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COMMERCIAL POLLINATION OF DECIDUOUS FRUIT

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Commercial pollination is a critical component of integrated orchard management practice. Obtaining optimal fruit set requires the correct orchard design (selection and positioning of pollinisers), flower management (pruning and thinning), control of alternative forage, as well as the proper introduction and usage of adequate strength honeybee colonies.

There is little published information or scientific data on the commercial pollination of deciduous fruit crops in South Africa. Most practices are based on experience and anecdotal evidence. A current DFPT project evaluating basic principles of pollination is intended to remedy this situation. This pamphlet should be used only as a GUIDELINE, to be updated as more information becomes available.

Pollination is one step in a multi-stage process that culminates in the development of seed or fruit, and is **the transfer of pollen from the male anther to the female stigma of the flower**. The agents (pollinators) that bring about this transfer of pollen are varied and include insects, birds, mammals, wind, water and gravity. The two most important agents are insects and wind. Most fruit, seed and berry crops are dependent to a lesser or greater extent on insects, first and foremost **honeybees**, to ensure a fruit or seed set.

What Pollinates Deciduous Fruit Crops in South Africa?

Insects typically are responsible for about 85% of pollination, and honeybees for about 80% of insect pollination. Honeybees are highly adapted as successful pollinators with bodies covered in finely-branched hairs that develop static electricity sufficient for the collection of as many as 40 000 pollen grains on the body, pollen baskets to collect pollen, and a high demand for pollen and nectar (Figure 1). Both nectar-gathering and pollen-gathering honeybees are important for pollination, the latter more so. Approximately one third of the foods which make up our total diet comes directly or indirectly from honeybee-pollinated crop plants. The value of fruit, vegetables and seeds resulting directly from pollination is about 150 times the value of bee products. In South Africa the value added to crops by the use of honeybees in paid pollination is in excess of R4 billion per annum of which almost R2 billion (Table 1) is from deciduous fruit crops.

Fig. 1 *Honeybees are highly adapted as successful pollinators*

Many growers believe that “other pollinators” are sufficient for the pollination of their crops. This might well have been true in days gone by but now insects other than honeybees play only a supplementary role in pollination. Recent data indicates that between **94-98% of all insect visitors to deciduous fruit trees in the Boland were honeybees**, and that honeybees made up more than 98% of actively pollinating insects. “Natural” pollinators are becoming increasingly scarce and unimportant, probably due to increasing habitat destruction and pesticide load. There are also no other “commercial” pollinators that can be used in South Africa, such as the leafcutter bees or bumblebees. **The deciduous fruit industry is almost totally dependent on a healthy honeybee population and a viable beekeeping industry.**

Why commercial pollination?

There is extensive data on almost all deciduous fruit species and cultivars that indicate that **the introduction of commercial honeybees for pollination improves fruit set, fruit weight and fruit quality**. Successful pollination results in fertilization with the fertilised ovule developing into a seed comprising an embryo (derived from the fusion of one male nucleus with the female egg) and the endosperm. The endosperm nourishes the embryo during its development but also has a second and perhaps more important function, for it secretes hormones that control the growth of the embryo and the growth and shape of the fruit and the retention of the developing fruit. Seed hormones are particularly important in apples and pears, with inadequate pollination resulting in low seed numbers causing fruit drop and misshapen fruit. While it is not necessary to have ten seeds in every fruit, the more seeds produced the more export quality fruit produced, and the better the pollination the more seeds that are produced. **There is generally a positive relationship between successful pollination and: (a) fruit set; (b) percentage of fruit that**

Table 1. *South African deciduous crops, their economic value, and their pollination requirements. The number of hives introduced and typical duration needed for pollination will vary for different crop types and different cultivars, as well as with region, different orchard designs, management strategies and level of competing forage.*

