Seminar report

POLLINIZERS – A CORNERSTONE IN FRUIT CROPS

By

Anju Jayachandran

(2018-12-008)

Presented on 06/12/2019

Submitted in partial fulfilment of the requirement for course

FLA 591: Master's Seminar (0+1)

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF HORTICULTURE

KERALA AGRICULTURAL UNIVERSITY,

VELLANIKKARA

THRISSUR, KERALA-680656

DECLARATION

I, Anju Jayachandran (2018-12-008) hereby declare that the seminar entitled 'Pollinizers – A cornerstone in fruit crops' has been prepared by me, after going through various references cited at the end and has not copied from any of my fellow students.

Vellanikkara | Anju Jayachandran
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CERTIFICATE

This is to certify that the seminar report entitled ‘Pollinizers – A cornerstone in fruit crops’ has been solely prepared by Anju Jayachandran (2018-12-008) under my guidance and has not been copied from fellow students.

Vellanikkara

25-01-2020

Dr. K. Ajith Kumar
Associate Director of Research
RARS Ambalavayal
Special officer, College of Agriculture,
Ambalavayal

CERTIFICATE

Certified that the seminar report entitled ‘Pollinizers – A cornerstone in fruit crops’ is a record of seminar presented by Anju Jayachandran (2018-12-008) on 08/11/2018 and is submitted for the partial fulfilment of the course FLA 591.

Dr. Anil Kuruvila

Professor

Department of Agricultural Economics

Dr. Reshmi Vijayaraghavan

Associate Professor

Dept. of Plant Pathology

Dr. Sangeetha kutty

Assistant Professor

Dept. of Olericulture

CONTENTS

List of tables

List of figures

Pollinizers – A cornerstone in fruit crops

1. Introduction

Pollination is a major phenomenon in flowering plants including horticultural crops which determine fruit set intensity and production efficiency. It involves effective integration of pollinator and pollinizer for sustainable crop production and diversity. A pollinator is an agent (bees, flies, birds, wind or water) that moves pollen from anther to the stigma of flower which leads to the development of fruits or seeds through fertilization. On the other hand, a pollinizer is the plant that serves as the pollen source for related plants for effective fertilization (Haldhar *et al.*, 2018). Some types of fruit trees may be pollinated with their own pollen and are considered self-fruitful. Other types of trees require pollen from a different variety of the same type of tree and are considered self-unfruitful or self-incompatible. They require cross pollination to produce seeds and fruit (Gregor, 1976). This problem can be overcome by the use of a suitable pollinizer that provides compatible, viable and plentiful pollen and flower at approximately the same time as the main commercial variety for effective pollination. Improving pollination can lead to increased production owing to larger and better-shaped fruit and/or a greater number of fruit per tree. Cross pollination is essential for Apple, Pear, Plum and Sweet cherry and hence they require mixed plantings of different cultivars for effective fruit-set (Raja *et al*., 2018).There are some fruit crops (Apricots, Nectarines, Peaches and Sour cherry) that are self- fruitful, but will set fruits more heavily and regularly if cross pollinated (Cory *et al*., 2016). Hence cross pollination necessitates the availability of sufficient quantity of compatible pollen which will be provided by the pollinizer cultivar since its flowering synchronises with the main cultivar and provision of bee hives ensures effective transfer of pollen for a satisfactory fruitset (Wani *et al*., 2019).

2. Conditions preventing self-pollination

1. Dioecious species - **Pistachionut, Kiwifruit, Date palm**
2. Dichogamy - **Plum (Protogynous)**
   Walnut (Protandry)
3. Heterostyly - **Almond (Thrum type)**
4. Pollen sterility - **Triploid apples, Pear**
5. Incompatibility - **Apple, Cherry and Plum**

3. Features of a good pollinizer variety

- The bloom of the pollinizer variety must overlap with the main variety.
- The pollinizer variety must have viable diploid pollen.
- It should produce pollen at relatively low temperature
- Not susceptible to pest and diseases
- Bees and other insects must be present in the orchard at the time of bloom and be active at bloom.

