2014

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WEST WALES BEE BREEDING PROGRAM

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DR ANITA MALHOTRA

Bee breeding

In a long-term, collaborative project, **Dr Anita Malhotra** and her team are working to create a genetically informed framework for the future development of their bee-breeding programme, and provide guidance for similar, smaller-scale programmes in Wales

At what point did you develop your interest in bee genetics?

My interest in bees was sparked through personal interaction with a beekeeper (my husband!), when he resumed beekeeping after a long break. Initially, he couldn't stop talking about honeybees and the interesting things they did. Eventually I began to read more about them and became hooked.

As an evolutionary geneticist (although my previous research interests focused on reptiles, in particular venomous snakes), the genetic aspect of beekeeping was quite an obvious area of interest to me. I began to develop small research projects for undergraduate and postgraduate students. My husband then left his teaching job to take up beekeeping commercially, which led me to understand how precarious this can be and how increasingly difficult it is to make a living as a honey producer.

What is the overarching aim of the West Wales Bee Breeding Program (WWBBP)?

WWBBP aims to enhance the local suitability of honeybee stock through selective breeding, while concurrently preserving genetic diversity and adaptive potential, in a simple and practical way, such as could be achieved within the busy schedule of a commercial bee farmer.

How did the Program come about?

WWBBP was set up as a partnership between Bangor University and Tropical Forest Products, which is based in the county of Ceredigion, one of Wales' largest bee farmers and importers of organic African honey and beeswax.

Wales is on the northwestern margin of the honeybee's natural range and the climatic conditions are far less conducive to the species than, for example, the southeast of England. Yet, the honey produced here is very high quality because of the wide range of natural habitats still available, from hay meadows to heather moors, providing ample nectar sources when the weather permits its collection.

Are there any particular difficulties or advantages to bringing together researchers and beekeepers within WWBBP?

Sometimes it was a challenge for each side to understand both the opportunities and limitations offered by the other partners' specialist areas. From a genetic and theoretical point of view, I started off with an attitude of 'the more the merrier', while David Wainwright (the commercial beekeeper involved in this project) had to emphasise the fact that, from his perspective, it was simply not feasible. Not only did we have to pare down the numbers of breeding lines in the Program, we also had to seriously consider which data were worth collecting and why, because each new characteristic monitored adds a significant amount of handling time per hive.

Also, although the apiaries and laboratory are only around 100 miles apart, the state of the connecting roads and lack of effective public transport links meant significant travelling time was required by the PhD student carrying out the work. Nevertheless, I believe that the answer to solving the current problems facing bees will be found using the novel genetic tools we have at our disposable, at both small and large scales; however, basing this on a two-way exchange of information is essential.

Did the project encounter any unforeseen challenges?

Yes – the weather! I started off saying that the climate in Wales was challenging for honeybees, but we were still not prepared for the series of exceptionally poor summers that followed the project's initiation.

We started off testing some simple ideas about the breeding set up and limits to breeding success caused by the weather in Wales, so were actually able to demonstrate that in 2010, only 20 of 30 experimental queens managed to establish mature colonies, while the number of drones that the successful queens mated with were below the accepted species mean and ranged from four to 10 drones per queen. At the lower end of this range, this may mean reduced genetic diversity and ability to carry out essential functions such as temperature regulation, less resistance to disease and even premature queen failure.

This is not a good background against which to impose additional selection. However, the advantage of using genetic screening as a tool in breeding programmes is that we were able to keep track of the loss of genetic diversity and compensate for it if necessary. We also found that the offspring of one particular queen, while doing well on other criteria, were particularly aggressive, so that line had to be eliminated from the Program.