Crop plant	Area planted (ha)	Gross annual value (R million)	Bee factor (%)	Bee contribution to gross value (R million)	Pollination requirements
Apple *Malus domestica*	22 379	1 279	95	1 215	2-4 hives/ha. Time/crop: 7-12 days. Mostly self-incompatible. Compatible polliniser needed. Nectar and pollen good.
Apricot *Prunus armeniaca*	4738	96	65	62	1-2,5 hives/ha. Time/crop: 10-14 days. Largely self-compatible, but pollen transfer by pollinator necessary. Some cultivars self-incompatible, requiring compatible polliniser. Nectar and pollen fair.
Peach/ Nectarine *Prunus persica*	10 927	540	65	351	1-2,5 hives/ha. Time/crop: 10-14 days. Largely self-compatible, but pollen transfer by pollinator necessary. Some cultivars self-incompatible, requiring compatible polliniser. Nectar and pollen fair.
Pear *Pyrus communis*	12 777	491	95	466	3-8 hives/ha. Time/crop: 7-14 days. Mostly self-incompatible. Compatible polliniser needed. Nectar very poor but good pollen.
Plum, Prune *Prunus domestica*	5 060	226	90	203	3-12 hives/ha. Time/crop: 10-14 days. Mostly self-incompatible. Compatible polliniser needed. Nectar value varies with cultivar, and poor pollen source.

do not drop; (c) effectiveness of chemical thinning; (d) fruit size; (e) fruit shape; and (f) fruit quality and shelf-life.

Honeybee Behaviour

Some basic principles regarding honeybee foraging behaviour are important in optimizing the performance of honeybee colonies in commercial pollination. Foremost among these is that honeybees forage on flowers only for a **reward** of pollen and/or nectar; pollination is a fortuitous consequence of the foraging. Honeybees are able to detect minor differences in the sugar concentration present in nectar, and in the protein content in pollen, and for the most part **will forage on the most rewarding resource available**. Nectar in apples and plums is relatively poor in both sugar content and quantity, with normally only enough nectar to sustain colonies and not enough for a honey surplus. Apple and plum nectar levels are inferior to those of common weeds such as Cape Weed (Gousblom) and Wild Radish (Ramenas). Pear flowers have extremely poor nectar, both in sugar content and quantity, and are not very attractive to foraging honeybees. All of apples, plums and pears have pollen that is readily collected by honeybees, but is not as attractive as that of common weeds. **It is because the reward provided by deciduous fruit crops is less than that of common weeds that the practice of introducing naïve bees (colonies introduced during blossom) has become standard in commercial pollination**. The rationale is that by introducing honeybee colonies when target crops are already 20% or more in bloom, that this will result in foragers working on the inferior-quality target crop for a number of days at least while other foragers locate better quality forage crops, to which the foragers will then switch. Recent results indicate that bees might not switch as readily as thought, and if confirmed, these practices (i.e. the use of naïve bees) might need to be reviewed.

Notwithstanding the ability of honeybees to assess forage quality and to rapidly direct foragers to more fruitful resources, individual honeybee foragers are remarkably **flower constant** and **area constant**. At any one time the field force of a honeybee colony will demonstrate a preference for a number of forage species, but individual foragers will tend to work only on a single forage species until that forage type becomes

Terminology

Pollination	transfer of pollen from anther to stigma.
Pollinator	the agent that transfers pollen, e.g. honeybee.
Fertilization	fusion of male and female gametes inside the embryo sac; takes place only after successful pollination.
Self-pollination	transfer of pollen, by way of a pollinator, *within a flower*, or to another flower *on the same plant*, or from one plant to another *of the same cultivar*.
Cross-pollination	transfer of pollen from one flower to another on a *different plant* of the same species, or to another flower of a *different cultivar* or *different breeding line*.
Self-compatible	fertilization and resultant fruit or seed set with *own pollen* (same cultivar). Bees are nevertheless still needed for pollen transfer. Examples are some old pear, apple and cherry cultivars.
Self-fruitful	a cultivar that sets and matures a *commercial crop* of fruit or seed, either with its *own pollen* or *parthenocarpically*.
Self-incompatible	no fruit or seed set with self-pollination; inter-planted *pollinizers* with compatible pollen are needed for *cross-cultivar pollination*. Most modern apple, pear and plum cultivars are self-incompatible.
Polliniser	male parent or *pollen source* for pollination of self-incompatible cultivars.
Cross-compatible	cultivars that set a commercial crop when two or more are properly *inter-planted for cross-pollination*; they are cultivars with *compatible pollen*.
Cultivar	from c**ulti**vated **var**iety, i.e. crop plants and ornamentals selected or bred by man.

unavailable or unrewarding, and will only "switch off" this forage if markedly better forage becomes available. Individual honeybee foragers will also tend to work in a small forage area of about $10m^2$, returning to the same tree or to adjacent ones on successive foraging trips. **This also means that in the repeated use of the same colonies for pollination, colonies should be moved a minimum of 3km, to prevent foragers returning to the old colony position.**

In summary: Relatively few foragers from any colony will be active on the relatively poor quality deciduous fruit crop but those that there are will not readily leave. If they do, however, they will not easily return. All efforts at management to improve commercial pollination should bear these principles in mind.

