Grower Summary

CP 118

Cucurbit Pollination: Mechanisms and Management to Improve Field Quality and Quantity

Final 2018

Disclaimer

The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

Use of pesticides

Only officially approved pesticides may be used in the UK. Approvals are normally granted only in relation to individual products and for specified uses. It is an offence to use non-approved products or to use approved products in a manner that does not comply with the statutory conditions of use, except where the crop or situation is the subject of an off-label extension of use.
Before using all pesticides check the approval status and conditions of use.
Read the label before use: use pesticides safely.

Further information

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Project title:	Cucurbit Pollination: Mechanisms and Management to Improve Field Quality and Quantity
Project number:	CP118
Project leader:	Professor Juliet Osborne, University of Exeter
Report:	Final, August 2018
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Key staff:	PhD student: Jessica Knapp Professor Juliet Osborne; Dr Frank Van Veen
Location of project:	Cornwall, United Kingdom
Industry Representative:	Ellis Luckhurst, P.E. Simmons and Son, Gwinear Road, Cornwall
Date project commenced:	01/01/2015
Date project completed (or expected completion date):	[31/06/2018]

GROWER SUMMARY

Headlines

- Honeybees (*Apis mellifera*) and buff-tailed bumblebees (*Bombus terrestris*) were the most abundant pollinators of courgette. *B. terrestris* had a more equal preference for visiting male and female courgette flowers and carried more loose pollen grains than *A. mellifera.* Therefore *B. terrestris* is likely to be the most effective pollinator of courgette.

- Full (hand pollination) increased courgette yield by 39% when compared to the yield when pollination was excluded. However, there was no evidence of pollination limitation (by insect pollinators) on crop yields when compared to the hand/full pollination.

- There was no evidence that (i) that wild flowers 'distract' pollinators from courgette flowers and (ii) putting commercial colonies of *B. terrestris* increase yields, in this study.

Background

Negative impacts from intensifying agriculture have generated concerns that pollinator-dependent crop species, such as courgette *Cucurbita pepo* L., may be experiencing a pollination deficit. This project explores the extent to which pollination influences fruit set; how pollination could be improved; and how in doing so growers' profits and agricultural resilience could increase, using UK field-grown courgettes as a model system.

This study is the first to explore cucurbit pollination in the United Kingdom. Consequently, no information was available prior to this study about how effective UK species were at pollinating cucurbits. Likewise, no work had been done on the pollinator dependence of "Tosca", a popular variety of courgette in the UK and the principle variety used in this study; whether these plants were experiencing a pollination deficit, and indeed, the economic value of pollination to UK courgette production. Based on this information floral resources influencing the most effective pollinators were explored, and the effect of cucurbit nectar and pollen on bumblebee population dynamics, using computer simulations was explored for the first time.

Accordingly, this research directly addresses priorities on the Outdoor Cucurbit Research and Development Priority List: "Pollination for fruit quality: supporting pollinating insects", and the Agriculture and Horticulture Development Board's Field Vegetable Sector Priority List: "To supply consistent quality product and continuity and to achieve customer satisfaction", as well as: "making efficient use of resources to improve returns".

Therefore, by understanding courgette pollination dynamics within the context of UK growing conditions, the project aimed to give commercial growers practical management options that would allow them to improve the quantity and quality of their yield, supporting sustainability and profitability. These finding are also relevant to hobbyist growers as well as the wider public by promoting the value of pollination to horticultural crop production.

Three key areas of courgette pollination are addressed in this project (highlighted with solid arrows in Figure 1). The first explores the mechanism, variability, and economic value of courgette pollination. The second looks at ways of improving pollination within courgette fields. Finally, the third explores the mutualism between courgette and its key pollinator species.