(Raja *et al*., 2018)

4. Pollinizer placement

The placement of pollinizers is very important in the orchard. Ideally, every tree in an orchard should be located as close as to a pollinizer tree. Closer a tree to a pollinizer, better the fruit-set will be. The preferred arrangement of pollinizers is in solid rows (Raja *et al*., 2018). One scheme is to alternate two rows of pollinizers between four rows of the major cultivar. In case of HDP every 6th tree should be pollinator. Pollinizers should be planted at proper ratio i.e. 11%, 15%, 25% and 33% for effective pollination (Pandith, 2014). It is important to locate them in such a way that a maximum number of trees can be planted for effective pollination. This means most rows have pollinizer. For most varieties, pollinizer trees should not be more than 100 feet apart (Way, 1978).

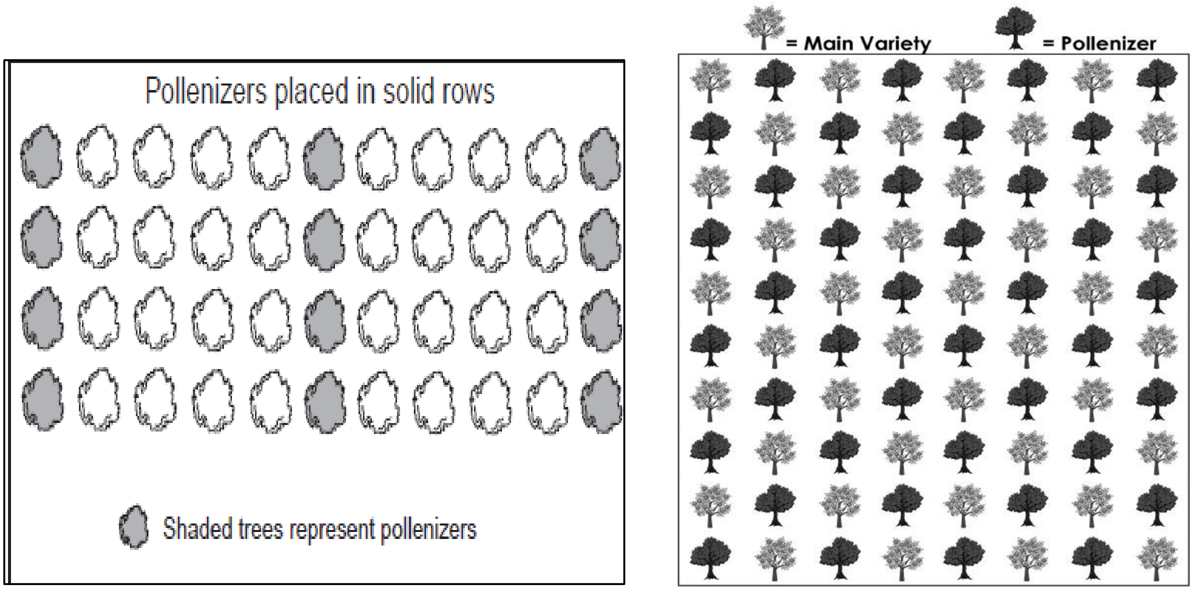


Figure 1. Pollinizer placement in an orchard

5. Pollinizer management

Modern, closely spaced, high density orchards in which the trees are allowed to form solid hedge row- like canopies can cause problem for cross pollination. Under such conditions, the pollinizer tree is trained to pillar shape so that there is little crowding of either the pollinizer or neighbouring trees. The pillar shape should be almost as tall as the main variety so that bees will fly from tree to tree throughout the foliage canopy, from pollen source to main variety etc. For wider planting system, the pollinizers are trained to central leader type for effective pollination.