Pollination Principles

Making arrangements for insect pollination is standard practice in the growing of many crops. Scientific information on the management practices to be followed is very limited and is largely based on experience and anecdotal evidence. Furthermore, there is very little local information available and most data is from temperate regions. The following are the suggested best management practices for commercial pollination in deciduous fruit orchards in South Africa, based on available information, and with the objective of optimal delivery of the correct pollen to the target crop.

When: It has generally been considered best practice to introduce honeybee colonies at 20-30% blossom. However, because flowers are often most receptive on the day that they open and are often only receptive for 2-3 days, and because recent data indicates that colonies require at least 24 hours to settle down and resume normal foraging after introduction, it is **recommended that colonies be introduced at 10% blossom**. There is also no value in keeping honeybee colonies in the orchard for longer than is needed, and **colonies should be removed as soon as possible after full bloom, and by 30% petal drop at the latest.**

Where: Conventional wisdom is that honeybee colonies should be **placed in the full sun or semi-shade, protected from the wind, and placed on stands of some sort to keep them off the damp ground**. Recent data suggests that this is less important than previously imagined. Common-sense should prevail. In extremely cold conditions, bees should be placed in the full sun; under very hot conditions, in the shade. Semi-shade is probably best for non-extreme conditions. The site should always be dry and out of the prevailing wind. It is apparent that intra-hive conditions, in particular ventilation, will have a significant impact on foraging rates. The type of hive material used (marine-ply, pine) and size of the colony entrance are most important (Figure 2). A poorly ventilated or overly insulated hive might hive difficulty keeping cool in the heat of the day, resulting in bees clustering outside the hive to keep cool, and this reduces foraging rates. Similarly for overly ventilated or under-insulated hives during the early morning or evenings. **The condition and type of hives used should be considered in determining the optimum position to place the hives.** Also take into account the movement of people, animals, vehicles and the planned spray programme in the placement of colonies.

Fig. 2 *The type of hive material, and size of colony entrance, are most important*

It is recommended that **colonies should be placed singly or in small groups of 2/3 colonies, and evenly distributed** around the orchard. Where possible, colonies should be placed **near pollinizers**, to facilitate cross-pollination. Colonies should be **placed at the end of rows of trees**, particularly with hedgerow systems, as bees forage down rows and are **10-30 times more likely to move to the next tree in the row than to move between rows**. Where possible, place colonies away from the immediate edge of the orchard, as this helps in the dispersal of foragers throughout the orchard. Colonies, however, should be placed no further than **100m of the target crop** as the numbers of foragers decreases rapidly with distance, especially in bad weather, and there should not be windbreaks between the colonies and the target crop. If rows are greater than 100m in length, colonies should be placed at both ends.

How: Honeybee colonies should be introduced **at night** whenever possible, or in bad weather conditions when no or a minimum of bees are foraging, and with **traveling screens or other means of adequate ventilation** to prevent over-heating and to allow colonies to settle down and resume foraging as quickly as possible. Each time a colony is moved there are forager losses and a decrease in the strength of the colony and it is recommended that colonies are used **not more than three times** for deciduous fruit pollination during a season.

How many: It makes little sense to have hard and fast rules as regards the numbers of honeybee colonies needed for the pollination of a particular crop, as the numbers of foragers needed is influenced by the cultivar type, the age of the trees, by the weather and by local conditions. There is little hard data on the number of colonies needed, or the direct impact of increasing colony numbers, and most recommendations are based on experience and assumptions. The critical factor is the numbers of blossoms in the orchard, and ensuring that **sufficient honeybee foragers are present for multiple visits to each flower.** Standard recommendations regarding the numbers of colonies needed are presented in Table 1, but it should be remembered that the more colonies present the more foragers there are available, and it is better for a crop to be too heavy than too light.

