abundance and diversity in crop areas (Mendelik et al. 2012; Rundlöf et al. 2014). Bee activity starts in the early spring and continues through fall (Williams et al. 2001). Social species like bumble bees are active throughout the year while most solitary bee species have short flight periods, around 4–6 weeks, and are active at different times of the year (Ginsberg 1983; Michener 2007). Because not all species overlap in their foraging periods and are active at different times, it is important to ensure that there are no periods without floral resources for bees.

Floral diversity also benefits bee communities. Diverse patches of flowers attract more species-rich and abundant communities of bees (Potts et al. 2003; Balzan et al. 2014; Gill et al. 2014; Williams et al. 2015). Most bees, including those most important for pollination services, exhibit generalist foraging behavior, collecting pollen and nectar from a variety of flowers (Williams et al. 2001; Vasquez and Aizen 2003). Diverse blooms are also important for pollinator health: they provide an array of pollen and nectar resources that can be necessary for the development of some bee larvae (Goulson et al 2002; Williams and Kremen 2007).

Flowering species can include trees, shrubs, or forbs known to provide pollen and/or nectar to pollinators. Invasive or noxious species cannot be included in calculations of flowering species. Planting specifications and/or seed mixes in should be included in the Bee Better Certified conservation plan and provided to inspectors during the on-farm inspection.

Forms
NA

Resources
Regional Habitat Installation Guides: http://www.xerces.org/pollinator-conservation/agriculture/pollinator-habitat-installation-guides/
Regional plant lists and native plant nursery listings can be found at the Xerces Society Pollinator Conservation Resource Center: http://www.xerces.org/pollinator-resource-center/

Vaughan, M., J. Hopwood, E. Lee-Mader, M. Shepherd, C. Kremen, A. Stine, and S. Black. 2015. *Farming for Bees*. Portland, OR: The Xerces Society for Invertebrate Conservation.

Seed calculator to develop regionally specific seed mixes: http://www.xerces.org/xerces-seed-mix-calculator/

Ladybird Johnson Wildflower Center: http://www.wildflower.org/collections/

Calflora: https://www.calflora.org

USDA PLANTS database: https://plants.usda.gov/java/

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Balzan, M. V., G. Bocci, and A. C. Moonen. 2014. Augmenting flower trait diversity in wildflower strips to optimise the conservation of arthropod functional groups for multiple agroecosystem services. *Journal of Insect Conservation* 18(4):713–728.

Gill, K. A., R. Cox, and M. E. O'Neal. 2014. Quality over quantity: buffer strips can be improved with select native plant species. *Environmental Entomology* 43(2):298–311.

Ginsberg, H. S. 1983. Foraging ecology of bees in an old field. Ecology 64(1):165–175
Goulson, D., J. C. Stout and A. R. Kells. 2002. Do exotic bumblebees and honeybees compete with native flower-visiting insects in Tasmania? *Journal of Insect Conservation* 6:179–189.

Mandelik, Y., R. Winfree, T. Neeson, and C. Kremen. 2012. Complementary habitat use by wild bees in agro-natural landscapes. *Ecological Applications* 22:1535–46.

Michener, C. D. 2007. *The Bees of the World*, 2nd edition. 992 pp. Baltimore: Johns Hopkins University Press.

Potts, S. G., B. Vulliamy, A. Dafni, G. Ne'eman, and P. Willmer. 2003. Linking bees and flowers: How do floral communities structure pollinator communities? *Ecology* 84(10):2628–2642.

Rundlöf, M., A. S. Persson, H. G. Smith, and R. Bommarco. 2014. Late-season mass-flowering red clover increases bumble bee queen and male densities. *Biological Conservation* 172:138–45.

Vazquez, D. P., and M. A. Aizen. 2003. Null model analyses of specialization in plant-pollinator interactions. *Ecology* 84:2493–2501.

Williams, N. M., and C. Kremen. 2007. Resource distributions among habitats determine solitary bee offspring production in a mosaic landscape. *Ecological Applications* 17(3):910–921.

Williams, N. M., R. L. Minckley, and F.A. Silveira. 2001. Variation in native bee faunas and its implications for detecting community changes. *Conservation Ecology* 5(1): 7. (Online at https://www.ecologyandsociety.org/vol5/iss1/art7/)

Williams, N. M., K. L. Ward, N. Pope, R. Isaacs, J. Wilson, E. A. May, J. Ellis, J. Daniels, A. Pence, K. Ullmann, and J. Peters. 2015. Native wildflower plantings support wild bee abundance and diversity in agricultural landscapes across the United States. *Ecological Applications* 25(8):2119–2131.

Standard 1.2.b

b. *Permanent pollinator habitat must contain a significant proportion of native, pollinator-attractive plants.*
    i. *For new permanent habitat, at least 70% of the vegetation established must be native to the region and acquired from local sources.*
    ii. *In natural or mature created permanent habitats, at least 35% of the species must be native.*

Rationale
Habitat dominated by native plants can provide critical resources habitat for bees. Although wild bees will visit nonnative plants—including crops—they are increasingly shown to prefer native species (Williams et al. 2011; Chrobock et al. 2013; Morandin and Kremen 2013; Ritchie et al. 2016). Native plant species provide some of the essential proteins and amino acids required by developing bees (Harmon-Threatt and Kremen 2015).Once established, native plants typically re-seed well, which can reduce long-term habitat costs (Isaacs et al. 2009).

Native plants are defined as species that are indigenous—occur naturally without human intervention—to a region.

Forms
Plant Materials Sourcing Record (form BBC_2017-b)

Resources
USDA PLANTS database: https://plants.usda.gov/java/

Lists of regional native plant nursery and seed companies can be found at the Xerces Society Pollinator Conservation Resource Center: http://www.xerces.org/pollinator-resource-center/

Vaughan, M., J. Hopwood, E. Lee-Mader, M. Shepherd, C. Kremen, A. Stine, and S. Black. 2015. *Farming for Bees*. Portland, OR: The Xerces Society for Invertebrate Conservation.

Seed zone maps for native plants: Bower, A., J. B. St. Clair, and V. Erickson. 2014. Generalized provisional seed zones for native plants. *Ecological Applications* 23:913–919.

References
Chrobock, T., P. Winiger, M. Fischer, and M. van Kleunen. 2013. The cobblers stick to their lasts: pollinators prefer native over alien plant species in a multi-species experiment. *Biological Invasions* 15:2577–2588.

Harmon-Threatt, A.N. and C. Kremen. 2015. Bumble bees selectively use native and exotic species to maintain nutritional intake across highly variable and invaded local floral resource pools. *Ecological Entomology* 40:471–478.

Isaacs, R., J. Tuell, A. Fiedler, M. Gardiner, and D. Landis. 2009. Maximizing arthropod-mediated ecosystem services in agricultural landscapes: the role of native plants. *Frontiers in Ecology and the Environment* 7:196–203.

Morandin, L. A., and C. Kremen. 2013. Bee preference for native versus exotic plants in restored agricultural hedgerows. *Restoration Ecology* 21(1):26–32.

Ritchie, A. D., R. Ruppel, and S. Jha. 2016. Generalist behavior describes pollen foraging for perceived oligolectic and polylectic bees. *Environmental Entomology* 45(4):909–919.

Williams, N. M., D. Cariveau, R. Winfree, and C. Kremen. 2011. Bees in disturbed habitats use, but do not prefer, alien plants. *Basic and Applied Ecology* 12(4):332–341.

Standard 1.2.c

c. The combined vegetative cover of the plant species in bloom should be classified "abundant" or "common" in each season
    i. Abundance Categories:

        Abundant: Numerous individuals of the flowering species are present (51–100% cover).

        Common: Several individuals of the flowering species are present (11–50% cover).

        Sparse: Only a few individuals of the flowering species are present (1–10% cover).

        Absent: No flowering species are present (0% cover).

Rationale

On farms, habitat patches with more flowers attract and support more abundant and diverse communities of bees, which can result in higher crop yields (Blaauw and Isaacs 2014; Williams et al. 2015; M'Gonigle et al. 2015; Motzke et al. 2016). Furthermore, because bee larvae require pollen and nectar, abundant floral resources are important for long-term persistence of bee populations, with the floral resource abundance in one year influencing the native bee abundance of the subsequent year (Potts et al. 2003; Roulston and Goodell 2011). Maintaining sufficient floral cover is one way to ensure adequate abundance of floral resources. In one study, the highest increases in crop yield were associated with 50% floral cover in adjacent pollinator habitat and a high proportion of natural habitat in the surrounding landscape (Motzke et al. 2016).

Forms
NA

Resources
Appendix D: Identifying Native Bee Nests (in Bee Better Certified Production Standards).