Protecting pollinators

In collaboration with beekeepers at Tropical Forest Products, **Bangor University** scientists are selectively breeding disease-resistant bees. Ultimately, this will enable small- to mid-scale beekeepers and farmers to improve the quality of their stock

AN ESTIMATED ONE-THIRD of the food we eat is pollinated by bees. Without pollinating insects fruits, vegetables and field crops would be defunct, leading to extreme economic hardship for the farm and food industry, and resulting in rising food costs. In recent years beekeepers have experienced high colony losses worldwide, and in Europe overwintering losses of around 40 per cent are common. The economic impact of the loss of honeybee colonies in parts of the Northern Hemisphere is already proving significant.

Known as colony collapse syndrome (CCS) in Europe, one single cause for this decline in bee colonies is yet to be identified by researchers. Honeybees are known to be vulnerable to a range of threats, including habitat loss, reduced foraging opportunities, irresponsible pesticide use, genetic 'pollution' from honeybee races adapted to very different climates, and a wide range of diseases, many of them recently introduced through human intervention. Interactions between two or more of these challenges can overwhelm susceptible bee populations, threatening the health of honey bees and placing the economic stability of commercial beekeeping and pollination operations in jeopardy.

ENHANCING BEE STOCK

In tangent, beekeeping in the UK is becoming an increasingly labour-intensive operation. However, despite being on the margins of the natural distribution of the western honeybee, west Wales is maintaining a long tradition of beekeeping and is home to the West Wales Bee Breeding Program (WWBBP), which is invested in breeding for local adaptation as a viable and promising solution to dwindling honeybee productivity. Established in 2009, the ongoing Program is a partnership between Bangor University and Tropical Forest Products, one of the largest bee farmers in Wales. Based at the University's School of Biological Sciences, molecular ecologist and evolutionary geneticist Dr Anita Malhotra heads WWBBP's genetics component, while Director and co-founder of Tropical Forest Products David Wainwright is beekeeping team leader.

The project is using selection to improve the resilience and production potential of a commercially managed Welsh bee stock. Through selective breeding the researchers will enhance the expression of observed desired traits; for example, improving productivity, disease resilience and temperament. This will be accomplished by essentially using the genes of the tougher bee colonies to breed genetically hardier variations of honeybees. "Beekeeping is becoming a lot more work, while productivity is declining, and it is therefore much harder to make a living from it," Malhotra explains. "We have very little control over most of this decline but, through selective breeding, we can affect variables such as the bees' response to periods of bad weather (eg. through adjusting the amount of brood present), and their resistance to disease." Importantly, the researchers are using traditional breeding techniques that use existing genetic variation and allow favourable traits to spread while unfavourable traits decrease in frequency.

HAPLODIPLOIDY HONEYBEES

If not conducted expertly, there is room for error in selective breeding and potential to weaken the colony. Honeybees are haplodiploid, whereby males have one copy of each chromosome, while females have two copies of each. Rather than being determined by having a particular set of chromosomes, sex is therefore dependent on the 'dosage' effect of alleles at a certain point in the genome – the complementary sex determination (csd). A single dose results in a male and a double dose a female. "The trouble is that a single dose can also be achieved by a genetic female having two identical alleles at the csd, and these diploid 'drones' do not survive, leading to weakening of the colony," Malhotra elaborates. "Inbreeding, or selective breeding, can cause this effect. Thus, many amateur beekeepers, who try to breed from their 'best' colony only, will rapidly run into problems of 'spotty brood'."

Therefore, large-scale breeding programmes are generally coordinated through government agencies or large coalitions. However, Malhotra and her team are testing the feasibility

WEST WALES BEE BREEDING PROGRAM

OBJECTIVE

To produce a hardy, productive, strain of bees suitable for the Welsh climate that is resistant to *Varroa* and other diseases without the use of medications.

KEY COLLABORATORS

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FUNDING

The funding for this project was provided by the Knowledge Economy Skills Scholarships (KESS), a major European Convergence program led by Bangor University on behalf of the HE sector in Wales. Benefiting from European Social Funds (ESF), KESS support collaborative research projects (undertaken by a PhD student) with external partners based in the Convergence area of Wales (ie. West Wales and the Valleys), with the aim of stimulating the economy of Wales.