Waves: It is recommended that difficult cultivars such as 'Packham's Triumph' receive **two waves of honeybee colonies for pollination**, the first at 10-20% blossom and the second at 60-70% blossom and no more than 7 days later. The rationale is that the "naïve foragers" of the first wave will work on the pear blossoms for only a few days and will then "switch-off" and begin working on more attractive alternative forage in the vicinity. Hence the second wave, to introduce a second set of naïve foragers to prolong the foraging on the pears. The value of sequential colony introductions is **presently being carefully researched**, and it is clear that honeybee foragers do not abandon pear blossoms as readily as was supposed. Results regarding the use of two waves in pear pollination obtained during the 2004 and 2005 seasons have been somewhat contradictory to established principles, and if confirmed, these practices might need to be revised.

Competitive forage: Many weeds common in orchards, such as the Cape Weed (Gousblom), “bloublommetjies” (*Echium)* and Wild Radish (Ramenas), are highly attractive to honeybees and offer better rewards than do deciduous fruit flowers, especially pear blossom. These weeds as well as any other attractive bee forage should be removed to prevent them drawing foraging bees away from the target crop. Recent data suggests that it is not critically important that ALL alternative forage be removed because some foragers attend to the fruit blossoms even in presence of more attractive alternatives. Excessive alternative forage will present a problem, however, and **alternative forage should be removed as far as is feasible**. Chemical control of weeds can be practiced before blossom time, but thereafter mechanical control should be used.

Pesticides: In any discussion on the impact of pesticide application on honeybees during commercial pollination two factors should be remembered. Namely, that deciduous fruit flowers are relatively unattractive to honeybees and secondly, that honeybee foragers discouraged from foraging in an orchard because of the application of a pesticide will not readily return after they have “locked onto” an alternative forage source. It follows that while it is accepted that modern agriculture requires pest control, it is probable that **all pesticide applications immediately before or during blossom time are disadvantageous** to the bees used for pollination, or to the pollination process. Great care should be taken in the choice of pesticides, and in the decision to spray, and the question should also be asked: **IS THIS ABSOLUTELY NECESSARY DURING BLOSSOM TIME?** If pesticide applications are unavoidable, use the least toxic or repellant pesticide or formulation available, and apply at night and away from the honeybee colonies to have as little effect as possible. Try not to spray anything in the first 3 days after the introduction of honeybees, and do not keep colonies in orchards longer than necessary.

Different classes of pesticides have differing effects on honeybees and on pollination. All pesticides have been classified as either **harmless to honeybees**, **moderately harmful to honeybees**, or **extremely harmful to honeybees**. If there is uncertainty of the bee hazard classification of a remedy the registration holder of such remedy should be contacted. Products extremely toxic to foraging honeybees may cause a knockdown of foragers in the orchard, or mass mortality at the colonies. Large numbers of dead bees on the orchard floor, or large numbers of crawling bees around the colony entrance, are almost always the result of pesticide poisoning. The use of insect growth regulators or microencapsulated insecticides may be equally deleterious to honeybees, and in all cases the use of such harmful products should not take place until honeybee colonies have been removed from the vicinity. Moderately harmful pesticides will typically cause some mortality in the colonies which will normally disappear after 24 hours, and can be used without removing the colonies from the orchard. Application should be at night to lessen the effect.

Products often regarded as harmless to honeybees (e.g. herbicides, fungicides, foliar sprays) may have a **repellency effect**, retarding the entry of foraging bees into the orchard and resulting in them failing to return. Practically anything can have a repellent effect on foraging bees, even the spraying of water. Although the honeybee colonies are seldom negatively affected by repellency, the result of repellency is a decrease in pollination efficacy and a reduction in fruit set.

Three final factors should be considered with regards to pesticide applications. Firstly, remember your **neighbour**. The application of a toxic pesticide may result in honeybee mortality in neighbouring orchards or properties, even if the colonies from the target orchard have been removed. Secondly, remember that successful pollination is the result of **co-operation between grower and beekeeper**, who should be informed timeously and in detail about all pesticide applications. Finally, be aware that spraying before and after bee introduction may cause damage to “natural” pollinators and beneficials, reducing future pollination potential.