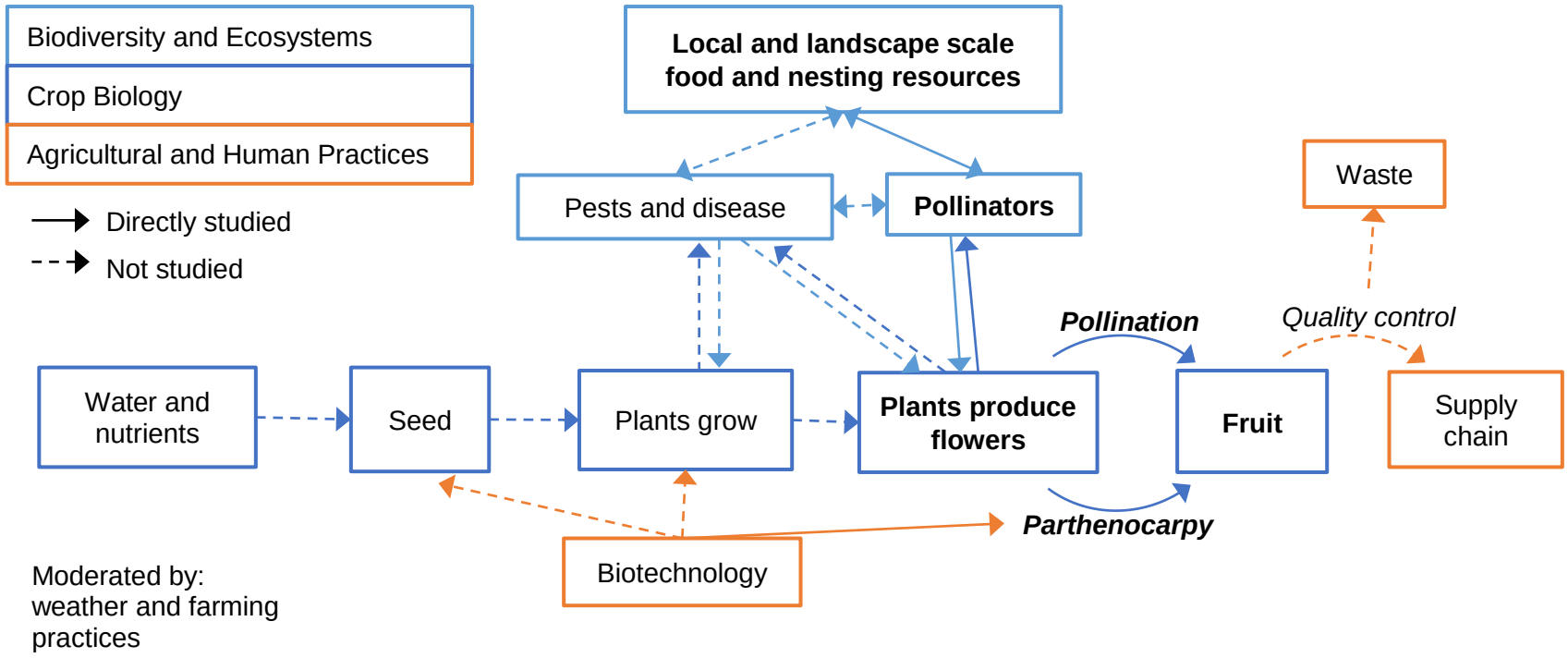

Figure 1 Conceptual framework of the different factors (broadly categorised into crop biology, agricultural and human practices, and biodiversity and ecosystems) which effect fruit set in pollinator-dependent crops. Solid lines and bold text show factors which were directly studied whilst dashed lines and plain text show factors which were considered but not directly studied in this project.

Summary

Funding Objective 1: What are the most effective wild pollinators of field-grown courgettes in South West UK in terms of visitation rate and pollen transfer efficiency?

