THE IMPORTANCE OF BEE POLLINATION OF THE SOUR CHERRY (*PRUNUS CERASUS*) CULTIVAR 'STEVNSBAER' IN DENMARK

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Abstract— Low fruit set, despite normally-developed flowers, is often a significant contributor to poor yield of the self-fertile sour cherry (*Prunus cerasus*) cultivar 'Stevnsbaer' in Denmark. The aim of this study was to investigate the effect of insect, and particularly, bee pollination on the fruit set of this cultivar, in order to provide orchard management information for both Danish 'Stevnsbaer' growers and beekeepers. Visits to cherry flowers by honey bees (*Apis mellifera), Bombus* species and solitary bees, were recorded during the flowering of 'Stevnsbaer' in five separate Danish orchards. The results indicate that there is a significantly higher fruit set on open pollinated branches when compared to caged branches, where bees and other pollinating insects where excluded. The results were qualitatively consistent over three different seasons (2007, 2009 and 2010). A period of prolonged cold, humid weather before and during early flowering probably reduced fruit set significantly in 2010 compared to 2009. Regarding the apparent benefits of bee pollination on fruit set and subsequent implications for yield, we recommend placing honeybees in 'Stevnsbaer' orchards during flowering to sustain commercially viable production. Another valuable management strategy would be to improve foraging and nesting conditions to support both honey and wild bees in and around the orchards.

Keywords: Fruit set, Prunus cerasus, bee pollination, Apis mellifera, Bombus

INTRODUCTION

The numbers of nearby wild bees (Hymenoptera: Apidoidea) and *Apis mellifera* hives are important, determining factors of the level of bee pollination available as a free service to cultivated crops. Thus, the growing evidence for the global loss of bee diversity and decline of numbers (Potts et al. 2010) is of concern. Many interacting factors are implicated in this decline, such as changes of land-use resulting in fragmentation of habitats, increasing use of pesticides, environmental pollution, decreased plant resource diversity, alien species, spread of pathogens and climate change (Potts et al. 2010; Krewenka et al. 2011). Solitary bees in particular, seem to be more sensitive to agricultural intensification than bumble bees (Féon et al. 2010). In Denmark, the number of *A. mellifera* colonies has declined considerably between 1985 and 2008, mainly because of diseases and halving of the number of beekeepers (Branner & Vejsnæs 2007; Vejsnæs et al. 2010). Consequently on a nation-wide level, *A. mellifera* is unlikely to compensate for reduced wild bee pollination, even on crops where they are valuable and highly effective pollinators. Therefore, it becomes increasingly necessary to document the likely effect of bee pollination on specific, cultivated crops to aid decision-making concerning changing management practices that will support yield, such as introducing bees during flowering.

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Pollinating insects are generally accepted as important for seed and fruit production of self-sterile crops such as sweet cherry and apples (Free 1993: McGregor 1976; Delaplane & Mayer 2000) but for self-fertile crops it is less clear whether such pollinating insects improve yield significantly (Benedek et al. 2005). However, reports have shown a positive effect of bee pollination on specific crops such as blackcurrant (Hansted 1993), raspberry (Chagnon et al. 1991) and strawberry (Blasse & Haufe 1989). Solitary bees (e.g. *Osmia aglaia)* have also been shown to be valuable pollinators of raspberry and blackberry (Cane 2005).

The sour cherry cultivar 'Stevnsbaer' is among the major fruit crops in Denmark, grown on 1400 ha with a commercial yield of 12,700 tonnes in 2010 (Faostat, 2012). It is self-fertile and wind plays a role in the transfer of its pollen (Hansen 1981, Ren 2005). Low fruit set in normally-developed flowers is a major problem and often the main reason for poor yield (Dencker et al. 1999). Preliminary studies by Ren (2005) where yield was increased by using an air blast orchard sprayer during flowering to increase air movement in the tree crowns indicated the limiting role of pollen availability in fruit set of 'Stevnsbaer'. Further, hand-pollination on the first day of flowering increased yield more effectively than on the second day (Ren 2005), suggesting that 'Stevnsbaer' stigma receptivity may be shorter than for many other cherry types (Toyama 1980; Furukawa & Bukovac 1989). Limited pollen tube growth through the style has also been suggested as a reason for a poor fruit set in 'Stevnsbaer', with slow growth rates, reduced receptivity of stigma surfaces and lower temperatures e.g. <15°C cited as contributing factors (Kühn 1988; Cerovic & Ruzic 1992).