Pollinisers: As almost all modern cultivars of deciduous fruit are self-incompatible, having the correct pollinisers in an orchard is critically important in setting an economic crop. The most critical factor in the choice of cultivar is overlapping flowering time; if anything, the polliniser should finish flowering just before the main cultivar finishes. As cultivars can vary greatly in terms of nectar quality and quantity, it is also important that the polliniser and the main cultivar are similarly attractive to honeybees, to facilitate cross pollination. **The best planting pattern of the pollinisers in the orchard has been the subject of much debate and is presently being researched**, but as yet there is insufficient data to deliver definitive answers, particularly with the hedgerow systems now being used. What is clear, however, is the tremendous local effect of pollinisers on fruit set. John Free (1962) demonstrated that the fruit set on the near-side of trees adjacent to a polliniser was far greater than the fruit set on the far-side of the same trees (Figure 3), proving that even a small increase in distance from the polliniser results in a significant decrease

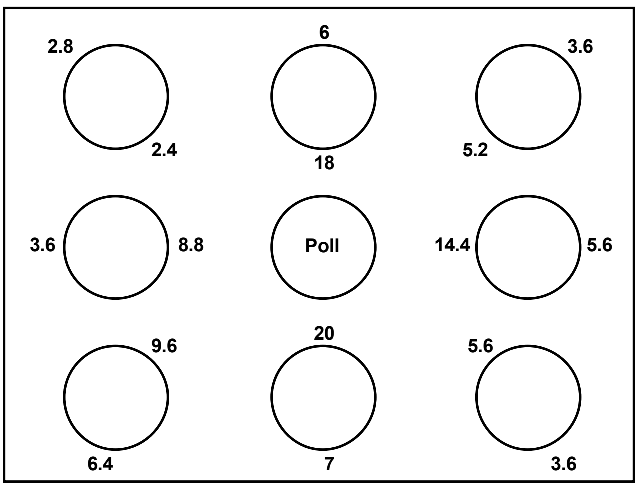

Fig. 3 *The average percentage of fruit set in Cox apples with a Worcester polliniser (from Free 1962)*

in fruit set. Similar results were obtained by Anderson (1985) in South Africa with fruit set on the near-side of the polliniser being 22% greater than that on the far-side. As distance from the polliniser is obviously critically important in fruit set pollinisers should be evenly distributed in the orchard as far as possible, and as abundant as is economically feasible. For orchards with insufficient or poorly positioned pollinisers, the only short-term solution is increasing the numbers of pollinators (honeybees) in the orchard during blossom. The extremely significant impact of distance from the polliniser on fruit set and the difficulty in providing sufficient pollinisers in an orchard suggest, however, that emphasis should be placed in developing more effective long-term methods in distributing polliniser pollen throughout the orchard.

A Joint Venture

First and foremost, it should be remembered that successful commercial pollination requires **co-operation between beekeeper and grower**. Each has responsibilities and duties, and successful pollination depends on both parties. It is incumbent on a beekeeper to provide honeybee colonies for commercial pollination that are of a certain standard, and that will deliver the quality of service expected by the grower. It is advisable that the grower and the beekeeper have a **written contract** specifying the **minimum colony standards** allowable and procedures for colony inspection, as well as other factors such as time of delivery, notification periods, allowable pesticide applications and liability in case of default. An example of a pollination contract is available of the DFPT website. It is also recommended that the grower requires the beekeeper to be a **registered member of the South African Bee Industry Organization (SABIO)** and subject to that organization's codes of conduct, not only in terms of pollination standards but also with respect to in-hive pesticide applications and general environmental accountability.

The responsibilities of growers and beekeepers are listed in Table 2. The hives to be used for pollination should be specifically and properly prepared by the beekeeper for that purpose. That means that the colonies should be equalized in strength, old frames removed and replace with new ones, surplus stored honey and pollen removed, and if necessary, the queen stimulated to begin laying by stimulatory feeding. For optimum pollination returns, colonies should be in a growth phase when introduced into orchards. The guiding principles for growers is at all times avoid practices that are harmful to honeybees and other pollinators, to do everything possible to increase the attractiveness of the target crop to pollinators, and to facilitate the successful introduction into the orchards of honeybee colonies by beekeepers. Growers should remember that beekeepers are normally introducing honeybee colonies through the night during pollination season, and are seldom able to visit all farms before pollination to ensure the best sites for their bees, nor visit farms to protect or manipulate their colonies to counter any problems that arise.

