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Pollination: An effective tool for reducing fruit drop and improving fruit quality

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Abstract
Insect pollination is important for food production globally and apples are one of the major fruit crops which are reliant on this ecosystem service. If apple production is to be successful it is essential that abundant crop of large high quality fruits are set on trees, in every year. It is fundamentally important that the full range of benefits of insect pollination to crop production are understood, if the costs of interventions aiming to enhance pollination are to be compared against the costs of the interventions themselves. Most previous studies have simply assessed the benefits of pollination to crop yield and ignored quality benefits and how these translate through to economic values. By ensuring adequate pollination of apple flowers we can increase yield and improve fruit quality of apple to the large extent.

Keywords: apple, pollination, fruit set, fruit quality, fruit growth.

Introduction
Apples have perfect flowers, meaning both female and male reproductive organs are present that contain the ovules and produce the pollen, respectively. The female organ of the flower, the gynoecium, comprises five carpels; each has a stigma, a style and an ovary (Weberling, 1989; Endress, 1994; Raven *et al*., 1999) [29, 13, 19] that normally contains two ovules (McGregor, 1976; Westwood, 1978; Faust, 1989; Free, 1993) [17-20, 31, 14]. The number and distribution of seeds within a developing apple affects its shape and weight (Brittain, 1933; Brittain and Eidt, 1933; Free, 1993; Brault and de Oliveira, 1995; Keulemans *et al*., 1996; Sheffield, 2014) [5-6, 5-6, 4, 15, 22].
Furthermore, flowers and developing fruit that are not pollinated, or are poorly fertilized, usually drop soon after they have bloomed (Free, 1993). Most immature fruit dropped within a few weeks of flowering typically have fewer developing seeds than fruit that remains on the tree (Brittain and Eidt, 1933; Brain and Landsberg, 1981) [5-6, 3], although the relationship is not always straightforward (Lee, 1988; Ward *et al*., 2001) [28], as many mature fruits do not contain a full complement of seeds (Sheffield, 2014) [22]. The structure of the apple flower facilitates pollinators, namely bees, as they access the floral nectaries and move through the anthers, where they come into contact with each of the stigmas (i.e. top-working bees). In contrast, they can enter through the side of the flower, where they access the nectaries through the base of the anthers (i.e. side-working bees). Side-working bees are less likely to touch the stigma than top-working bees (e.g. for honey bees, side-working behaviour is well documented in 'Delicious' apples. In cultivars without a compitum, the pollen must be distributed evenly among the stigmas in order to obtain a full complement of seeds (Visser and Verhaegh, 1987) [26].

Results and Discussion
For effective pollination and consistently good yields of most apple cultivars, pollinizer trees must be interplanted in the orchard along with the main variety. These pollinizers must be compatible with the mainvariety, produce a good supply of viable pollen every year, and possess as many days of bloom overlap as possible with the main variety. The particular flower structure of a cultivar may reduce the effectiveness of pollination. 'Delicious' flowers have basal gaps between stamen filaments through which bees can extract nectar without touching any stigma (Dennis, 1979; Schneider et al., 2002) [12, 21]. Guerrero-Prieto *et al.* (2009) studied the effective pollination period in 'Red Chief' and 'Golden Delicious' apples (*Malus* × *domestica* Borkh.) and reportedthat apple fruit yield is strongly determined by the initial fruit set, which is the result of a series of physiological events, such as pollination, pollen tube growth, ovule longevity and fertilization. Ward *et al.* (2001) [28] studied effect of Stigma

excision in apple and reported that Stigma excision induced variability in seed number and effected fruit set and retention. Abbott (1959) [1] found that if seeds were removed within 4-5 weeks of petal fall from apple fruits of 'Cox's Orange Pippin' and 'Crawley Beauty', the fruits would shed. Similar results were obtained with 'Golden Delicious' by Beruter and Droz (1991) [2]. Dennis (1967) [11] found that whereas untreated, unpollinated flowers of 'Wealthy' apple almost all shed, those treated with an extract of immature 'Wealthy' seeds gave normal sized but seedless fruits. Besides affecting fruit set, seed count affects several fruit quality parameters, especially fruit size and weight (Tomala and Dilley, 1989; Miller and Kaiser, 1994; Volz *et al*., 1995; Keulemans *et al*., 1996 and Uemura *et al*., 2001) [24, 18, 27, 15, 23]. A low seed count has often been found to correlate with ribbed or malformed fruits (Brault and de Oliviera, 1995; Brookfield et al., 1996; Buccheri and Vaio, 2004) [4, 7, 9-10]. A high seed count has also been associated with increased calcium content, reduced fruit length-to-width ratio, increased firmness, and increased acidity (Broom et al., 1998; Tomala, 1999; Buccheri and Vaio, 2004) [8, 23, 9-10].

Conclusion

- Poor pollination leads to reduced fruit set in apple, making it no longer a profitable enterprise.
- There is a relationship between low seed number, low calcium contents of the fruit, and high bitter pit disorder incidence. This suggests that attention to pollination will help optimize flesh calcium contents and postharvest quality.
- Understanding the multiple benefits of an ecosystem service, such as pollination, is critical for ensuring food security, as it is not only the yield but the quality and value of produce which are important.

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