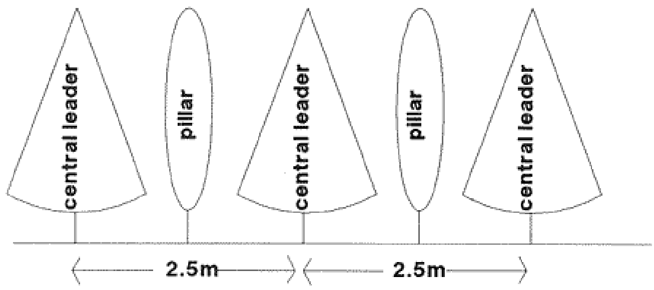


Figure 2. Management of pollinizer in an orchard

6. Temporary aids to pollination

Used when low temperature kill or delay the bloom on pollinizer variety or weather condition reduce honey bee activity

6.1. Top grafting of pollen source variety

If an orchard has not been provided with cross pollination at planting time, scions of Winter Banana or another good pollen source variety can be top grafted onto the main variety (Way, 1978). The fruits of Winter Banana has no market value and therefore will not be picked at the time of harvest. A pollen source can be quickly introduced into an orchard by top grafting than by planting new young trees. The disadvantage of this method is the necessity to clearly mark the limb to prevent it from being pruned out in the winter and mixing of fruits at the time of harvest.

6.2. Bouquets in the orchard

When there is no provision made for cross pollination from another variety, open fresh blossom of an appropriate pollen source are placed in bucket of water. Fifty five gallon metal drums cut cross-section-ally through their middle make good water containers that are about 18 inches deep (Way, 1978). Bouquets should be placed throughout the orchard; the more the better- at least one bouquet for every four trees. The use of bouquets is a poor substitute for pollinizers, and should only be considered as a temporary makeshift pollination system.

6.3. Use of pollen dispensers

It is a device fitted to the hive entrance and loaded with pre-collected foreign pollen. The use of pollen dispensers increased fruit-set level and average fruit weight. However, the method is not commercialized mainly due to the high cost of imported pollen and the high risk of pathogen introduction that goes along with it. Bees exiting the hive unwillingly pick up pollen and carry it to the flowers visited (Din *et al*., 2019).

7. Introduction of pollinators

Honey bees (*Apis mellifera*) has been recognized as the primary and most effective pollinating agent (Gregor, 1976). To ensure adequate pollination of plants that are benefitted by insect pollination, colonies of honeybees should be located in or near orchards or fields at the rate of one or more strong colonies per acre. Colonies are generally placed in groups of 10 to 20 in numbers in orchards and in larger groups for the pollination of field crops (Eckert, J. E. 1960). Sharma and Gupta (2001) have reported low fruit drop and increased fruit set in orchards with increased bee visits and placement of bee colonies.

Fruit crops	**Number (hives/ha)**
Apple	3-5
Pear	3-4
Peach, Nectarine and Plum	2-3
Cherry	2-3
Almond	5-8

Table 1. Number of hives per hectare for different fruit crops

8. Fruit-set and factors affecting it

Fruit-set is the transformation of ovary to a rapidly growing young fruit which is initiated by successful pollination and fertilization. In most plants even though every flowers are pollinated, fruit-set does not occur with all the flowers. There are some factors affecting fruit-set and it is categorized into two – Internal and External Factors.

8.1. Internal factors

8.1.1. Pollination

Successful pollination requires the transfer of pollen to the stigmatic surface followed by the adhesion of pollen grains to the papilla cells of the stigmatic surface (Dresselhaus and Franklin 2013). Pollinizers must produce sufficient quantities of viable and compatible pollen and flower at approximately the same time as the main commercial cultivar. There must also be adequate pollen vectors, usually insects such as bees, in the orchard at flowering time and the pollen must be sufficiently attractive to these vectors. Almost all apple cultivars are reported to be either self-incompatible or semi-compatible and require cross-pollination to set fruit in marketable quantities (Garratt *et al*., 2014). For commercial production, at least two cross-compatible cultivars with synchronous flowering are recommended (Banday and Sharma, 2010).