In addition to assisting the beekeeper in the delivery of quality pollination services, the grower needs to consider **aids to pollination** so as to further improve the service. Many **pollination enhancement** methods have been tried, mostly with little success. Growers should also reflect that there is only so much that can be done in terms of manipulating honeybees to improve pollination, and other efforts need to be made to achieve **long-term improvements**.

> **Bouquets**, **grafts** and **pollinisers in pots**. All should be regarded as emergency measures and at present are not recommended on a large scale.
> The application of **bee attractants or bee lures.** Many products have been developed and applied to flowering orchards in an effort to make orchards more attractive to honeybees and to improve pollination and fruit set. **Scented sprays**, designed to "direct" foragers to a particular blossom type, uniformly failed to deliver any increase in forager numbers, nor any increase in fruit set. **Carbohydrate based sprays**, such as honey or fruit juice dramatically increase the numbers of foragers in the orchard, creating the impression of improved pollination, but generally do not increase the numbers of foragers on the blossom and normally result in a small decrease in fruit production. **Pheromone based sprays** are also unproven. At present all bee attractants should beregarded as **essentially ineffective**.
> **Pollen inserts** have been developed that are placed on hive entrances so that all departing foragers are covered in polliniser pollen, thus ensuring that every forager is an effective pollinator. Despite some positive results, the use of these devices has been beset by logistical difficulties, and they have not reached widespread acceptance.

Table 2. *Responsibilities of beekeepers & growers.*

FOR THE BEEKEEPER	FOR THE GROWER
> Colonies in standard Langstroth brood chambers, preferably with a minimum of **8 frames of bees** and **4 frames of brood,** of which 2 frames should be open brood. > If necessary, beekeepers are expected to feed their colonies dilute sugar water before pollination to stimulate queen laying and brood production. The presence of open brood in colonies increases the demand for pollen, and hence stimulates pollen foraging and improves pollination and fruit set. > An **active, laying queen**, indicated by the presence of open brood. > Essentially **disease-free** with a maximum of 5 varroa mites per 100 bees sampled and with no more than traces of European Foulbrood or Chalkbrood. > Removal of excess stored pollen and honey in the brood chamber. > Introduced with a **traveling screen** or other ventilation, in leak-proof hives. > Placement and removal of hives as agreed. > Rapid response to any reported problems.	• Prepare and maintain **good access roads** to the orchards, allowing the colonies to be introduced at night with a minimum of problems. • Prepare **good hive sites** for the beekeeper in the sun or semi-shade, protected from prevailing winds, and with stands to protect the colonies from the cold and damp. • Give the beekeeper **advance warning** as far as possible as to when the colonies will be required, and the numbers of colonies that will be needed, and early reporting of any problems. • Ensure there is **water** within 250m of the colonies, and **control ants & other pests** that might attack and disrupt the honeybee colonies. • **Eliminate alternative forage** as far as possible to direct the honeybees to the target crop (weed control). • Use **pesticides as sparingly as possible**, always using the least harmful pesticide or formulation, and always **notify** the beekeeper as to what will be used. • Enough and correct pollinizers and correct orchard design. • Security of hives.

They are presently being researched to determine their true potential.

> Many serious pollination problems are the result of nectar and pollen rewards in deciduous fruit cultivars being of limited reward, and long-term solutions need to focus on the **breeding** of cultivars that are more attractive to honeybees and other pollinators, so as to enhance pollination.

Finally, it is an unfortunate truth that in many cases a grower attempts to accommodate pollination requirements only when the orchard is almost in bloom, and that there are few growers that consider pollination requirements during **orchard design**. It is often impossible to adequately site honeybee colonies for pollination given the structure of many present orchards. To improve the situation growers should consider where to place honeybee colonies and where to have pollinisers right from the outset, and plan accordingly.