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ANITA MALHOTRA obtained a BA in Zoology from Oxford University (Jesus College) in 1985, followed by a PhD from the University of Aberdeen in 1992. After postdoctoral positions at Aberdeen and Bangor Universities, she took up a lectureship at Bangor University in 1995. Author of over 100 publications on the dynamics of natural selection, vicariance and evolutionary responses to changing environmental conditions in island lizards, and pit viper systematics and venom evolution, she has more recently been applying molecular genetic techniques to honeybees.

Selection and breeding guidance

Although the science may sound complicated, the team's findings can be distilled into a few simple guidelines for beekeepers:

1. Pick as many of the best colonies as possible for breeding, and raise as many queens from each as possible to maximise adaptive potential. This was the most influential factor affecting rate of loss of genetic diversity in selected lines
2. To maximise the number of queen lines while maintaining a feasible workload, breed from the best colony per line every other year and use all the selected daughter colonies as drone producers for that year, breeding from them the following year
3. Start with as many nucleus colonies per line as possible – there can be c. 50 per cent attrition before selecting the next generation of breeders
4. Consider screening for low rates of mite infestation, if time permits, using the sugar shake method
5. Don't let temperamental colonies breed (re-queen if possible) or be drone sources

for successful small-scale farmers. "On an intermediate scale, a commercial bee farmer may have 200-500 hives (although the majority of them are dedicated to honey production), and at least in the UK, there should be enough genetic diversity present to successfully run small-scale breeding programmes," she clarifies. The end goal of WWBBP is to produce a hardy, productive strain of bees resistant to *Varroa*, an external parasitic mite that causes varroosis, and transmits other diseases, without the use of medications.

CHANGING PROTOCOLS

The researchers began breeding for desired traits in 2011, focusing primarily on colony strength, levels of mite infestation and temperament. Despite challenges in the form of limited available time and poor weather, the group established 100 new colonies using eight queens from the strongest overwintered colonies, which were monitored throughout the summer. Using genetic monitoring, the team gauged the amount of genetic diversity carried by the source population, while monitoring post-selection generations revealed how these genetic signatures changed through time. The reserachers then used modelling and simulation work to predict how this population might change in time if current breeding protocols are maintained.

The project was supported by the Knowledge Economy Skills Scholarships (KESS), which provided extensive funding and training opportunities. This directly facilitated PhD student Ian Williams' training in beekeeping techniques and analytical skills. Important contributions have also been made by a number of Master's and undergraduate students. "One student successfully located two drone congregation areas (where male honeybees hand out waiting for the virgin queens to come to mate) in the valley in which the main mating apiary is located, one being much larger than the other," Malhotra enthuses. "In the subsequent year, another student showed that they were located in the same places, but that the smaller one only formed later in the summer."

A NEW FRAMEWORK

Results to date have value for the purpose of small-scale breeders hoping to establish a breeding programme (see guidance above) and have been disseminated through talks in Wales and beyond. Findings will also be communicated through scientific journals and conferences. The project will continue into the long term as only one generation of honeybees is selected each year. "During the lifetime of the funding, we completed the first two rounds of selection," Malhotra reveals. "Although evidence indicating adaptive change due to selection is difficult to detect across this timeframe, we did demonstrate a reduction in the variance of colony strength, which is consistent with the action of selection." Although there have been problems maintaining all the lines during a succession of difficult years for beekeeping in Wales, the results have been good. "Last year, the hives with queens bred from the lines established in this project did as well as hives in other areas with queens produced from large scale breeding programmes in Denmark," Beekeeper Wainwright explains. "They produced more than three times as much honey as the average production for the unselected hives in Wales. I have also seen steadily declining levels of *Varroa*, low levels of swarming, gentle behaviour and other desirable characteristics."

The project's key output is to provide a genetically-informed framework for the future development of WWBBP, while also providing guidance to other smaller-scale breeding programmes in Wales.