Grower Summary

PE 031

Tomato: An investigation into poor pollination performance by the native bumblebee, *Bombus terrestris audax*

Final Report 2017

Project title:	Tomato: An investigation into poor pollination performance by the native bumblebee, *Bombus terrestris audax*
Project number:	PE 031
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Report:	Final report, December 2017
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The results and conclusions in this report are based on a series of investigations and a survey conducted over a one-year period. The conditions under which the studies were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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GROWER SUMMARY

Headline

- This report summarises the experiences and opinions of growers representing 98% of the UK tomato production area.
- The results provide a foundation of knowledge upon which to build a practical research programme aimed at improving pollination with *Bombus terrestris audax* in tomato cultivars currently grown in the UK.

Background

Bumblebees were first introduced to British tomato growers in 1989 via trials in glasshouse crops on the Isle of Wight. The benefits, in terms of reduced labour and improved fruit set, were so great that by 1992 bumblebees were being used to pollinate virtually all long-season tomato crops in the UK. There followed a few revisions to hive design and some tweaks to hive placement programmes, but the pollination system was so reliable that growers came to expect perfect fruit set with minimal maintenance.

In the 1980s, the three commercial bumblebee producers tested many populations *of Bombus terrestris* to determine which could be reared most efficiently in culture and which provided the best results in tomato crops. They independently selected two non-native sub-species; *B. terrestris terrestris* (Btt) and *B. terrestris dalmatinus* (Btd). The British native sub-species, *B. terrestris audax* (Bta) was dismissed at that stage due to inferior performance. In the 27 years since the first release of non-native bumblebees in UK tomato crops, there has been no evidence of their establishment outside glasshouses or any detrimental effect on natural bumblebee populations.

In 2014, Natural England (NE) produced a document which suggested that non-native bumblebees could escape from glasshouses and hybridise with wild Bta leading to the local extinction of Bta. In addition, NE proposed that the use of non-native sub-species could lead to the transfer of harmful parasites / pathogens from commercially reared *Bombus terrestris* to wild bumblebees in the UK. Following an open consultation, NE revised its policy and permission to use non-native bumblebees in unscreened glasshouses was withdrawn from 31 December 2014. Commercially reared native Bta could still be used without a license.

The use of Bta in 2015 proved to be far from the reliable and maintenance-free experience to which growers had become accustomed. In fact, several growers suffered such poor results

that they reverted to the labour-intensive manual methods of pollination that had not been used since bumblebees were first introduced.

British tomato growers are not averse to using Bta if this can be done without significant economic loss. In the short term, the Tomato Growers Association (TGA) Technical Committee requested that an appropriate team be formed to conduct an in-depth survey of UK tomato growers to gather more precise information about the current situation. The results of that survey form the basis of this report. It is important to stress that the information presented here represents the views of UK tomato growers rather than the views of the authors of the report. In the longer term, the information generated from this survey will be used to provide a foundation of knowledge upon which a practical research programme can be constructed.

Summary

What was done

The study was done in three distinct stages with interim reports prepared after each stage. These reports were used by the project team to take stock of progress up to that point and determine how the project should proceed.

The first stage began by searching scientific and horticultural literature as well as interviewing consultants and scientists who had been involved with practical work on flowering and fruit set in tomato. In addition, tomato consultants who currently specialise in tomato 'crop registration' were interviewed with particular emphasis on 'vegetative' versus 'generative' plant growth and how plant condition might influence flower quality and fruit set. There followed visits to three UK tomato growers who had suffered serious difficulties with fruit set during 2015/16 to investigate the circumstances surrounding those problems. Finally, representatives of each of the three bumblebee supply companies were interviewed to obtain their opinions on how biological pollination had changed during the transition from non-native to Bta bumblebees. The combined findings were used by the team to produce a series of notes to help steer the subsequent grower interviews.

In the second stage, growers from a further ten tomato production sites were interviewed following the agreed procedures. All interviews were conducted by the same team member to aid consistency. Care was taken to ensure that the interviewer did not ask leading questions or inadvertently direct the discussion in a particular direction. However, the growers

were encouraged to develop any subject which they felt was particularly important in their situation. The second interim report was used by the team to refine the overall approach for the remaining interviews. Where necessary, further contact was made with the stage 1 and 2 growers to clarify any points that had not been adequately covered.