Assessing Pollination

Growers are always concerned about the quality of honeybee colonies introduced for pollination, and wondering if they are delivering the service required of them. Common questions are, "how many bees should there be on my trees" and "how many foragers should there be from each colony?" As with the question as to how many colonies of bees should be introduced per hectare, there are no right answers to these questions as they are intrinsically linked to weather, local conditions and the forage available to the bees, as well as to the quality of the colonies. Nonetheless, **assessing the performance of honeybee colonies introduced for pollination as well as the success of pollination** should be a part of a growers' quality control.

- If there are insufficient bees departing from the colonies, the problem is probably due to the colonies themselves. They may be sited badly, preventing normal foraging, or may be of insufficient quality. Note that bee activity normally ceases or is much reduced below 15ºC. Dead bees around the colony will normally indicate if the absence of foraging has been caused by a pesticide application.
- If there are sufficient bees departing from the colonies, but insufficient bees on the target trees, this means either that the target trees are insufficiently attractive, or that there is too much alternative forage available, or that some application is keeping the bees out of the orchard. None of these are the fault of the beekeeper or the colonies.
- If there are sufficient bees departing from the colonies, and sufficient bees on the target crop, but inadequate fruit set and an insufficient number of seeds in most fruit, then once again the problem is not related to the bees but more likely to weather conditions, nutrients, or pollinisers.

A guideline of what can be expected from honeybee colonies during pollination, in all cases in good weather conditions (around 25ºC) and at 10h00, is as follows:

- **Foraging rate**: 120 foragers departing the colony in a 2 minute period is an acceptable average.
- **Bees per tree**: 6 bees per tree at any one moment in time is acceptable for apples and plums, and 3 bees per tree is acceptable for pears (in all cases, mature trees).
- **Acceptable fertilization**: 8 seeds per fruit is the objective for apples and pears, with 6 seeds per fruit being acceptable.

Pollination of crops under cover

Small but increasing volumes of deciduous fruit crops are produced under cover, primarily apples but also some plums, and mostly under shade netting. The reasons for the use of netting is to prevent damage from hail or rain, or to prevent sunburn of the fruit while improving fruit colour. While the use of shade nets does not provide pollinators (bees) with the scale of problems caused by tunnels or other enclosures, they can cause some problems to foraging bees and result in foragers becoming disoriented and causing bee losses. Good rules of thumb to follow are:

1) Have the shade net as high as possible; the lower the net, the bigger the problem for foraging bees.
2) Do not have nooks and crannies and gables and folds in the shade net, which will result in foraging bees being trapped. Rather have the net in a single plane.
3) Bee hives should be placed outside the orchards, and not under the shade netting.

Other factors influencing pollination

Foragers departing from honeybee colonies introduced for pollination may visit every flower in the orchard, may indeed visit each flower twenty times or more, and yet there may be very poor pollination and very poor fruit set. This is because there are many factors that influence the success of pollination other than the presence of sufficient honeybees. Foremost of these is the **weather**; bees and other pollinators need good weather to affect optimum pollination. Rain can wash away pollen, winds can dry out nectar, and rain and cold can prevent pollinators from flying. In addition, low temperatures can **retard pollen tube growth**, preventing the germination of the seed. When all is said and done, with all the multitude of factors that can affect successful pollination, favourable weather is the single most important, with probably only one single day of perfect weather needed for the setting of an adequate crop, especially for apples and pears, and assuming that all other pre-conditions (such as the sufficient of the correct polliniser) have been met.

There are many other factors that may influence pollination and fruit set and all need to be considered in successful crop production. Among others are:

> **Nectar quality** affects the attractiveness of flowers and the visitation rate by pollinators, and can often be influenced by trace elements such as potassium, and even by the amount of irrigation received.
> The **nutritional state of the trees**, which dictate the numbers of flowers produced, the quality of the flowers, as well as the pollen supply. Only good flowers will produce good fruit.
> **Poor pruning** which can prevent light reaching side branches, limiting the numbers of pollinators reaching these branches, and decreasing pollination.
> Some **fungicides** can kill pollen and retard pollination.
> **Crop loads** of previous years.