Quantifying the effectiveness of individual pollinator species can help growers target their pollination management to species most likely to increase yields. Pollinator surveys were conducted throughout the project to determine which pollinator species were most abundant, had the highest visitation rate to male and female courgette flowers and transferred the most courgette pollen. Buff-tailed bumblebees (*B. terrestris*) and honeybees (*A. mellifera*) were the most abundant pollinator species in courgette fields and had the highest visitation rates to courgette flowers. Of these two species *B. terrestris* had a more equal preference to male and female courgette flowers and transferred the most pollen grains. Therefore, *B. terrestris* is likely to be the most effective pollinator of courgette in the South West of the UK.

Funding Objective 2: Does pollination deficit limit yield (number, quality of fruits)?

Courgette production in the UK is estimated to be worth £6.7 million. However, little is known about this crop's requirement for insect-mediated pollination (pollinator dependence) and if pollinator populations in the landscape can fulfil its pollination needs (pollination deficit). Consequently, pollination experiments were conducted to ask to what extent does pollination influence fruit set and if field grown courgettes were experiencing a pollination deficit? Results showed that full or hand pollination increased yield by 39% but there was no evidence of insect pollination limitation on crop yield. This was evidenced by a surprisingly low pollination deficit of just 3% between the hand pollinated and the open pollinated crop and there was no statistical difference in yield (length grown, circumference, and weight) between the open- and hand-pollinated crops. Nonetheless, the high economic value of courgettes means that reducing even the small pollination deficit could still increase profit by ~ £166/ha. Interestingly, 56% of fruit was able to reach marketable size and shape without any pollination – this finding led to the parthenocarpy meta-analysis presented in the science section. Results are discussed in the context of the economic value of pollination to courgette production in the UK.

Funding Objective 3: Does the introduction of commercial bumblebees improve yield?

Introducing commercial bumblebee colonies or honeybee hives can interrupt the damaging cycle of lower yields from a reduced diversity and abundance of wild pollinators, often caused by losses in (semi-) natural habitat. To explore if commercial colonies of *B. terrestris* improved courgette yield, colonies were placed into a field at the stocking density recommended by

Koppert Biological Systems. There was no difference in courgette yield when *B. terrestris* colonies were open, compared to when they were closed. This is likely due to the already high level of 'natural' pollination at study sites.

Funding Objective 4: Does the introduction of a flower strip between rows or along a field edge alter the effectiveness of pollination? If pollinators are supported with other floral resources do they visit the courgette flowers more (attraction) or less (distraction)?

Allocation of floral resources to increase pollinator abundance is the primary basis for pollinator-supportive land management; however, relatively little is known about how the scale of floral resources (field or farm) may affect different pollinator groups which may or may not pollinate the focal crop. Bumblebees were significantly more abundant on courgette flowers in fields with a greater species richness of wild flowers which would be viewed as weeds in the crop. No flower-strips were grown between the rows in this study. Although solitary bees were not observed to visit courgette flowers, their abundance and species richness in courgette fields were significantly greater with more semi-natural habitat and a greater species richness of wild flowers. For both honeybees and bumblebees, their abundance in field margins did not significantly reduce their abundance on courgette flowers and both species show a preference for courgette flowers in the morning when flowers are open, before 'switching' to wild flowers around the cropped area when courgette flowers are closed. These findings suggest that wild flowers do not compete with courgette flowers for pollination services. Indeed, wild flowers help to fulfil bees' nutritional requirements beyond the nectar and pollen provided by courgette.

Funding Objective 5: Is there an interaction between nitrogen and pollination levels?

Whilst several studies have explored the positive, mediating effect of forage availability on pollinator visitation and crop yield many overlook other factors which influence yield (pre or post pollination) such as, soil quality, water availability, weather conditions, and farming practices. Using the experimental design for funding objective 4, additional data were collected on the farming intensity (e.g. the type of farm machinery used during picking, the number of herbicide, fungicide and fertiliser applications and cropping practices), soil nutrients and yield. Results showed that region, field size and nutrients were not important predictors of courgette yield. Instead, bumblebee abundance on flowers in the field margin was the most important factor for increasing courgette yield (although this was not statistically significant). There was also no evidence of competition for soil resources between wild flowers and courgette flowers, with neither floral abundance nor floral species richness negatively affecting courgette yield. Unfortunately, the limited sample size of eight fields meant that it was not possible to test the interaction of soil nutrients and pollination.