Regional Habitat Installation Guides: http://www.xerces.org/pollinator-conservation/agriculture/pollinator-habitat-installation-guides/

Vaughan, M., J. Hopwood, E. Lee-Mader, M. Shepherd, C. Kremen, A. Stine, and S. Black. 2015. *Farming for Bees*. Portland, OR: The Xerces Society for Invertebrate Conservation.

References
Blaauw, B. R., and R. Isaacs. 2014. Flower plantings increase wild bee abundance and the pollination services provided to a pollination-dependent crop. *Journal of Applied Ecology* 51(4):890–898.

M'Gonigle, L. K., L. C. Ponisio, K. Cutler, and C. Kremen. 2015. Habitat restoration promotes pollinator persistence and colonization in intensively managed agriculture. *Ecological Applications* 25(6):1557–1565.

Motzke, I., A.-M. Klein, S. Saleh, T. C. Wanger, and T. Tscharntke. 2016. Habitat management on multiple spatial scales can enhance bee pollination and crop yield in tropical homegardens. *Agriculture, Ecosystems and Environment* 223:144–151.

Potts, S. G., B. Vulliamy, A. Dafni, G. Ne'eman, and P. Willmer. 2003. Linking bees and flowers: how do floral communities structure pollinator communities? *Ecology* 84(10):2628–2642.

Roulston, T. H., and K. Goodell. 2011. The role of resources and risks in regulating wild bee populations. *Annual Review of Entomology* 56:293–312.

Williams, N. M., K. L. Ward, N. Pope, R. Isaacs, J. Wilson, E. A. May, J. Ellis, J. Daniels, A. Pence, K. Ullmann, and J. Peters. 2015. Native wildflower plantings support wild bee abundance and diversity in agricultural landscapes across the United States. *Ecological Applications* 25(8):2119–2131.

1.3 Sourcing Plants and Seed

Standard 1.3.a

a. *Plant materials for new permanent pollinator habitat should be obtained from ecologically appropriate sources.*
    i. *Source plant materials from within 150 miles of your property; if no plant sources are available with this radius, document which suppliers you contacted and expand the radius to 300 miles.*
        1. *Contact at least 3 suppliers within 150 miles of your property, if that many are present within that radius.*
    ii. *If ecologically appropriate plant materials are available from sources outside the noted radii, provide documentation that they were collected from a similar climatic or ecological region to the one present on your property.*
    iii. *Document the native status of all plants purchased. Native plant materials are always preferred to nonnative seed and, when available, should be prioritized.*

Rationale

Research suggests that many native plant populations establish, grow, and reproduce best in environments where they are adapted to local conditions (Leimu and Fischer 2008). Using regionally sourced plant material increases the likelihood that plants will be adapted to your farm's environment (Johnson et al. 2010). Some native plants exhibit a wide range of adaptation while others have a narrow range of adaptation. The best current recommendation is to source regionally available native plants—as opposed to bringing in seed from external sources—to help ensure that the plants are suited to local conditions, which can help with both establishment and persistence.

Advice for Selecting Plant Materials

Search for native plant nurseries within 150 miles of your property. When you contact them, ask them where they collect their seed/cuttings from. Do they separate out plants from different watersheds or microclimates? If so, then select plants that were collected from an area near the project site or one that has similar conditions. If no local nurseries have the desired plant materials in stock, consider contracting with a nursery that will collect seeds from specific locations within your target region. When purchasing seed, ask whether they supply pure live seed (PLS). PLS is a measure of the quantity of the seed that will germinate; thus higher is better. Consider whether or not conducting current seed test should be done on each seed lot to verify viability and germinability.

Resources

NA

Forms
Plant Materials Sourcing Record (form BBC_2017-b)

Resources
USDA PLANTS database: https://plants.usda.gov/java/

Lists of regional native plant nursery and seed companies can be found at the Xerces Society Pollinator Conservation Resource Center: http://www.xerces.org/pollinator-resource-center/

Seed zone maps for native plants: Bower, A., J. B. St. Clair, and V. Erickson. 2014. Generalized provisional seed zones for native plants. *Ecological Applications* 23:913–919.

References
Johnson, R., L. Stritch, P. Olwell, S. Lambert, M. Horning, and R. Cronn. 2010. What are the best seed sources for ecosystem restoration on BLM and USFS lands? *Native Plants Journal* 11:117–131.

Leimu, R., and M. Fischer. 2008. A meta-analysis of local adaptation in plants. *PLoS One* 3:1–8.

1.4 Nesting Features

Standard 1.4.a

a. *Pollinator nesting sites must be identified and protected.*
    i. *Known nesting areas outside crop fields must be left undisturbed.*
    ii. *Identified nesting areas must be marked on a map and, if necessary, physically flagged to identify them to farm workers.*
    iii. *Employees must be trained in the location and protection of nest sites.*

Rationale
Wild bees have a diverse range of nesting habits. Most solitary bees excavate nests in the ground while others utilize pithy-stemmed plants or dead wood as nesting sites (Michener 2007). Ground-nesting bees utilize a variety of different soil types, though soils with high clay content are less favored (Cane 1991). Piles of wood can support twig-nesting native bees if they contain remnants of pithy-stemmed plants. Some species of sweat bee (e.g., *Augochlora*) burrow into rotting logs (Stockhammer 1966) while carpenter bees chew nests into dead wood. Bumble bees, on the other hand, often nest in cavities, such as abandoned rodent burrows (Kells and Goulson 2003) or

spaces created native bunch grasses when they reach maturity (Svensson et al. 2000).

Wild bees nest in a variety of locations on and around farms, including natural areas (Potts et al. 2005), field margins (Sardiñas et al. 2016a), habitat areas (May et al., in review), and within crop fields (Sardiñas et al. 2016b). Thus, care must be taken throughout the farm to preserve nesting habitat. If nests are discovered, they should be marked, identified to farm workers, and protected over time. Avoid disturbing nest sites (Winfree et al. 2009; Williams et al. 2010). Disturbance includes cultivation or other management that alters the soil profile or disrupts plants and wood that supports above-ground nesting bees.

Forms
NA

Resources
Learn more about native bee biology here: http://www.xerces.org/pollinator-conservation/native-bees/

Appendix D: Identifying Native Bee Nests (in Bee Better Certified Production Standards).

Vaughan, M., J. Hopwood, E. Lee-Mader, M. Shepherd, C. Kremen, A. Stine, and S. Black. 2015. *Farming for Bees*. Portland, OR: The Xerces Society for Invertebrate Conservation.

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Cane, J. H. 1991. Soils of ground-nesting bees (Hymenoptera: Apoidea): texture, moisture, cell depth and climate. *Journal of the Kansas Entomological Society* 64(4):406-413.

Kells, A. R., and D. Goulson. 2003. Preferred nesting sites of bumblebee queens (Hymenoptera: Apidae) in agroecosystems. *Biological Conservation* 109:164–174.

Michener, C. D. 2007. *The Bees of the World*, 2nd edition. 992 pp. Baltimore: Johns Hopkins University Press.

Sardiñas, H. S., L. C. Ponisio, and C. Kremen. 2016a. Hedgerow presence does not enhance indicators of nest-site habitat quality or nesting rates of ground-nesting bees. *Restoration Ecology* 24(4):499–505.

Sardiñas, H. S., K. Tom, L. C. Ponisio, A. Rominger, and C. Kremen. 2016b. Sunflower (*Helianthus annuus*) pollination in California's Central Valley is limited by native bee nest site location. *Ecological Applications* 26(2):438–447.

Stockhammer, K. A. 1966. Nesting habits and life cycle of a sweat bee, *Augochlo-*

ra pura (Hymenoptera: Halictidae). *Journal of the Kansas Entomological Society* 39(2):157–192.

Svensson, B., Jan. Lagerlöf, and B. G. Svensson. 2000. Habitat preferences of nest-seeking bumble bees (Hymenoptera: Apidae) in an agricultural landscape. *Agriculture, Ecosystems and Environment* 77:247–255.

Williams, N. M., E. E. Crone, H. R. T'ai, R. L. Minckley, L. Packer, and S. G. Potts. 2010. Ecological and life-history traits predict bee species responses to environmental disturbances. *Biological Conservation* 143(10):2280–2291.

Winfree, R., R. Aguilar, D. P. Vázquez, G. LeBuhn, and M. A. Aizen. 2009. A meta-analysis of bees' responses to anthropogenic disturbance. *Ecology* 90(8):2068–2076.