An earlier study on a small number of 'Stevnsbaer' trees documented a positive effect of bee pollination on fruit set (Hansen 1981), confirming work by Benedek et al. (2005) who recorded increased fruit set in four self-fertile sour cherry varieties when pollinated by bees. In preliminary studies with 'Stevnsbaer', supplementary hand-pollination did not increase fruit set on freely-pollinated branches in orchards where bees were present (the authors, unpublished data), suggesting that bee pollination is indeed highly effective. However, a wide variation in yield is common between trees and orchards (Dencker & Toldam-Andersen 2003), even if the trees are clonally produced and expected to have a high degree of uniformity. Consequently, the positive effect of bee pollination on fruit set of 'Stevnsbaer' reported by Hansen (1981) for a limited number of trees and in a single orchard has to be validated for other, larger orchards.

The aim of this work was to study the effect of bee pollination on fruit set of 'Stevnsbaer' on a large number of trees in a number of different locations. Fruit set was recorded on branches of the same tree that were either open pollinated or caged to exclude bees and other pollinating insects. Numbers of bees and other insects visiting the flowers was also recorded. This information is intended to help 'Stevnsbaer' growers and beekeepers when considering the future role of bees in orchard management.

MATERIALS AND METHODS

Study sites

The experiments were carried out in 2007, 2009 and 2010 in five 'Stevnsbaer' orchards in the eastern part of Denmark and 20-60 trees were included each year in each orchard. *Apis mellifera* colonies, *Bombus terrrestris* colonies and O*smia rufa* cocoons were placed in, or nearby, the orchards either before or at the beginning of bloom. A detailed description of the sites and bee introductions is shown in Tab. 1.

Fruit set

Fruit set was measured on spurs of two year old branches. On each tree, two spurs of closely similar form and shoot development were selected in the middle of the crown. When the flowers were at the balloon stage, a 30-45 cm long section was marked on the innermost part of the branches and the number of flowers per spur recorded. Just before flowering, one of the branches (randomly selected) was covered with a chicken-wire and tulle net cage, shaped as an oblong tube (16-25 cm diameter). This was carefully placed to completely avoid contact between the net and the flowers (Fig. 1). The tulle net had 30 perforations cm^{-2}, each with a diameter of 2 mm. The second selected branch on each tree was left uncaged. The cages were removed as soon as the petals had fallen from the flowers. Five weeks later the number of fruits per spur was counted and percentage fruit set calculated. The period between full bloom (> 90% open flowers) and the onset of senescence as indicated by the first colour change of the flowers was approximately four days in all orchards in all years.

Number of pollinators

Numbers of bees and other insects were recorded in each orchard in each year. In 2007, recordings were made on one day in all orchards; in 2009, they were made on one day in Slagelse and on 3 days in Taastrup and Ringsted;in 2010, they were made on 2 days in Slagelse and on 3 days in Taastrup and Ringsted. On each day, records were taken at 07:30, 10:00, 13:00 & 16:00 hours using the same rows of trees for all recordings. The observer walked slowly (15 m/minute) for 10 minutes along each of 4 rows. Numbers of *A. mellifera*, *Bombus* sp. queens and workers (the latter in

Location	Year	Study area (ha)	No. of trees	Bee populations within 130 m of the orchard	Timing of bee placement
Guldborg	2007	0.8	24	A 19	Before bloom
Klippinge	2007	1.0	40	A 2	Before bloom
Taastrup	2007	1.0	40	A 1	Start of bloom
	2009			A 8	A 2 at start of bloom
		1	40	B 2	A 6 at full bloom
	2010			O 100	B and O before bloom
Ringsted	2009	0.5	60	A 10 B 4	Before bloom
	2010	0.5	20	O 180	
Slagelse	2009			A 42	Before bloom
		0.2	20	B 2	
	2010			O 100	

Legend: A = *A. mellifera* colony, B = *B. terrestris* colony with 75 workers, O = *O. rufa* cocoon.

