Grower Summary

PE 031b

Tomato: Phase 3 of an investigation into poor pollination performance by the native bumblebee, Bombus terrestris audax

Annual Report 2019-20

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TOMATO GROWERS' ASSOCIATION

ANNUAL REPORT

To:

AHDB Horticulture

Stoneleigh Park, Kenilworth

Warwickshire, CV8 2LT

Tomato: Phase 3 of an investigation into poor pollination performance by the native bumblebee, *Bombus terrestris audax*

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Rob Jacobson Consultancy Science into Practice

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THE UNIVERSITY OF WARWICK

Project title:	Tomato: Phase 3 of an investigation into poor pollination performance by the native bumblebee, *Bombus terrestris audax*
Project number:	PE 031b
Project leader:	Mr Philip Pearson (TGA Technical Committee Chairman) British Tomato Growers' Association, Pollards Nursery, Lake Lane, Barnham, West Sussex, PO22 0AD
Report:	Annual report, 15 February 2020
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Location of project:	RJC Ltd, Bramham, West Yorkshire Warwick University, Wellesbourne, Warwickshire R & L Holt Ltd, The Cross, Evesham, Worcestershire Eric Wall Ltd, Barnham, West Sussex Red Roofs Nursery Ltd, Cottingham, East Yorkshire Various other UK tomato production nurseries
Industry Representative:	Dr Philip Morley (TGA Technical Officer) British Tomato Growers' Association, Pollards Nursery, Lake Lane, Barnham, West Sussex, PO22 0AD
Date project commenced:	1 January 2019
Date project completed:	31 December 2020

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[The results and conclusions in this report are based on a series of investigations conducted over a twelve-month period. The conditions under which the experiments 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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Signature ..... Date .....

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GROWER SUMMARY

Headline

- Bta produced larger colonies in an outdoor habitat than in glasshouse tomato crops.
- Bta flight activity in an outdoor habitat was substantially greater than in tomato crops.
- Bta flights in tomato crops coincided with pollen availability.
- Methods have been developed to further investigate Bta flight activity, tomato flower development, pollen flow and pollen viability.

Background

British tomato growers had successfully pollinated their crops with two non-native sub-species of bumblebees (*B. terrestris terrestris* [Btt] and *B. terrestris dalmatinus* [Btd]) for over 27 years when Natural England (NE) withdrew permission for their use in unscreened glasshouses. NE suggested that non-native bumblebees could escape from glasshouses and hybridise with the British native sub-species, *B. terrestris audax* (Bta), leading to the local extinction of Bta. As a consequence of the NE decision, growers had to switch to Bta in the 2015/16 growing season. However, Bta failed to provide the reliable and maintenance-free pollination experience to which the industry had become accustomed. This should not have been a surprise because at least one of the producers, Brinkman Bunting Bumblebees BV, had already tested and dismissed Bta due to inferior performance during the 1980s.

British tomato growers are keen to use Bta if this can be done without significant economic loss and they have instigated several studies since 2015 in an attempt to improve the situation. The first was an AHDB-funded independent review of the scientific literature relevant to the effects of releasing non-native sub-species of bumblebees as pollinators in commercial crops. The resulting peer-reviewed paper concluded that there was insufficient reliable and consistent evidence to support claims that the use of Btt/Btd was harmful to wild populations of *B. terrestris* in the UK. Furthermore, the review reported the genetic structure of Bta to be complex with significant differences between populations from different parts of the British Isles. This information, along with known hybridisation among European mainland sub-species, raises questions about the validity of the current classification of *B. terrestris* sub-species.

In 2017, the TGA Technical Committee (TC) organised an in-depth survey of UK tomato growers to gather more precise information about the use of Bta up to that time. Growers representing 98% of the UK production area participated in the survey. In summary, most growers believed Bta to be less vigorous than the non-natives and more likely to fail to provide adequate pollination should any influencing factor be sub-optimal. Modern small-fruiting tomato cultivars (*eg* cv Piccolo) were most likely to suffer significant issues with fruit set. The survey was repeated in 2019. It identified a marginal improvement in growers' perception of the performance of Bta, which could perhaps be attributed to improved Bta breeding stock and / or improved in-crop management of Bta. Nonetheless, growers still considered Btt/Btd to be substantially superior to Bta.