Standard 1.4.b

b. *At least 5% of new permanent pollinator habitat plantings must be comprised of pithy-stemmed plants, plants that are used for nest cell materials, and butterfly host plants; some of each category must be included.*

Rationale

Above-ground nesting bees comprise approximately 30% of all bee species. Above-ground nesters include leaf-cutters (Megachile sp.) and mason bees (Osmia sp.). They are important pollinators of a variety of crops including alfalfa (Cane 2002), almond (Brittain et al. 2013) and blueberry (Sampson and Cane 2000). Above-ground nesters create their nests in pre-existing cavities in pithy-stemmed plants or dead wood (Potts et al. 2003; Potts et al. 2005; Grundel et al. 2010), using mud, leaves or flower petals to create divisions between the chambers where they lay their offspring (Cane et al. 2007). Sometimes nesting sites and/or materials used to construct nests are not adjacent to flowering plants (Westrich 1996). Bee Better Certified aims to support bee reproduction by providing access to plant species used for nesting in addition to plants that provide floral resources.

While not excellent crop pollinators (Sahli and Conner 2007), butterflies are important pollinators in natural systems and key parts of natural communities. They can benefit from habitat created for bees, but many of them have special relationships with host plants—specific plants on which they lay their eggs and that their offspring (caterpillars) must eat. (A well-known example is the monarch's reliance on milkweeds.) To support these beautiful invertebrates, we ask farmers to include some butterfly host plants in their pollinator habitat. Host plants range from native bunch grasses, to flowers attractive to bees, to woody species including many trees (see Resources below).

Forms

NA

Resources
Appendix E: Pithy-Stemmed Plants that Above-Ground Nesting Bees Use for Nest Sites (in Bee Better Certified Production Standards).

Appendix F: Plants that Above-Ground Nesting Bees Use as Nesting Materials to Create Cell Divisions (in Production Standards for Bee Better Certified).

Black, S. H., B. Borders, C. Fallon, E. Lee-Mäder, and M. Shepherd. 2016. *Gardening for Butterflies: How You Can Attract and Protect Beautiful, Beneficial Insects*. 288 pp. Portland, OR: Timber Press.

NWF's Native Plant Finder, which provides lists of native plants that are host plants for butterflies and moths (can be filtered by zip code): http://www.nwf.org/NativePlantFinder/About

Butterflies and Moths of North America (BAMONA), which provides host plant information for specific species: http://www.butterfliesandmoths.org/. You can also get regional lists of butterfly species based on your county/location.

BAMONA host plant database through the Lady Bird Johnson Wildflower Center: http://www.wildflower.org/collections/collection.php?collection=bamona

References
Brittain, C., N. Williams, C. Kremen, and A.-M. Klein. 2013. Synergistic effects of non-*Apis* bees and honey bees for pollination services. *Proceedings of the Royal Society of London B: Biological Sciences* 280(1754):20122767.

Cane, J. H. 2002. Pollinating bees (Hymenoptera: Apiformes) of US alfalfa compared for rates of pod and seed set. *Journal of Economic Entomology* 95(1):22–27.

Cane, J.H., T. Griswold, and F.D. Parker. 2007. Substrates and materials used for nesting by North American *Osmia* bees (Hymenoptera: Apiformes: Megachilidae). *Annals of the Entomological Society of America* 100(3):350–358.

Grundel, R., R. P. Jean, K. J. Frohnapple, G. A. Glowacki, P. E. Scott, and N. B Palovic. 2010. Floral and nesting resources, habitat structure, and fire influence bee distribution across an open-forest gradient. *Ecological Applications* 20(6):1678–1692.

Potts, S. G., B. Vulliamy, A. Dafni, G. Ne'eman, and P. Willmer. 2003. Linking bees and flowers: how do floral communities structure pollinator communities? *Ecology* 84(10):2628–2642.

Potts, S. G., B. Vulliamy, S. Roberts, C. O'Toole, A. Dafni, G. Ne'eman, and P. Willmer. 2005. Role of nesting resources in organising diverse bee communities in a Mediterranean landscape. *Ecological Entomology* 30(1):78–85.

Sahli, H. F., and J. K. Conner. 2007. Visitation, effectiveness, and efficiency of 15 genera of visitors to wild radish, *Raphanus raphanistrum* (Brassicaceae). *American Journal of Botany* 94(2):203–209.

Sampson, B. J., and J. H. Cane. 2000. Pollination efficiencies of three bee (Hymenoptera: Apoidea) species visiting rabbiteye blueberry. *Journal of Economic Entomology* 93(6):1726–1731.

Westrich, P. 1996. Habitat requirements of central European bees and the problems of partial habitats. In *The Conservation of Bees*, edited by A. Matheson, S. L. Buchmann, C. O'Toole, P. Westrich, and I. H. Williams, 1–16. London: Academic Press Limited.

1.5 Tillage

Standard 1.5.a

a. *Develop a standard operating procedure (SOP) for how to reduce the impact of tillage activities on ground-nesting bee nests located both within crop fields and in non-crop areas.*
   i. *The SOP should demonstrate that existing tillage practices are low risk or that new practices reduce the risk of disturbance to ground-nesting bees.*
   ii. *The SOP should encompass at least one-third of the total certified acreage each year.*
   iii. *The SOP must address at least two of the following:*
      1. *Tillage depth*
      2. *Timing of tillage*
      3. *Frequency of tillage*
      4. *Equipment type*
      5. *Location of tillage*

Rationale
Ground-nesting bees spend the majority of their lives in underground nests - developing from an egg stage into and adult. Their nests are distributed throughout farms, including in both cropped and non-cropped areas (Kim et al. 2007; Sardiñas et al. 2016). Disturbance can negatively impact nesting (Williams et al. 2010), which is why we recommend minimizing soil disturbance to the largest extent possible within and around crop fields. Maintaining undisturbed areas each year may be able to help create reservoirs of nesting populations that can repopulate disturbed areas.

The location of brood chambers, cells in bee nests that contain offspring, range from the top few inches of soil to several feet underground depending on the species (Michener et al. 1958; Parker et al. 1981; Cane 1991). Although nest cells can be located in the first 4” of soil, the majority of them are found deeper (e.g., Michener et al. 1958). Tillage can disrupt the underground chambers of ground-nesting bees, destroying offspring and subsequently reducing the population of bees emerging the following year (Schuler et al. 2005; Ullmann et al. 2016). How much soil is disturbed when tilling depends on both the tillage implement and soil conditions (Keller and Arvidson 2009). Certain implements can disrupt soil more than other types and disrupt ground-dwelling insects to die. For example, weed seed-eating ground beetles were less active in fields tilled with mold-board ploughs and using rotary tillage than in fields where chisel ploughs were used (Shearin 2007).

Examples of each SOP category

Tillage depth: No till or reduced tillage depth—ideally no deeper than 4”— following planting fruit, nut, vegetable or herb crops or fallow fields.

Timing of tillage: In half of the fields, tillage will only occur during time periods when bees are actively building nests in the spring and summer (not during time periods when bees are developing in their nests and unable to create new nests).

Frequency of tillage: Crop fields containing fruit, nut, vegetable or herb crops known to be attractive to bees will only be tilled 1 - 2 times per year for the year following planting.

Location of tillage: Some fields or strips within fields left untilled each year and 50% of field edges are managed through mowing instead of tilling.

Proportion of farm tilled: At least 1% of farm (field and/or edges) left untilled every year.

Equipment type: Less disruptive tillage implements will be chosen (e.g. will use chisel ploughs instead of mold board ploughs).

Sample prescriptions for Bee Better compliance

For row crop:

1. Crop fields containing crops known to be attractive to bees will only be disked at 4” depth 1 -2 x per year for the year following planting. Fallow fields will be mowed instead of tilled.
2. Field edges will be mowed instead of cultivated.

For perennial crop:

1. Every other alley between rows will be scraped annually instead of tilled.
2. Will use chemical fallow instead of disking to control weeds in field edges.

If already using no-till system:

1. No till will continue to be practiced throughout the farm.

Recommendations

We recommend limiting tillage to the surface and using equipment that minimizes disturbance whenever possible.

If weed control is a concern (and weeds are usually controlled with cultivation), try other options that reduce disturbance. You can use a roll crimper, flamer or mulching to target problem areas or combat specific weedy species. Repeated mowing is also an option that decreases soil disturbance. The NRCS Organic Farming Handbook provides additional guidance on non-chemical, no-till weed management techniques: www/nrcs.usda.gov/organic

Forms

NA

References

Cane, J. H. 1991. Soils of ground-nesting bees (Hymenoptera: Apoidea): texture, moisture, cell depth and climate. *Journal of the Kansas Entomological Society* 64(4):406–413.

Keller, T., and J. Arvidsson. 2010. Soil disturbance and soil fragmentation during tillage. Chapter 4 in *Soil Engineering, Soil Biology 20*, edited by A. P. Dedousis and T. Bartzanas, 51–66. Heidelberg: Springer-Verlag.

Kim, J., N. Williams, and C. Kremen. 2006. Effects of cultivation and proximity to natural habitat on ground-nesting native bees in California sunflower fields. *Journal of the Kansas Entomological Society* 79(4):309–320.