TABLE 1. Location and size of study sites in Denmark and number of investigated trees. The species and numbers of introduced bee colonies are given, together with the time they were placed in the orchard.

FIGURE 1. Sour cherry (*Prunus cerasus*) cultivar 'Stevnsbaer' flowers covered with a net cage made from chicken wire and tulle. The cage was placed around the spurs on the inner part of two year old branches.

2009 and 2010 only), other wild bees and insects visiting flowers were recorded, with those on leaves or flying within the canopy being ignored. It should be noted that *Bombus* sp. workers are not naturally present at the time of 'Stevnsbaer' flowering (late April - first weeks of May) and were only recorded in 2009 and 2010 when commercially-sourced *B. terrestris* colonies had been placed in the orchards.

Climate

In 2010, temperature and relative humidity (2 m above ground level) and precipitation (1.5 m above ground level) measurements were taken from weather stations at Roskilde (14 km southwest of Taastrup) and Flakkebjerg (9 km southeast of Slagelse) and temperature only at Taastrup and Ringsted. These data are not reported here in detail but gave valuable weather information to aid the discussion of results.

Data analysis

Fruit set data were analyzed using a two-sample t-test for correlated samples. Data were analyzed separately for all years and orchards.

RESULTS

In any one season and in all orchards a significantly higher fruit set ($t = 4.96$-8.49, $P < 0.05$) was detected on open pollinated compared to caged branches (Tab.2). This difference held despite the inevitably different seasons, management practices (including the introduction of bees), variation in other plant species present and in insect abundance in the different orchards. Fruit set was significantly higher ($t = 1.79$-4.28, $P < 0.05$) in 2009 compared to 2010 for both caged and non-caged flowers in Ringsted and Slagelse, and for caged flowers in Taastrup (Tab. 2).

Bees and other insects were visiting the flowers in all orchards in all years and *A. mellifera, Bombus* sp., wild bees (*Andrena* sp.) and Dipterans were recorded (Tab. 3). *A. mellifera* was proportionally the most numerous of these potential pollinators in each of the orchards, always exceeding 40% or even more of all flying insects (Tab. 3). Close observations confirmed that each bee species was in contact with both anthers and stigma while visiting a flower and would thus be able to transfer pollen.

DISCUSSION

It has been suggested that the window pollen transfer to flowers in full bloom leading to successful fruit set is as short as 1-2 days for 'Stevnsbaer' (Ren 2005) and that numbers of flying insects are significant for eventual pollination levels (Hansen 1981). If there is little or no wind to assist pollination then bees and other insects will be responsible for transferring the sticky pollen (Hansen 1981). Therefore, bees kept within or close to an orchard will raise fruit set and yield, particularly if there are few wild pollinators in the orchard. In this study it was noted that flowers both on the caged and open pollinated branches were similarly agitated under windy conditions, indicating that the net was not a major obstacle to wind pollination.

The consistently higher fruit set on open pollinated branches compared to caged ones (Tab. 2) is likely to result from the pollination activity of insects, given that wind pollination was possible in both circumstances In our study, we observed that wind could enter the cages and move flowers thus, allowing for wind-pollination. The number of bees visiting the 'Stevnsbaer 'flowers (Tab. 3) could have been influenced by the introductions close to the orchards as part of the

Location	Fruit set (%) 2007 Caged	2007 Exposed	2009 Caged	2009 Exposed	2010 Caged	2010 Exposed
Guldborg	9.34 ± 2.48	18.25 ± 3.3				
Klippinge	4.75 ± 1.68	18.49 ± 3.19				
Taastrup	3.79 ± 1.39	14.29 ± 3.04	6.99 ± 1.60	13.33 ± 2.05	1.27 ± 0.95	9.43 ± 3.14
Ringsted			16.56 ± 2.57	29.28 ± 4.26	2.23 ± 1.14	15.65 ± 5.47
Slagelse			28.93 ± 5.13	44.21 ± 6.29	0.76 ± 0.68	11.93 ± 2.91

TABLE 2. Fruit set (%, presented as mean ± SE) for exposed and caged flowers of sour cherry (*Prunus cerasus*) cultivar 'Stevnsbaer' five weeks after petal drop. Values for exposed branches were significantly higher than for caged ones (t test, t = 4.96-8.49, $P < 0.05$) for each year at each location.

study (noted in Tab. 1) and the study clearly indicates the value provided by bees with respect to fruit set, particularly if there are relatively few other, wild pollinators in the orchard.