In 2018, the TGA TC organised a short (6 months) AHDB-funded practical project to begin to investigate factors raised by tomato growers in three key subject areas. First, the team discovered that most Bta colonies went into decline soon after placement in tomato crops, which was in stark contrast to previous experience with Btt/Btd colonies. Second, a study of traffic from Bta hives strongly indicated that there was considerably less flight activity in glasshouse tomato crops than outdoors. Finally, a preliminary study to investigate flower development and pollen production in cv Piccolo provided a foundation for more detailed experimentation.

Based on the results from all the above studies, the TGA TC organised the present AHDB-funded project to further investigate the following important factors:

- Activity of Bta in commercial tomato crops in the UK.
- Effects of high temperatures on within-hive behaviour of Bta and Btt/Btd.
- Effects of high temperatures on pollen production / viability with emphasis on the tomato types that are most vulnerable to poor fruit set.
- Relative performance of Bta and Btt/Btd in commercial tomato crops.

The work done during the first year of this two-year project included studies into Bta colony development, Bta flight activity / flower visitation and tomato flower / pollen development.

Summary

What was done

The original intention was to work with Bta colonies from one commercial tomato crop throughout the 2019 growing season and compare them to Bta colonies that had been placed outside in a more natural habitat. However, it soon became clear that there was large inherent

variation in the numbers of bees present in the delivered hives and this confounded our experimental designs. We were forced to modify our original plans and subsequently sampled hives as opportunities arose to explore potentially informative situations. Overall, we covered more combinations of sites, tomato cultivars and bumblebee suppliers than originally intended but we had to compromise on factors such as the time the colony had been in position on site.

Forty eight bumblebee hives were sampled from three commercial tomato crops (cv Piccolo in the Midlands, cv Sweet Jane in West Sussex and cv Funtelle in East Yorkshire) and a natural habitat at Warwick Crop Centre (WCC). Upon receipt at the WCC laboratory, each hive was frozen, the colony destructively sampled and the numbers of bees, brood and eggs recorded. While our counts inevitably included some bees that were already dead inside the hive at the time of sampling, we believe that this method did provide a good indication of the size of each colony.

As the season progressed, it became clear that it would be useful to identify a best case scenario for Bta against which we could compare other situations. Our starting point for this scenario was a crop of baby plum tomatoes (cv Funtelle) in which there had been near perfect fruit set during the preceding five months. A preliminary investigation identified two Bta colonies which stood out as performing much better than any others in that crop. The study was done during a prolonged period of moderate weather when neither plants nor bumblebees had been subjected to stressful conditions. Bee flight, flower development and pollen flow were carefully monitored from sunrise until evening. We thus produced a ‘positive base-line’ against which we could compare flights from hives in other tomato crops, with less successful fruit set, and hives positioned in a natural habitat.

Bta hives were set up in an old redundant orchard in such a way as to simulate natural conditions with free access to a variety of flowering plants that grew in the vicinity. Bee traffic was first monitored from dawn to sunset recording all exit and entry flights. The same hives were observed on a further four occasions to determine the effect of weather on flight. Similar ‘snap shots’ of daily bumblebee flight activity were recorded in 31 hives over three occasions in a cherry tomato crop (cv Piccolo) in the Midlands, 8 hives in a cherry tomato crop (cv Sweet Jane) in West Sussex and 11 hives in a baby plum tomato crop (cv Funtelle) in East Yorkshire. In addition to these ‘snap shots’ of daily traffic, an additional study explored flight activity over the life of colonies both in the orchard and in the crop in the Midlands.

A preliminary study was organised to refine techniques for monitoring flower visitation ahead of tomato crop-scale trials in 2020. GoPro cameras were attached to roof support posts and aimed at developing flower trusses in the tomato crop. Flower development and bumblebee visitations were recorded from sunrise to sunset. The results were determined by replaying the recordings at increased speed in the laboratory.

Our experiments in 2018 indicated that the anthers of an individual tomato flower were generally able to produce many more pollen grains than were needed to fertilise all the ovules in the ovary of the same flower. However, it was possible that not all of the pollen grains were viable. During 2019, we concentrated on researching the methods available for assessing pollen viability ahead of more detailed experimentation in 2020.

Summary of Bta colony development, flight activity and flower visitation

There was considerable variation in the numbers of all Bta life stages in the colonies destructively examined regardless of the origin, age and / or history of those colonies. Prior to 2015, we had come to expect Btt/Btd colonies in tomato crops to show a peak in the number of adults at about six to eight weeks, after which the colony switched from rearing sterile workers to producing a small number of sexual males / females, and the total number of adult bees subsequently began to decline. No such pattern was seen in the data set from these tomato crops. In fact, the average numbers of adults and brood per hive remained relatively small and the development pattern over time was quite flat, which was broadly consistent with our observations from 12 tomato production sites in 2018. In contrast, hives collected from the outdoor habitat contained substantially more adult bees / brood than those from the glasshouses, and colony development did follow the pattern to which we had previously been accustomed.