Michener, C. D., R. B. Lange, J. J. Bigarella, and R. Salamuni. 1958. Factors influencing the distribution of bees' nests in earth banks. *Ecology* 39(2):207–217.

Parker, F. D., V. J. Tepedino, and G. E. Bohart. 1981. Notes on the biology of a common sunflower bee, *Melissodes* (*Eumelissodes*) *agilis* Cresson. *Journal of the New York Entomological Society* 89(1):43–52.

Sardiñas, H. S., K. Tom, L. C. Ponisio, A. Rominger, and C. Kremen. 2016. Sunflower (*Helianthus annuus*) pollination in California's Central Valley is limited by native bee nest site location. *Ecological Applications* 26(2):438–447.

Schuler, R. E., T. H. Roulston, and G. E. Farris. 2005. Farming practices influence wild pollinator populations on squash and pumpkin. *Journal of Economic Entomology* 98(3):790–795.

Shearin, A. F., S. C. Reberg-Horton, and E. R. Gallandt. 2007. Direct effects of tillage on the activity density of ground beetle (Coleoptera: Carabidae) weed seed predators. *Environmental Entomology* 36(5):1140–1146.

Ullmann, K. S., M. H. Meisner, and N. M. Williams. 2016. Impact of tillage on the crop pollinating, ground-nesting bee, *Peponapis pruinosa* in California. *Agriculture, Ecosystems & Environment* 232:240–246.

Williams, N. M., E. E. Crone, H. R. T'ai, R. L. Minckley, L. Packer, and S. G. Potts. 2010. Ecological and life-history traits predict bee species responses to environmental disturbances. *Biological Conservation* 143(10):2280–2291.

2 Pesticide Mitigation

2.1 Preventive Non-Pesticide Management

Standard 2.1.a

a. *Develop a written pest/disease scouting and monitoring protocol and demonstrate that scouting and monitoring occurs.*

For more information see Appendix I: Pest Scouting and Monitoring Guidance, in Bee Better Certified Production Standards.

Rationale
Scouting and monitoring for crop pests and diseases is critical for decision making in integrated pest management (IPM) (Matthews 1996; Radcliffe et al. 2009). The information obtained from scouting and monitoring can help outline if and/or when additional pest management actions such as pesticide use may be appropriate for a given pest population. Creating a written pest scouting and monitoring protocol for a particular farm and its pest issues ensures that the most appropriate and practical monitoring plan is implemented.

Forms
NA

Resources
Appendix I: Pest Scouting and Monitoring Guidance (in Bee Better Certified Production Standards)

Integrated Pest Management Scouting in Field Crops (Extension Bulletin E3294). 3 pp. East Lansing: Michigan State University Extension. Available at http://msue.anr.msu.edu/uploads/resources/pdfs/Pest_Scouting_in_Field_Crops.pdf

Integrated Pest Management Scouting in Vegetable Crops (Extension Bulletin E3293). 3 pp. East Lansing: Michigan State University Extension. Available at http://msue.anr.msu.edu/uploads/resources/pdfs/Pest_Scouting_in_Vegetables.pdf

Hodgson, E., A. Sisson, D. Mueller, L. Jesse, E. Saalau-Rojas, and A. Duster. 2012. *Field Crop Insects*. 74 pp. Ames: Iowa State University Extension and Outreach.

IPM—Scouting and Monitoring for Pests in Commercial Greenhouses (HLA-6711). 8

pp. Stillwater: Oklahoma State University Extension Service. Available at http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-1281/HLA-6711web.pdf

Overview of Monitoring and Identification Techniques for Insect Pests (Clemson University). Available from eXtension.org; online at http://articles.extension.org/pages/19198/overview-of-monitoring-and-identification-techniques-for-insect-pests

University of California Integrated Pest Management Program. http://ipm.ucanr.edu/index.html

"2013 Crop Scouting Manual". 262 pp. Lancaster: University of Wisconsin – Extension. Available at http://ipcm.wisc.edu/download/pubsPM/UW-IPM-ScoutingManual-web.pdf

References

Matthews, G. A. 1996. The importance of scouting in cotton IPM. *Crop Protection* 15(4):369–374.

Radcliffe, E. B., W. D. Hutchison, and R. E. Cancelado, eds. 2009. *Integrated Pest Management: Concepts, Tactics, Strategies and Case Studies*. 529 pp. Cambridge: Cambridge University Press.

Standard 2.1.b

b. *Implement and maintain at least 2 preventive non-pesticide pest management strategies.*
    i. *Select strategies from the Bee Better Certified non-pesticide management strategies list.*

Rationale

Maintaining pest monitoring and scouting records allows for confirmation of pest occurrence as well as documentation of pest abundance on a farm (Radcliffe et al. 2009). Under IPM, pesticides should only be used when a pest population is great enough to cause significant economic damage to the crop. Economic thresholds have been developed for some pests and diseases to assist with pest management decisions. For crops where no threshold exists, expert opinion (e.g., extension agents, crop advisors) can help make these determinations. Maintaining documented pest information can be used for justifying use of a pesticide, which is required by Bee Better Certified. Such records can also be valuable for evaluating effectiveness of management practices over time.

Forms

There are no specified forms for keeping these records. See Appendix I: Pest Scouting and Monitoring Guidance, in Bee Better Certified Production Standards for examples of suitable forms. You may also create your own recording forms as long as they collect the same information listed in the example forms in Appendix I.

Resources
"Forms – Pest Monitoring Record-Keeping" at University of Massachusetts Extension. https://ag.umass.edu/fact-sheets/forms-pest-monitoring-record-keeping

Appendix I: Pest Scouting and Monitoring Guidance (in Bee Better Certified Production Standards)

References:
Radcliffe, E. B., W. D. Hutchison, and R. E. Cancelado, eds. 2009. *Integrated Pest Management: Concepts, Tactics, Strategies and Case Studies*. 529 pp. Cambridge: Cambridge University Press.

2.2 Pesticide Application

Standard 2.2.a

a. There must be no unjustified use of pesticides.

i. A justified use must be supported by evidence that a severe pest or disease outbreak exists or has strong potential to exist.

ii. Farm-specific scouting and monitoring records can be used to demonstrate an outbreak. Additional documentation (e.g., extension publications, newspaper articles) that supports the severity of the issue may also be submitted.

iii. Documentation should provide evidence that an economic threshold has been exceeded. If no threshold is available, provide an expert opinion. Experts may include a certified pest control adviser, accredited crop consultant, extension agent, or other credentialed independent pest management specialist. Advice or recommendations from pesticide or seed company representatives is not considered sufficient evidence to justify pesticide use.

iv. Even if use is shown to be justified, growers must follow all other Bee Better Certified pesticide mitigation standards.

Rationale
Exposure of pollinators to pesticides can cause lethal or sub-lethal effects, both of which can cause population level declines of pollinator species. Exposure should be avoided or minimized whenever possible. One way to reduce exposure is to limit pesticide applications to times when they are absolutely necessary. Bee Better Certified

asks growers to only apply pesticides in direct response to a pest or disease outbreak, what is termed a "justified use." An unjustified pesticide use is the application of a pesticide without evidence that a severe pest or disease outbreak exists or has strong potential to exist. The unjustified use of pesticides has the potential to increase pest resistance and disrupt predator–prey relationships between natural enemies and crop pests leading to secondary outbreaks (Douglas and Tooker 2015; Douglas and Tooker 2016). Unjustified use is also contrary to long-established principles of integrated pest management, which help to reduce pesticide overall use. In addition, low pesticide use is associated with high productivity and profitability, which can benefit farmers who limit pesticide applications (Lechenet et al. 2017).

Forms
NA

Resources
NA

References

Douglas, M. R., and J. F. Tooker. 2015. Large-scale deployment of seed treatments has driven rapid increase in use of neonicotinoid insecticides and preemptive pest management in U.S. field crops. *Environmental Science and Technology* 49:5088–5097.

Douglas, M. R., and J. F. Tooker. 2016. Meta-analysis reveals that seed-applied neonicotinoids and pyrethroids have similar negative effects on abundance of arthropod natural enemies. *PeerJ* 4:e2776; doi:1.7717/peerj.2776

Lechenet, M., F. Dessaint G. Py, D. Makowski and N. Munier-Jolain. 2017. Reducing pesticide use while preserving crop productivity and profitability on arable farms. *Nature Plants* 3:17008. doi:10.1038/nplants.2017.8

Standard 2.2.b

b. *Do not apply any pesticides classified by the U.S. Environmental Protection agency (EPA) as highly toxic or moderately toxic to bees during bloom for crops that are visited by or pollinated by insects.*

Rationale
Wild bees are key pollinators of a number of different crops (Garibaldi et al. 2013). While they can be exposed to pesticides throughout the landscape, they experience their highest risk of exposure during visits to blooming crops as they collect pollen and nectar to provision their nests (Brittain and Potts 2010). Eliminating applications of pesticides classified by the EPA as moderately to highly toxic to bees during bloom

can greatly reduce bee mortality as well as other sublethal effects that arise from pesticide exposure (e.g., suppressed reproduction, inability to navigate).