The low fruit set on both caged and exposed branches in 2010 compared to 2009 may be explained by a prolonged period of high humidity and low temperatures in early May 2010, when flower development in the orchards ranged from bud burst to white bud. These weather conditions probably slowed flower development but did not halt it. Ren (2005) showed that the amount of airborne 'Stevnsbaer' pollen correlates negatively with humidity but positively with temperature. Therefore, it may be assumed that due to the weather conditions the amount of pollen in the air in early May 2010 would have been low and, consequently, wind pollination would have been limited. At the same time, only few insects (and especially bees) were flying and so transfer of pollen by insects was likely to be limited as well. These adverse conditions continued until 17 May when the majority of branches had > 50% open flowers. Once the weather conditions improved and became more favourable for bee activity, many of those hitherto unpollinated flowers would have been too old for successful pollination.

In 2006, Dencker (2010) had investigated several of the same orchards as in this study, using the same trees. In Guldborg and Taastrup, where colonies of *A. mellifera* had been available, he reported levels of fruit set similar to those for exposed branches recorded in 2007 in this study. At Klippinge, where *A. mellifera* colonies were not present in 2006, he reported markedly lower fruit set than as observed in this investigation in 2007, after the introduction of *A. mellifera*.

The present study is the first systematic investigation of the value of bee pollination for fruit set in sour cherry in Denmark, and it clearly documents that bees are important pollinators of 'Stevnsbaer', irrespective of individual orchard management practice. Compared to options such as developing new sour cherry varieties, keeping *A. mellifera* colonies in an orchard is, a simple, low-cost measure that can be implemented easily and will ensure the presence of pollinators during bloom. To maximize the abundance of

Location	Year	No.of sample days	*Apis mellifera*	*Bombus* sp. inc. queens	*B. terrestris* worker bees	Solitary bee	Flies incl. Syrphids
Taastrup	2007	1	6	4	-	1	1
Guldborg		1	24	14	-	7	8
Klippinge		1	26	15	-	5	17
Taastrup	2009	3	23	1	1	1	0
Ringsted		3	30	1	0	2	0
Slagelse		1	32	0	0	0	1
Taastrup	2010	3	95	1	3	2	3
Ringsted		3	37	0	3	1	1
Slagelse		2	45	0	2	0	5
Total			318	36	9	19	36

TABLE 3. Total number of bees and pollinating dipterans visiting sour cherry (*Prunus cerasus*) cultivar 'Stevnsbaer' flowers, recorded in 4x10 min observations on 1-3 days per location.

bees during bloom, landscape and orchard management practices should be integrated to improve foraging conditions for *A. mellifera* and wild bees and to increase the nesting possibilities for wild bees (Wittman et al. 2005; Klein et al. 2007).

Detailed knowledge on the pollination requirements of different crops and possible pollinator species, including fruit crops such as the 'Stevnsbaer' sour cherry, is often lacking, and it is of the utmost importance that more research into these aspects of crop pollination is undertaken (Williams 1994; Klein et al. 2007).

Globally, 35% of the food supply comes from crops that depend on animal (mainly bee) pollination (Klein et al. 2007). As agriculture is vulnerable to the risks and impacts of climate change (Fischer et al. 2002), then the yield of pollinator-dependent crops might be threatened due to continued pollinator shortages (Aizen et al 2009). It is therefore important that future agricultural practices are appropriately sensitive to pollinators (Howden et al. 2007; Ortiz 2011).

The present study is the first systematic one in Denmark on the value of bee pollination for fruit set in sour cherry, and it clearly documents that bees are important pollinators of 'Stevnsbaer', irrespective of individual orchard management practice and that without them fruit set is significantly reduced. Placing *A. mellifera* colonies in the orchards during bloom can support yield and appropriate management to provide sustainable nesting habitats and foraging possibilities for wild bees can also contribute to a higher fruit set.

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