In the third stage, the same team member contacted all the remaining UK tomato growers and conducted interviews following the latest agreed procedures. In total, growers from 32 tomato nurseries were interviewed. This represented 186.2 hectares of crops which the TGA believe to be 98% of the UK glasshouse area currently devoted to tomato production. In fact, only one company failed to contribute to the survey. The sites ranged in size from 0.2 ha to 23.5 ha with an average of 5.8 ha. A third interim report was produced which was used by the team to tease out the key factors for inclusion in this AHDB final report.

Summary of findings

The term 'fruit set' is used in this report to denote flowers which reach anthesis (flower opening) normally and subsequently produce fruit of marketable size for that tomato type / cultivar. Very little research has been published on flowering and fruit set in tomato since the introduction of commercial bumblebees for pollination in the late 1980s. This reflects the reliability of the biological system between 1990 and 2015.

There are reported to be nine sub-species of *B. terrestris* in Europe and North Africa. Btt occurs naturally in continental Europe (north of the 45th parallel) and is considered to be the 'type species' to which the others are compared. Btd is naturally found in south east Europe (from S.E. France to Iran) but has an overlapping range with Btt and some hybridisation has been reported in the common territories. Bta evolved within the British Isles. There is very little information in the scientific literature which quantifies differences in vigour between Bta, Btt and Btd. However, in one field experiment in southern England, colonies of Bta (reared from nest searching queens caught in the wild) and Btd (obtained from a commercial supplier) were found to have different nectar foraging performances, with Btd performing significantly better than Bta in four out of five study locations. This was attributed to the larger body mass of Btd.

The clearest overall message from British tomato growers in this survey was the general belief that Bta are less vigorous than the previously used non-native sub-species and more likely to fail to provide adequate pollination should any aspect of flower development or ambient conditions be sub-optimal for their performance. In fact, 72% of growers said they would prefer to return to using the non-native bumblebees.

No growers considered the performance of Bta to have surpassed Btt/Btd but 34% believed that their performance was similar - albeit with many more Bta hives being used than had previously been required with Btt/Btd. 28% of growers said Bta were poorer, 28% said much poorer and 9% said very much poorer than Btt/Btd. One grower estimated that poor fruit set had cost his business £50k / ha in 2015. Due to reduced confidence in bumblebees, 75% of growers now devoted more labour to monitoring fruit set than when they were using non-native bumblebees which was an additional cost to the business.

Planned Bta hive input schedules varied greatly between suppliers, sites, types / cultivars of tomatoes and length of growing season. A large proportion of the growers' interviewed said they had also required additional hives to those included in the planned schedule. In most cases (78%), the supplier accepted the growers' judgement and provided the extra hives without further investigation. In summary, 28% of growers occasionally ordered extra Bta hives while 69% said this was a usual or frequent requirement.

47% of growers thought that Bta colony life was shorter than they had come to expect from non-native bumblebees with estimates ranging from 2 to 6 weeks less than Btt/Btd. Shorter than anticipated colony life could result in gaps in the planned schedule with an associated breakdown in the continuity of bumblebee activity. This might help to explain why so many additional Bta hives are ordered during the season. Four growers reported improved results when they changed from fortnightly to weekly hive deliveries which was thought to reduce peaks and troughs in bumblebee activity.

44% of growers linked poor performance of Bta to poor foraging during hot environmental conditions. Such conditions were poorly defined but probably involved temperatures exceeding 28^{O}C around the heads of the plants for at least 5-6 hours. This may be a direct effect of temperature on the bumblebees or an indirect effect via flower development and quality of pollen. Most of these growers based their comments on subjective observations rather than actual measurements. The remaining 56% of growers did not express an opinion on the subject.

About one third of growers said that their staff had asked "*Where are the bees*?" at some point during the season. This related to the apparent lack of Bta activity during normal working hours. One grower believed that this was because Bta forage very early in the morning so that their activity is underestimated. If correct, then Bta activity may not be very well synchronised to our understanding of pollen release / flow in tomato flowers. As yet, there is little evidence to support this theory but it must be investigated in more detail.