Bloom is defined as the time period from when first blooms open until petal drop or closure of all blooms (e.g., squash blossoms are open for a single day, but spent flowers can remain attached for a long period after they cease to be viable). See Appendix M of the Bee Better Certified Production Standards for a list of exempt crops—crops that are not visited by insects and crops that do not bloom (e.g., leafy greens not grown for seed production).

Forms
NA

Resources
Environmental Protection Agency Protecting Bees and Other Pollinators from Pesticides: https://www.epa.gov/pollinator-protection

Environmental Protection Agency Proposal to Protect Bees from Acutely Toxic Pesticides: https://www.epa.gov/pollinator-protection/proposal-protect-bees-acutely-toxic-pesticides

University of California IPM Bee Precaution Pesticide Rating: http://www2.ipm.ucanr.edu/beeprecaution/

Johansen, E., L. A. Hooven, and R. R. Sagili. 2013. *How to Reduce Bee Poisoning from Pesticides*. Corvallis, OR: Oregon State University Extension Service. Available at https://catalog.extension.oregonstate.edu/pnw591 (accessed 4/10/17).

References
Brittain, C., and S. G. Potts. 2010. The potential impacts of insecticides on the life-history traits of bees and the consequences for pollination. *Basic and Applied Ecology* 12:321–331.

Garibaldi, L. A., I. Steffan-Dewenter, R. Winfree, M. A. Aizen, R. Bommarco, S. A. Cunningham, C. Kremen et al. 2013. Wild pollinators enhance fruit set of crops regardless of honey bee abundance. *Science* 339(6127):1608–1611

Standard 2.2.c

c. *Do not make foliar applications of certain DeMethylation Inhibitor (DMI), multi-site contact activity, or carboxamide fungicides during bloom for crops that are visited by or pollinated by insects.*

Rationale
Although commonly considered low toxicity to pollinators (and classified by EPA as practically non-toxic) research indicates that some fungicides pose a threat to bees. One study found that after exposure to the multi-site contact activity fungicide chlorothalonil bumble bee colonies produced fewer workers and had smaller queens (Bernauer et al 2015). Another study found that as fungicide use increased, native bee abundance and richness declined, even when applications occurred outside bloom time (Park et al 2015). Fortunately, an increasing proportion of pollinator habitat did buffer the fungicide effects (Park et al 2015). Furthermore, new research shows that Ergosterol-inhibiting fungicides (such as DMI fungicides) significantly contribute to the spread and abundance of honey bee pathogens and parasites (Sanchez-Bayo et al 2016). DMI and multi-site contact activity fungicides have also been detected at elevated rates in colonies that died during the summer (Traynor et al 2016). DMI fungicides may also block bee's natural detoxification route, increasing the toxicity of some insecticides (Biddinger et al 2013, Iwasa et al 2004, Pilling et al 1993, Piling et al 1995, Schmuck et al 2003). To protect bees from these chemicals, we require that Bee Better certified growers cease foliar applications during the crop bloom period.

Forms
NA

Resources
NA

References
Bernauer, O., H. Gaines-Day, and S. Steffan. 2015. Colonies of bumble bees (*Bombus impatiens*) produce fewer workers, less bee biomass, and have smaller mother queens following fungicide exposure. *Insects* 6(2):478–488. doi:10.3390/insects6020478

Biddinger, D. J., J. L. Robertson, C. Mullin, J. Frazier, S. A. Ashcraft, E. G. Rajotte, N. K. Joshi, and M. Vaughan. 2013. Comparative toxicities and synergism of apple orchard pesticides to *Apis mellifera* (L.) and *Osmia cornifrons* (Radoszkowski). *PLoS One* 8(9):e72587.

Iwasa, T., N. Motoyama, J. T. Ambrose, and R. M. Roe. 2004. Mechanism for the differential toxicity of neonicotinoid insecticides in the honey bee, *Apis mellifera*. *Crop Protection* 23:371–378.

Park, M. G., E. J. Blitzer, J. Gibbs J. E. Losey, and B. N. Danforth. 2015. Negative effects of pesticides on wild bee communities can be buffered by landscape context. *Proceedings of the Royal Society of London B: Biological Sciences* 282:20150299.

Pilling, E. D., K. A. C. Bromley-Challenor, C. H. Walker, and P. C. Jepson. 1995. Mechanism of synergism between the pyrethroid insecticide λ-cyhalothrin and the imidazole fungicide prochloraz, in the honeybee (*Apis mellifera* L.). *Pesticide Biochemistry and Physiology* 51:1–11.

Pilling, E. D., and P. C. Jepson. 1993. Synergism between EBI fungicides and a pyrethroid insecticide in the honeybee (*Apis mellifera*). *Pest Management Science* 39:293–297.

Sanchez-Bayo, F., D. Goulson, F. Pennacchio, F. Nazzi, K. Goka, and N. Desneux. 2016. Are bee diseases linked to pesticides?—A brief review. *Environment International* 89–90:7–11.

Schmuck, R., T. Stadler, and H.-W. Schmidt. 2003. Field relevance of a synergistic effect observed in the laboratory between an EBI fungicide and a chloronicotinyl insecticide in the honeybee (*Apis mellifera* L, Hymenoptera). *Pest Management Science* 59:279–286.

Traynor, K. S., J. S. Pettis, D. R. Tarpy, C. A. Mullin, J. L. Frazier, M. Frazier, and D. vanEngelsdorp. 2016. In-hive pesticide exposome: assessing risks to migratory honey bees from in-hive pesticide contamination in the Eastern United States. *Scientific Reports* 6:33207. doi:10.1038/srep33207.

Standard 2.2.d

d. Never apply within three days of one another pesticides that jointly may increase toxicity to bees.

  i. Use the online Bee Precaution pesticide rating tool from University of California Statewide Agricultural & Natural Resources Integrated Pest Management Program to determine if there is potential for a pesticide combination to increase toxicity.

Rationale

The Bee Precaution pesticide rating tool from the University of California Statewide Agricultural & Natural Resources Integrated Pest Management Program (see resources below for URL) is a very simple risk-assessment tool that evaluates potential risk of pesticides that are classified by the EPA as moderately and highly toxic to bees as well as other pesticides that have shown to be of concern for bees. Furthermore, the Bee Precaution tool provides information on whether pesticides applied in close temporal proximity (e.g., within a few days of each other or as tank mixes) could increase risk to bees beyond additive effects (synergies). Synergism is the interaction of two or more substances to produce a combined effect greater than the sum of their individual effects (Andersch et al. 2010). Scientific research as well as bee incident reports indicate that the mixture of some insecticide classes with certain fungicides can cause synergistic effects that increase the lethality of the substances to bees (Biddinger et al. 2013; Johnson et al. 2013; Ramoutar et al. 2010, Wachendoorff-Neumann et al. 2012). For example, mixing a pyrethroid or neonicotinoid insecticide and a DeMethylation Inhibitor (DMI) could increase toxicity to insects. Eliminating the combination of these chemicals reduces the likelihood of causing acute bee incidents due to pesticide combinations known to synergistically increase toxicity.

Use the online Bee Precaution pesticide rating tool (see resources below for URL) from University of California Statewide Agricultural & Natural Resources Integrated Pest Management Program to determine if there is potential for a pesticide combination to increase toxicity. Pesticides that are likely to increase toxicity when combined are identified by a code in the "other effects on bees" column.

Resources
To assess potential harm to bees from pesticides, including potential combined effects from pesticides go to The UC IPM Bee Precaution Pesticide Rating available at: http://www2.ipm.ucanr.edu/beeprecaution/

For guidance on how to use the Bee Precaution website, see Appendix N: Bee Precaution Use Instructions, in the Bee Better Certified Production Standards.

To access full lists of the insecticide chemical classes listed above see: http://www.irac-online.org/modes-of-action/

To get a full list of the DMI fungicides see: http://ipm.ifas.ufl.edu/resources/success_stories/T&PGuide/pdfs/Appendices/Appendix6-FRAC.pdf

References
Andersch, W. et al. 2010. "Synergistic insecticide mixtures." US Patent US 7,745,375 B2. Bayer CropScience AG.

Biddinger, D. J., J. L. Robertson, C. Mullin, J. Frazier, S. A. Ashcraft, E. G. Rajotte, N. K. Joshi, and M. Vaughan. 2013. Comparative toxicities and synergism of apple orchard pesticides to *Apis mellifera* (L.) and *Osmia cornifrons* (Radoszkowski). *PLoS One* 8(9):e72587.