Bta flights between late Spring and early Autumn generally began 2-3 hours after sunrise regardless of hive location and temperature. The frequency of exit flights increased during the morning, peaked at around 11:00 hrs, remained at that level until late afternoon and then declined into the early evening. Exit flights within one hour of sunset were rare but return flights continued until sunset. Bta flight activity in the outdoor habitat was substantially greater than in the glasshouse tomato crops.

The combined observations of colony development and flight activity reinforced the opinion that Bta simply do not like tomato plants! When we take these results along with the data obtained from estimates of bee colony size done the previous year, it is clear that bee colonies

placed in tomato crops do not ‘take-off’ in terms of rearing brood and producing new foragers in the same way that a colony would normally do when held outside under more natural conditions. The colonies go into decline at about two weeks from being placed in the glasshouse. Therefore it is likely that most of the pollination is being done in tomato crops by adult forager bees that are present in the hive at the time of delivery, or which emerge shortly after delivery of the hive.

The GoPro camera method was successful in recording bumblebee flower visitation in a commercial crop. That technique, together with the Arnia remote hive monitoring system currently undergoing refinement, should become useful tools when we compare Bta and Btt/Btd flight activity and flower visitation in commercial crops in 2020.

Summary of tomato flower development and pollen production

Our ‘positive-base line’ study provided a detailed illustrated record of flower production and pollen flow in a crop of baby plum tomatoes (cv Funtelle). This record is available in the main project report and will be used by our team for reference in future trials. Significant visual changes were only observed to three flowers on the monitored truss. The first flower to open had clearly been visited by bees the previous day and produced no discernible quantity of pollen. The second flower to open became fully reflexed 3 hours after sunrise and began releasing pollen during the following 30 minutes. This continued until mid-afternoon when the flower began to close. The third flower became fully reflexed 4.5 hours after sunrise and started releasing pollen 30 minutes later. This continued into the evening. Pollen was thus available from two flowers per truss per day, in overlapping sequence, starting about 3 hours after sunrise and continuing until early evening. Bumblebee flights coincided with pollen availability. These observations were broadly comparable to those made in a crop of cv Piccolo in 2018. However, in cv Piccolo there were many more flowers per truss than cv Funtelle and up to four of them could be open at any one time. There appeared to be considerably less pollen within cv Piccolo flowers and it was more difficult to release by manual action.

Studies into tomato pollen production, availability and viability are continuing into 2020. It is interesting to note that several of the methods described in older published papers did not prompt germination of pollen from modern tomato cultivars in our experiments in 2019. We will continue to refine methods and then assess the viability of pollen from cv Piccolo under a range of temperature regimes during the coming growing season.

Financial Benefits

UK growers have become dependent upon the financial benefits from using biological pollination. It is difficult to generalise about the value of UK tomatoes, due to the wide range of products and production methods, but if we assume an average farm gate value of £850k / ha / season, then the total value of the British crop is about £162m / season. The loss of set due to inadequate pollination on just two trusses per plant (*i.e.* equating to 5% of annual production) is about £45k / ha / season or £8.6m across the whole British industry. The TGA's original investment appraisal for the first phase of this series of projects demonstrated a potential payback from just one hectare of crop in one growing season. If this project is successful in identifying and redressing the issues which lead to inadequate pollination equating to a 5% loss of annual production then, if extrapolated to the whole industry over a 5 year period, the potential cost:benefit of this series of three PE 031 projects is greater than 1:250.

Action Points

As an interim report, half way through a two-year project, this document is intended to provide an update on progress towards the ultimate objectives rather than provide firm recommendations on changes to be implemented by industry. Nonetheless, in the short term, the TGA can advise growers to:

- liaise with their bumblebee supplier to produce a hive input programme that compensates for the shorter colony life of Bta bumblebees.
- check Bta colonies regularly to ensure that they are still active.
- check pollen flow from flowers when conditions are deemed to be stressful for plant growth.
- monitor Bta foraging activity around mid-day, when most open flowers have peak pollen flow, and supplement with manual pollination when there is little activity.