There is a common perception among UK growers that it is the greater size of Btt and Btd which makes them more effective pollinators. In reality, the physical features of the *B. terrestris* sub-species are quite varied and there is certainly some overlap between the sub-species that have been available to British growers. Furthermore, the non-native bumblebees that were being released immediately prior to 2014 were probably very different to those originally collected from the wild due to further selection, manipulation and possible hybridisation while in culture. It is entirely possible that Bta breeding stock may also become stronger as the producers select Bta queens which produce larger and more vigorous colonies.

All types of tomato can be affected by poor set but problems are most serious in smaller fruiting cultivars which produce more flowers. The plant may compensate for missed set by producing larger remaining fruit. Assuming the larger fruit are picked loose, sold by weight and still within the permitted size category, then some of the lost yield will be recovered. The issues are always more serious where tomatoes of any type are ripened on the plant and harvested as whole trusses. Apart from the obvious loss of fruit, missed set within a truss results in additional work at harvest and / or in the pack house in order to make the necessary adjustments to the trusses.

One grower, who reported a marked reduction in bumblebee efficacy since the switch to Bta, also reported the move at his site to small fruiting cultivars during the same period. This prompted the project team to look at the overall UK change to small fruiting varieties during the period that NE have enforced the switch from Btt/Btd to Bta. In 2011, only 28.8% of UK tomato production was of the cherry / cocktail type (including both loose and vine harvested produce) but by 2016 (*i.e.* post Bta) that had increased to 76.9%. This is clearly an important factor when considering the efficacy of bumblebees.

Six growers presented examples of exceptional cases where they believed the condition of the plants had been the underlying cause of poor set. Three were due to excessive vegetative growth resulting from i) a prolonged period without heat, ii) inappropriate growing conditions for a new specialist cultivar and iii) root mat disorder. Two cases were due to weak plants infected with pepino mosaic virus and the other due to excessive manganese in the water supply.

Apart from these exceptional cases, only 12% of growers considered that the condition of the plants could have been the underlying cause of poor set experienced during the last three years. Nonetheless, there is a strong belief among some consultants and growers that

vegetative, rather than generative, tomato plant growth results in weaker flowers and poorer set. Although one grower believed that Bta are 'weaker' than Btt/Btd, he also thought that current crop husbandry practice led to poor pollen quality in modern tomato cultivars and this was the underlying cause of poor fruit set. In his opinion, if plants are strong and generative, then pollen flows freely and may not even need disturbance by bumblebees to pollinate. There can be little doubt that any future studies into pollination by bumblebees must also take into account the impact of environmental conditions on the condition of plants with particular emphasis on flower development and pollen quality.

One grower said pollen did not flow freely in humid conditions and speculated that Btt/Btd could cope with this but Bta could not. This should be further investigated.

Financial Benefits

The economics of tomato production in the UK have changed considerably since bumblebees were first introduced for pollination. Pressure from retail customers has greatly reduced financial margins and growers have become dependent upon the benefits that are obtained from using biological pollination. It is difficult to generalise about the financial value of British tomato crops due to the wide range of products supplied to retail customers. However, if we assume the farm gate value to be about £850k / ha / season, then the total value of the British crop is about £162m / season. Long season tomato plants produce 35-40 trusses per season. The loss of set due to inadequate pollination on just two trusses equates to about 5.3% of annual production which is in the region of £45k / ha / season. The equivalent losses across the British industry would be over £8.6m.

Action Points

Future studies into fruit set should focus upon:

- Bta biology and behaviour under different environmental conditions with particular emphasis on synchrony between bumblebee foraging and optimum pollen flow.
- Bta colony life in greenhouses and the impact this has on hive input schedules and frequency of hive deliveries.
- The influence of environmental conditions on flower quality and pollen flow in the small fruiting cultivars which now make up 76.9% of UK production.
- Changes in bumblebee usage and agronomic practice that will be required to optimise all aspects of pollination and fruit set.