Johnson, R. M., L. Dahlgren, B. D. Siegfried, and M. D. Ellis. 2013. Acaricide, Fungicide and Drug Interactions in Honey Bees (*Apis mellifera*). *PLoS One* 8:e54092.

Ramoutar, D., R. S. Cowles, E. Requintina, and S. R. Alm. 2010. Synergism between Demethylation Inhibitor fungicides or Gibberellin Inhibitor plant growth regulators and bifenthrin in a byrethroid-resistant population of *Listronotus maculicollis* (Coleoptera: Curculionidae). *Journal of Economic Entomology* 103(5):1810–1814.

Wachendoorff-Neumann, U. et al. 2012. "Synergistic mixture of trifloxystrobin and imidacloprid." Google patents United States Bayer CropScience AG.

Standard 2.2.e

e. *Do not use nitroguanidine neonicotinoids (clothianidin, dinotefuran, imidacloprid, and thiamethoxam).*
    i. *This ban includes the planting of treated seeds.*

Rationale
Nitroguanidine neonicotinoids are a high priority concern due to their systemic nature, persistence, high toxicity, and widespread use. Very small quantities of neonicotinoids can cause harm to invertebrates, including bees, and, because they are absorbed into the plant, neonicotinoids can be present in pollen and nectar, making the plants toxic to pollinators that feed on them. Furthermore, their persistence in plants and soil makes it possible for these chemicals to harm pollinators even when the initial application is made weeks to months before the bloom period.

Forms
NA

Resources
The literature review, How Neonicotinoids Can Kill Bees can be found at: http://www.xerces.org/pesticides/

The literature review, Beyond the Birds and the Bees, which looks at neonicotinoid impacts on beneficial insects can be found at: http://www.xerces.org/pesticides/

References
NOTE: There are dozens of studies outlining potential concerns that neonicotinoids pose to bees. A few example studies are listed below.

Bonmatin, J. M., I. Moineau, R. Charvet, M. E. Colin, C. Fleche, and E. R. Bengsch. 2005. Behaviour of imidacloprid in fields. Toxicity for honey bees. In *Environmental Chemistry, Green Chemistry and Pollutants in Ecosystems*, edited by E. Lichtfouse, J. Schwarzbauer, and D. Robert, 483–494. New York: Springer.

Laycock, I., K. C. Cotterell, T. A. O'Shea-Wheller, and J. E. Cresswell. 2014. Effects of the neonicotinoid pesticide thiamethoxam at field-realistic levels on microcolonies of *Bombus terrestris* worker bumble bees. *Ecotoxicology and Environmental Safety* 100:153–158.

Rundlöf, M., G. K. S. Andersson, R. Bommarco, I. Fries, V. Hederstrom, L. Herbertsson, O. Jonsson et al. 2015. Seed coating with a neonicotinoid insecticide negatively affects wild bees. *Nature* 521:77–80.

Stanley, D. A., M. P. Garratt, J. B. Wickens, V. J. Wickens, S. G. Potts, and N. E. Raine.

2015. Neonicotinoid pesticide exposure impairs crop pollination services provided by bumblebees. *Nature* 528:548–550.

Stanley, D. A., K. E. Smith, and N. E. Raine. 2015. Bumblebee learning and memory is impaired by chronic exposure to a neonicotinoid pesticide. *Scientific Reports* 5:16508. doi: 10.1038/srep16508.

Whitehorn, P. R., S. O'Connor, F. L. Wackers, and D. Goulson. 2012. Neonicotinoid pesticide reduces bumble bee colony growth and queen production. *Science* 336(6079):351–352.

Standard 2.2.f

f. *Do not use genetically modified crops that express pesticides or are resistant to herbicides.*

Rationale

Genetically modified (GM) crops that express pesticides or are resistant to herbicides can have direct and indirect effects on invertebrate populations, including beneficial insects, present within agricultural landscapes. While pesticide-expressing crops like corn are not insect pollinated, bees have been noted to collect corn pollen (Krupke et al. 2012). Other GM crops, such as cotton, benefit from cross-pollination and are attractive to pollinators (Cusser et al. 2016). While Bt Cry proteins have not been shown to directly negatively impact adult or larval honey bees (Duan et al. 2008), GM crops can alter bee foraging and abundance. Bees were shown to visit GM canola less frequently than organic or conventional canola (Morandin and Winston 2005).

Herbicide-resistant crops have helped spur a multifold increase in the application of herbicides in agricultural areas since their introduction (Benbrook 2012; Perry et al. 2016). This overuse can cause populations of noncrop plants, including flowering weeds, to plummet (Nicholls and Altieri 2013). The reduction in these weeds can indirectly impact nonpest insects by eradicating their host plants or altering the food web. An analysis of factors causing recent decline in monarch butterfly populations found that the dramatic reduction of milkweed host plants in the US caused by increasing use of genetically modified crops was the main factor precipitating the decline (Flockhart et al. 2015). Herbicide resistant crops can also aid in the development of herbicide-resistant weeds ("superweeds"; Schütte et al. 2017). These superweeds can invade adjacent natural habitats and becoming weeds on farms (e.g., glyphosate-resistant Palmer amaranth; Sosnoskie and Culpepper 2014). In Oregon, glyphosate-resistant creeping bentgrass, which was never commercially released, escaped into the wild (Reichman et al. 2006). Its spread poses a risk to the habitat of the endangered Fender's blue butterfly (USFWS, undated). Bee Better Certified asks farmers to eliminate use of genetically modified crops that express pesticides and are herbicide resistant because of the risk of unintended effects on insect populations and broader farm habitat.

Forms
NA

Resources
Pesticide National Synthesis Project: Estimated Annual Agricultural Pesticide Use, Glyphosate; available at https://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=2014&map=GLYPHOSATE&hilo=L

References
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Flockhart, D. T., J. B. Pichancourt, D. R. Norris, and T. G. Martin. 2015. Unravelling the annual cycle in a migratory animal: breeding-season habitat loss drives population declines of monarch butterflies. *Journal of Animal Ecology* 84:155–165

Krupke, C. H., G. J. Hunt, B. D. Eitzer, G. Andino, and K. Given. 2012. Multiple routes of pesticide exposure for honey bees living near agricultural fields. *PLoS One* 7(1):e29268.

Morandin, L. A., and M. L. Winston. 2005. Wild bee abundance and seed production in conventional, organic, and genetically modified canola. *Ecological Applications* 15(3):871–881.

Nicholls, C. I., and M. A. Altieri. 2013. Plant biodiversity enhances bees and other insect pollinators in agroecosystems. A review. *Agronomy for Sustainable Development* 33(2):257–274.

Perry, E. D., F. Ciliberto, D. A. Hennessy, and G. Moschini. 2016. Genetically engineered crops and pesticide use in US maize and soybeans. *Science Advances* 2(8):e1600850.

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Schütte, G., M. Eckerstorfer, V. Rastelli, W. Reichenbecher, S. Restrepo-Vassalli, M. Ruohonen-Lehto, A.-G. Wuest Saucy, and M. Mertens. 2017. Herbicide resistance and biodiversity: agronomic and environmental aspects of genetically modified herbicide-resistant plants. *Environmental Sciences Europe* 29(1):5. doi:10.1186/s12302-016-0100-y

Sosnoskie, L. M., and A. S. Culpepper. 2014. Glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) increases herbicide use, tillage, and hand-weeding in Georgia cotton. *Weed Science* 62(2):393–402.

USFWS (U.S. Fish and Willife Service. (Undated.) Letter (draft) from Gary Frazer, Assistant Director of Endangered Species Program, U.S. Fish and Wildlife Service(US FWS) to Michael Gregoire, Biotechnology Regulatory Services, Animal and Plant Health Inspection Services (APHIS). Available from http://www.centerforfoodsafety.org/files/fws-biop-on-rr-bentgrass-deregulation_received-via-foia_2011_49385.pdf

Standard 2.2.g

g. Do not use soil fumigants.

Rationale
Soil fumigants can be toxic to a broad spectrum of invertebrates and are active on most, if not all, life stages of insects. Furthermore, fumigants are designed to penetrate spaces where other types of pesticides don't reach. With approximately 70% of North America's native bees nesting in the ground, they are at risk of exposure to soil fumigants (Johansen et al. 2013). To avoid detrimental effects to beneficial ground-nesting invertebrates, including bees, do not fumigate soil.

Forms
NA

Resources
For information about soil fumigants currently registered in the U.S., go to: https://www.epa.gov/soil-fumigants/soil-fumigant-chemicals

References
Johansen, E., L. A. Hooven, and R. R. Sagili. 2013. *How to Reduce Bee Poisoning from Pesticides*. Corvallis, OR: Oregon State University Extension Service. Available at https://catalog.extension.oregonstate.edu/pnw591 (accessed 4/10/17).