More information

Valuable information on the practical management of honeybees for the pollination of deciduous fruit crops may be found in the following books and on the following websites:

- *Beekeeping in South Africa*, 3rd Edition, 2001, edited by M F Johannsmeier
- *Insect Pollination of Crops*, 2nd Edition, 1993, John B Free
- *Insect Pollination of Cultivated Crop Plants*, 1976, S E McGregor, available in full and for free at http://bee.airoot.com/beeculture/book/index.html
- The pollination Home Page at http://pollinator.com/

Pollination Check List: *Principles and Actions*

Design & Plan for Proper Pollination (Orchard Design)	The correct pollinizers should be planted in the rows and as abundantly as is economically viable Hive site placement and road access at night should be planned during orchard design & layout Spray programmes should be sorted out and planned before each season starts
Establish Good Communication	Develop a mutually beneficial relationship with a reputable and knowledgeable beekeeper Use a written pollination contract Ensure spray supervisors adhere to the spray programme and communicate changes sufficiently beforehand
Acquire Good Bees	Use only healthy & vibrant honeybee colonies, and don't overuse colonies (no more than three times each) Hives should be properly managed for pollination and prepared / designed for adequate ventilation Hives should be transported with care, never moved less than 3 km at a time, and not moved once placed
Optimize the Number of Pollinators	Use the correct number of colonies as recommended for each crop & cultivar Introduce colonies in good time according to orchard-specific circumstances (allow 1 day to settle down) Consider using more colonies per shift and/or waves of colonies in difficult pollination circumstances
Optimize the Placement of the Hives	Place in the sun or semi-shade and protected from wind and damp Distribute colonies evenly around the orchard, singly or in small groups Place close to target crop, within 100 m, at row ends and not inside the orchard
Direct the Bees onto the Target Crop	Consider the repellency of pesticides and try not spray anything just before or just after introducing colonies Remove excess alternative forage from the near vicinity where possible Never introduce colonies before sufficient flowers (at least 10%) are open on the target crop
Protect the Bees	Manage the execution of the previously planned spray programme meticulously Spray only when necessary, after notifying the beekeeper, and using the safest method & product possible Take other flowering orchards, your neighbour's actions and other natural pollinators & beneficials into account
Manage the Pollination Process	Monitor the bee activity at the hives, in the orchard and in adjacent orchards or fields regularly Take weather conditions into account Contact the beekeeper immediately in case of a suspected problem

Pollinantion Management: *Scale unit = days (typical)*

0	BLOSSOM DEVELOPMENT	100														X	X	X	X	x	x	x	x	x	x
		90												X	X	X	X	x	x	x	x	x	x	x	
		89											X	X	X	X	x	x	x	x	x	x	x		
		70										X	X	X	X	x	x	x	x	x	x	x			
		60									X	X	X	X	x	x	x	x	x	x	x				
		50								X	X	X	X	x	x	x	x	x	x	x					
		40							X	X	X	X	x	x	x	x	x	x	x						
		30						X	X	X	X	x	x	x	x	x	x	x							
		20					X	X	X	X	x	x	x	x	x	x	x								
		10			X	X	X	X	x	x	x	x	x	x	x										
1	BLOSSOM %	0	2	5	10	15	20	30	40	50	60	70	80	90	95	96	97	97	98	98	98	99	99	99	99
2	BLOSSOM FALL %														5	10	15	20	30	40	50	60	70	80	90
3	EARLY BALLOONS	-4	-3																						
4	BEE VISITS				-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
5	ALTERNATIVE FORAGE RISK	-4	-3	-2	-1	0	1																		
6	NEW BLOSSOMS				-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13						
7	CROSS POLLINATION NEEDED						1	2	3	4	5	6	7	8	9	10									
8	POLLINATION WINDOW						1	2	3	4	5	6	7	8	9	10									
9	BEES IN / BEES OUT					0									9	10	11	12							
10	NO CHEMICALS - REPELLENCY		-3	-2	-1	0	1	2	3																
11	SAFE CHEMICALS ONLY									4	5	6	7	8	9	10	11	12							
12	CHEMICALS - AT NIGHT ONLY																		13	14	15	16	17		
13	CHEMICALS - WITH CARE	-4																						18	19

For more information, contact Mike Allsopp, Honeybee Section, ARC Plant Protection Research Institute.
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