Funding Objective 6: Design and run a citizen science project to record courgette pollination within garden/ allotment systems in comparison to commercial systems.

This objective was not achieved because it was clear that it was not going to give useful results to the UK commercial growing industry. Instead a meta-analysis exploring parthenocarpy (fruit set in the absence of pollination) in horticultural crops was judged to be more important to growers. This meta-analysis is provided as supplementary information in the science section of the full report. Results showed genetic modification, hormone application and selective breeding for parthenocarpy were able to significantly increase fruit quantity and quality in 18 usually pollinator-dependent crop species. The effect of courgette nectar and pollen on wild bee populations was also thought to be more important - model simulations using Bumble-BEEHAVE showed that early season courgette increased the number of hibernating queens, colonies, and foragers.

Pollination workshop

Findings of this PhD project have been presented to outdoor cucurbit growers group (2015, 2016 and 2018), as well as within annual reports and the cucurbit pollination factsheet.

Whilst a single overarching workshop was not held, bespoke expert-advisory meetings were held with Riviera Produce, Southern England Farms, Trevaskis Farm, and the Hall-Hunter partnership on pollination of their crops. Meetings continue with growers and farmers across the South West UK to provide bespoke pollinator management advice under the BEE-STEWARD project. BEE-STEWARD combines the latest research on pollinators to create an environment that benefits pollinators, farmers, businesses and society. A demonstration and discussion of the BEE-STEWARD support tool can be found in the supplementary information at the end of this report.

Financial Benefits

Since 41% of courgette yield is dependent on pollination the total economic value of insect pollination to courgettes is estimated to be worth approximately £3,398/ha (Table 1). Due to high levels of open pollination observed in Cornwall, pollination deficit was estimated to be just 3%. Nevertheless, if pollination was maximised, the economic value of courgettes would increase by approximately £166/ha (Table 1).

Table 1 Calculation of the economic value of pollinators to courgette production at a hectare and national scale. *P* was 0.43 £/ha (DEFRA 2016). Total area of UK courgette production is 807.75 ha (British Growers Association, personal communication 22nd September 2016). *D* was 0.41 and *Dmax* 0.43 calculated from experimental results for funding objective 2.

	Economic value (£)	
	Per ha	UK Value

Quantity *Q* (Kg)	19,274	-
Economic value *EV* (£)	8,288	6,694,632
Total economic value of insect pollination *IPEV* (£)	3,398	2,744,735
Maximum economic value of pollination service *MaxEV* (£)	3,564	2,878,821
Value of pollination deficit *PDef* (£)	166	134,086

Action Points

Since the total economic value of insect pollination to courgette is estimated to be worth £3,398 per ha growers may wish to:

1) **Preserve their wild flowers within, and on the edge of fields as a way of attracting pollinators into courgette fields.** Wild flowers facilitate pollination services to courgette and support pollinator nutrition. There is no evidence that they 'distract' pollinators from courgette flowers.

2) **Use parthenocarpic varieties, in combination with other environmentally considerate practices to achieve stable pollination.** Parthenocarpy could be advantageous to all crops, whether they are experiencing a pollination deficit or not by improving fruit uniformity caused by stochastic poor pollination. In return, these parthenocarpic crops can continue to provide valuable nectar and pollen resources for wild and managed bees, and other flower-visiting insects

3) **Plant courgette near to previous courgette crops (within the season and over time) to utilise local bumblebee populations which may have been boosted by the availability of courgette nectar in the past.** However, bees will also need alternative floral resources to fulfil their nutritional requirements for pollen and nectar over space and time.