2.3 Minimizing Off-Site Movement of Pesticides

Standard 2.3.a

a. *No aerial pesticide applications.*

Rationale
While any sprayed pesticide application can drift—even when applied under appropriate conditions following label instructions—aerial applications are more prone to overspraying (sprays that do not hit the targeted area). Furthermore, due to the spray release height, which is often higher than ground applications, pesticides applied aerially can drift further than ground applications. Despite appropriate application measures, overspray and misapplication can and do occur (e.g., Wood 1979). To reduce off-target spraying that could contaminate pollinator habitat, Bee Better Certified prohibits aerial application of pesticides.

Forms
NA

Resources
U.S. EPA Reducing Pesticide Drift: https://www.epa.gov/reducing-pesticide-drift

"Spray Drift Management." University of Nevada Cooperative Extension, https://www.unce.unr.edu/programs/sites/pesticide/files/pdf/DriftManagementNDOA.pdf

References
Wood, G. W. 1979. Recuperation of native bee populations in blueberry fields exposed to drift of fenitrothion from forest spray operations in New Brunswick. *Journal of Economic Entomology* 72(1):36–39.

Standard 2.3.b

b. *Calibrate application equipment according to manufacturer specifications at least on an annual basis.*

Rationale
Regular calibration of equipment ensures that the intended application rates are being achieved. Failure to keep equipment properly calibrated can result in over or under applications of pesticides. Over applications can increase the risk of runoff or drift, while under applications can reduce the effectiveness of the application.

Forms
NA

Resources
Wilson, J. 2006. Calibration of Pesticide Spraying Equipment. South Dakota State University, Cooperative Extension Service. http://sdda.sd.gov/legacydocs/Ag_Services/Agronomy_Services_Programs/Pesticide_Program/SDSU_spray_eqip_calib.pdf

U.S. EPA Reducing Pesticide Drift, https://www.epa.gov/reducing-pesticide-drift

Pesticide Environmental Stewardship, http://pesticidestewardship.org/drift/Pages/default.aspx

UC IPM Educational Programs, Pesticide Application Equipment and Calibration, http://ipm.ucanr.edu/training/incorporating-calibration.html/

References
NA

Standard 2.3.c

c. *Establish a pesticide-free buffer around permanent pollinator habitat.*
   i. *Spatial buffers should meet the following minimum widths:*
      1. *40 feet for ground-based applications, except airblast.*
      2. *60 feet for airblast applications.*
      3. *125 feet for seed treated with nitroguanidine neonicotinoids.*
   ii. *Vegetative buffers (drift fences) of species that are not attractive to pollinators may be used instead of spatial buffers, or if spatial buffer distances cannot meet the above requirements.*
      1. *Vegetative buffers should be comprised of densely planted, small-needled evergreen species.*
      2. *Airflow must be maintained within vegetative buffers.*
      3. *Vegetative buffers should be designed to grow above spray release height. Until the buffer is above spray release height any pesticide applications on your property must be in accordance with the drift and runoff precautions on the label in order to minimize potential for movement into permanent pollinator habitat.*
   iii. *Buffers are required within your own property, as well as between new permanent pollinator habitat on your property and neighboring farms or land where insecticides are known or suspected to be applied.*

1. *When insecticide application practices on neighboring properties change following permanent habitat creation on your parcels, spatial buffer requirements can be waived, although when feasible, we recommend incorporating a vegetative buffer.*
2. *When permanent habitat is adjacent to farms containing canola, corn, cotton, soy, sunflower, and wheat, seed treatment buffer requirements must be adhered too unless there is proof that neighboring farms are not treated with nitroguanidine neonicotinoids (e.g., they are certified organic).*

iv. *Herbicides (except paraquat dichloride) may be applied within buffers.*

Rationale
Permanent habitat areas are intended to provide pollinators and other beneficial insects a refuge from exposure to potentially harmful pesticides. Without adequate setbacks, pesticide applications in cropped areas can move into habitat areas and result in unintended exposure, harming pollinators and other beneficial insects (Longley et al. 1997; Hewitt 2000). Airblast sprayers increase the risk of drift, thus increased setbacks are required for airblast applications (Wilson 2014). The herbicide paraquat dichloride is prohibited because research suggests that its use can cause direct harm to bee larvae (Cousins et al 2013). The larger spatial buffer next to areas where neonicotinoid coated seeds have been planted has been imposed because this class of insecticides have been shown to be harmful at extremely low, environmentally relevant levels and they are systemic, which means pollinators can be exposed orally when foraging on contaminated plants. Furthermore, studies have shown that habitat next to crops grown from coated seed can be contaminated with levels of neonicotinoids that could harm pollinators and other beneficials (Botias et al 2015; David et al 2015; Long and Krupke 2016; Mogren and Lundgren 2016; Pecenka and Lundgren 2015). This contamination could be caused by a variety of pathways including dust-off when seeds are planted as well as uptake from plants from soil contamination.

Additional Information
A spatial buffer is an unsprayed space, such as roads or equipment turnarounds, or a section of crop that remains unsprayed. Setbacks are required within your own property. Setbacks are also required between permanent pollinator habitat on your property and neighboring farms or land where insecticides are known or suspected to be applied. Nitroguanidine seed treatment buffer requirements must be followed adjacent to the following crops: canola, corn, cotton, soy, sunflower, and wheat. Neconicotinoid buffer requirements do not apply if there is proof that neighboring farms are not treated with nitroguanidine neonicotinoids.

Within setbacks, herbicides—except paraquat dichloride—may be applied for nonaesthetic purposed in a targeted fashion. All other pesticides applications must adhere to the set-back requirements. Existing habitat adjacent to a neighboring property where pesticide application practices change following habitat creation is not required to meet setback requirements, although when feasible, we recommend incorporating a vegetative buffer.

Vegetative buffers (drift fences) of species that are not attractive to pollinators may also be used instead of setbacks, or if setback distances cannot meet the above requirements. Vegetative buffers should be comprised of densely planted, small-needled evergreen species that achieve at least 60% porosity. They should be designed to grow above spray release height. Until the buffer is above spray release height any pesticide use must be strictly in accordance with the drift and runoff precautions on the label in order to avoid off-site movement.

Proof accepted to demonstrate no nitroguanidine neonicotinoid seed coatings are used:

- Organic certification status.
- Signed statement from neighboring farmer indicating no treated seed used.
- Receipts of seed purchase (if company discloses seed treatments).

Forms

Appendix P: Vegetative Pesticide Buffer Candidate Species (in Bee Better Certified Production Standards)

Recommendations

When planting a vegetative buffer, select bare root or container plants that are at least 4' tall and with an extensive root system to assist with rapid establishment.

Resources

"Pesticide Drift." Pesticide Environmental Stewardship, http://pesticidestewardship.org/drift/Pages/default.aspx/

Flint, M. L. 2012. *IPM in Practice*. Oakland: University of California Agriculture and Natural Resources.

References

Botias, C., A. David, E. M. Hill, and D. Goulson. 2016. Contamination of wild plants near neonicotinoid seed-treated crops, and implications for non-target insects. *Science of the Total Environment* 566–567:269–278.

Cousin, M., E. Silva-Zacarin, A. Kretzschmar, M. El Maataoui, J.-L. Brunet, and L. P. Belzunces. 2013. Size changes in honey bee larvae oenocytes Induced by exposure to paraquat at very low concentrations. *PLoS One* (8)5:e65693.

David, A., C. Botias, A. Abdul-Sada, E. Nicholls, E. L. Rotheray, E. M. Hill, and D. Goulson. 2016. Widespread contamination of wildflower and bee-collected pollen with complex mixtures of neonicotinoids and fungicides commonly applied to crops. *Environment International* 88:169–178.

Hewitt, A. J. 2000. Spray drift: impact of requirements to protect the environment. *Crop Protection* 19(8-10):623–627.

Long, E. Y., and C. H. Krupke. 2016. Non-cultivated plants present a season-long route of pesticide exposure for honey bees. *Nature Communications* 7:11629. doi:10.1038/ncomms116291.

Longely, M., and N. W. Sotherton. 1997. Measurements of Pesticide Spray Drift Deposition into Field Boundaries and Hedgerows. *Environmental Toxicology and Chemistry* 16(2):165–172.

Mogren, C. L., and J. G. Lundgren. 2016. Neonicotinoid-contaminated pollinator strips adjacent to cropland reduce honeybee nutritional status. *Scientific Reports* 6:29608. doi:10:1038.srep29608.

Pecenka, J. R., and J. G. Lundgren. 2015. Non-target effects of clothianidin on monarch butterflies. *The Science of Nature* 102:19. doi.10.1007/s00114-015-1270-y

Wilson, J. 2014. "Air Blast Sprayers." Pesticide Environmental Stewardship, http://pesticidestewardship.org/drift/Pages/AirBlastSprayers.aspx/

2.4 Pesticide Use in Pollinator Habitat

Standard 2.4.a

a. *Do not use pesticides other than herbicides in designated permanent pollinator habitat.*
    i. *Do not apply herbicides to plants in bloom, including weeds.*
    ii. *Paraquat dichloride may not be used within permanent pollinator habitat.*

Rationale
Habitat areas are intended to provide a refuge for pollinators and beneficial insects, safe from potentially harmful pesticide applications. Recommended plant species for permanent habitat plantings do not generally harbor significant populations of crop pests, so it is unlikely that pest management will need to occur in these areas (Morandin et al. 2011; Bianchi et al. 2013; Morandin et al. 2014). Herbicide use is an exception to this recommendation, as herbicides can be an effective and economical habitat management tool, and most herbicides are not listed as toxic to bees. The use of the herbicide paraquat dichloride is prohibited because research suggests that its use can cause direct harm to bee larvae (Cousins et al. 2013).

Forms
NA

Resources
Xerces Society pollinator habitat installation guides, http://www.xerces.org/pollinator-conservation/agriculture/pollinator-habitat-installation-guides/

Vaughan, M., J. Hopwood, E. Lee-Mader, M. Shepherd, C. Kremen, A. Stine, and S. Black. 2015. *Farming for Bees*. Portland, OR: The Xerces Society for Invertebrate Conservation.

References
Bianchi, F. J. J. A., N. A. Schellhorn, and S. A. Cunningham. 2013. Habitat functionality for the ecosystem service of pest control: reproduction and feeding sites of pests and natural enemies. *Agricultural and Forest Entomology* 15:12–23.

Cousin, M., E. Silva-Zacarin, A. Kretzschmar, M. El Maataoui, J.-L. Brunet, and L. P. Belzunces. 2013. Size changes in honey bee larvae oenocytes Induced by exposure to paraquat at very low concentrations. *PLoS One* (8)5:e65693.

Morandin, L. A., R. F. Long, C. Pease, and C. Kremen. 2011. Hedgerows enhance beneficial insects on farms in California's Central Valley. *California Agriculture* (Oct-Dec):197–201.

Morandin, L. A., R. F. Long, and C. Kremen. 2014. Hedgerows enhance beneficial insects on adjacent tomato fields in an intensive agricultural landscape. *Agriculture, Ecosystems and Environment* 189:164–170.

Standard 2.4.b

b. *Do not apply highly or moderately toxic pesticides as classified by U.S. EPA or herbicides to temporary blooming in-field habitat (e.g., cover crops, insectary strips) or to crops with temporary in-field blooming habitat growing beneath or adjacent.*
    i. *If pesticide applications need to occur during the bloom period of temporary in-field habitats, mow or otherwise remove blooms at least 24 hours prior to any pesticide applications.*

Rationale
In-field habitat is designed to be attractive to bees and other pollinators and is likely to be visited by these insects while it is in bloom (Saunders et al. 2013). In the event that a pesticide application is absolutely necessary during in-field habitat bloom in order to protect adjacent crops, the application is permitted only if the area is mowed

and application delayed at least 24 hours post mowing. The mowing and subsequent 24 hours will disperse pollinators from the area and reduce the likelihood of exposure.

Forms
NA

Recommendations
When mowing of in-field habitat is required, seed set of late-blooming species may be curtailed. Inter-seeding late-blooming species (re-seeding them in the fall) can help ensure that they are present in future years. When possible, design within-field habitats to senesce prior to the period when pesticides are known to be needed (e.g., in almonds, our wildflower mixes die back by May, when pesticide application typically begins). However, we recognize that the bloom period of some in-field temporary habitat can occur for an extended period of time.

Resources
University of California Agriculture and Natural Resources: Statewide Integrated Pest Management Program, http://www.ipm.ucdavis.edu/

Environmental Protection Agency: Information on Residue Toxicity, https://www.epa.gov/pollinator-protection/information-residue-toxicity-time-growers-and-beekeepers/

References
Saunders, M. E., G. W. Luck, and M. M. Mayfield. 2013. Almond orchards with living ground cover host more wild insect pollinators. *Journal of Insect Conservation* 17(5):1011–1025.

3 Managed Bumble Bees

3.1 Use of Commercial Bumble Bees

a. *Do not use commercial bumble bees for open field pollination. Commercial bumble bees may only be used in secure indoor facilities, such as screened greenhouses, in which they are not able to interact with wild bumble bees.*
    i. *Carefully screen or seal vents and other greenhouse entrances to prevent individual bumble bees from entering or exiting the facility.*

b. *Only use native managed bumble bee species that are produced within their native ranges.*
    i. *Use queen excluders on all colonies.*
    ii. *After crop bloom, do not release any individuals from commercially acquired bumble bee colonies into the wild.*
    iii. *Properly dispose of all individuals through incineration, freezing, or hot soapy water (complete submersion for at least two minutes).*
    iv. *Dispose of materials (pollen, nectar, bedding, and cardboard) through incineration. Do not burn plastic materials, but dispose of in sealed trash bags.*

Rationale

Commercial bumble bees pose a number of risks to wild, unmanaged bumble bees, including competition, hybridization, introduction of pathogens, and spread of diseases (e.g., Murray et al. 2013; Goulson and Hughes 2015; Manley et al. 2015; Graystock et al. 2016; Herbertsson et al. 2016;). Many wild bumble bee species are imperiled, with several formerly abundant species nearly disappearing from their large portions of their historic range (Evans et al. 2008; Cameron et al. 2011). Bumble bee pathogens amplified in commercial settings have been implicated as a causal factor in many of these declines (Colla et al. 2006; Otterstatter and Thomson 2008; Cameron et al. 2011, 2016). Bumble bees can escape greenhouses (Morandin et al. 2001), however proper screening and disposal measures can prevent commercial bumble bee escape into the wild. Wild bumble bees and wasps, and managed honey bees may find materials (e.g., pollen and nectar) from within managed bumble bee colonies attractive. These materials can be contaminated with diseases. It is important to ensure nesting materials are destroyed and/or cannot be removed from disposal sites.

Forms

NA

Resources
Netting a greenhouse to prevent bumble bee escape: http://www.conservationevidence.com/actions/40

Appendix Q: Distribution Maps of Commercially Managed Bumble Bees (in Bee Better Certified Production Standards)

References
Colla, S. R., M. C. Otterstatter, R. J. Gegear, and J. D. Thomson. 2006. Plight of the bumble bee: pathogen spillover from commercial to wild populations. *Biological Conservation* 129(4):461–467.

Cameron, S. A., H. C. Lim, J. D. Lozier, M. A. Duennes, and R. Thorp. 2016. Test of the invasive pathogen hypothesis of bumble bee decline in North America. *Proceedings of the National Academy of Sciences* 113:4386–4391.

Cameron, S. A., J. D. Lozier, James P. Strange, J. B. Koch, N. Cordes, L. F. Solter, and T. L. Griswold. 2011. Patterns of widespread decline in North American bumble bees. *Proceedings of the National Academy of Sciences* 108(2):662–667.

Evans, E., R. W. Thorp, S. Jepsen, and S. H. Black. 2008. Status review of three formerly common species of bumble bee in the Subgenus *Bombus*. Portland, OR: The Xerces Society for Invertebrate Conservation.

Goulson, D., and W. O. Hughes. 2015. Mitigating the anthropogenic spread of bee parasites to protect wild pollinators. *Biological Conservation* 191:10–19.

Graystock, P., E. J. Blane, Q. S. McFrederick, D. Goulson, and W. O. Hughes. 2016. Do managed bees drive parasite spread and emergence in wild bees? International Journal for Parasitology: Parasites and Wildlife 5(1):64–75.

Herbertsson, L., S. A. Lindström, M. Rundlöf, R. Bommarco, and H. G. Smith. 2016. Competition between managed honeybees and wild bumblebees depends on landscape context. *Basic and Applied Ecology* 17(7):609–616.

Manley, R., M. Boots, and L. Wilfert. 2015. REVIEW: Emerging viral disease risk to pollinating insects: ecological, evolutionary and anthropogenic factors. *Journal of Applied Ecology* 52(2):331–340.

Morandin, L. A., T. M. Laverty, P. G. Kevan, S. Khosla, and L. Shipp. 2001. Bumble bee (Hymenoptera: Apidea) activity and loss in commercial tomato greenhouses. *The Canadian Entomologist* 133:883–893.

Murray, T. E., M. F. Coffey, E. Kehoe, and F. G. Horgan. 2013. Pathogen prevalence in commercially reared bumble bees and evidence of spillover in conspecific populations. *Biological Conservation* 159:269–276.

Otterstatter, M. C., and J. D.Thomson. 2008. Does pathogen spillover from commercially reared bumble bees threaten wild pollinators? *PLoS One* 3(7):e2771.

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