8.1.2. Stigmatic receptivity

It is the ability of the stigma to support pollen germination. Cessation of stigmatic receptivity has been associated with degeneration of stigma and rupture of papillar integrity in kiwifruits (Sanzol and Herrero, 2001). It was reported that the initial fruit set was highest for flowers pollinated at anthesis and 2 days after anthesis and significantly reduced after 4 to 6 days of anthesis. Fruit-set in kiwifruit was high, averaging 80% during the first 4 days following anthesis. However fruit set was decreased to 36% when flowers were pollinated 5 days after anthesis and fruit-set was practically nil after 7 days of anthesis. Thus, the effective pollination period (EPP) was limited to the first 4 days and the stigmatic receptive averaged 84% (Gonazel *et al*., 1995).

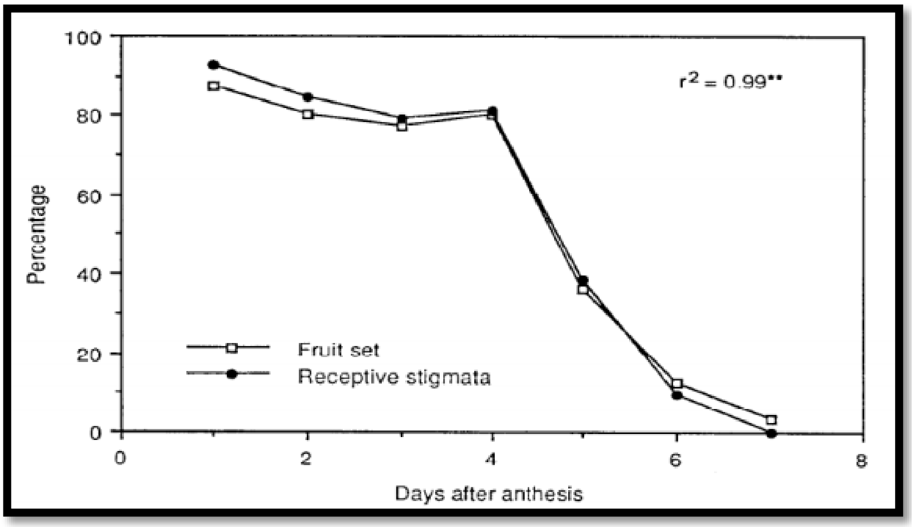


Figure 3. Stigma receptivity and fruit set in “Hayward” cv. of kiwi fruit

8.1.3. Incompatibility

Incompatibility is defined as failure of viable pollen to grow down the style of flower of the same variety (self in compatibility) or of the different varieties (cross incompatibility). Many cross-pollinating species exhibit self-incompatibility, so that fertilization by their own pollen is prevented. Incompatibility is a genetically controlled character manifested by the presence of multiple alleles. Self in compatibility is more common in fruit crops like apple, pear, sweet cherry, almond, avocado, fig, mango, citrus, olive, etc.

8.1.4. Non-viable pollen

It is due to non-functional pollen or the ovule. Non-viability of pollen results in unfruitfulness. Unfruitfulness in the case of Muscadine grape is due to defective pollen. Late flowering in apricot genotypes showed lower pollen viability than early flowering genotypes (Ruiz and Egea, 2008).

8.2. External/ environmental factors

8.2.1. Temperature

Among the external factors, temperature has a great importance. A period of cool, yet frostless, weather is conducive to better blossoming, fertilization and fruit set. However, the abscission of flower bud, fruit, etc. is a function of temperature.

Above 32°C, desiccation of the stigmatic surface and more rapid deterioration of embryo sac occurs (Jindal *et al*., 1993).). The optimum temperature for pollination and fertilization in temperate fruits like apple, pear, plum and cherry is between 20-25°C (Rai *et al.*, 2015). Temperature is important in bee flight. Bees will not fly well at temperatures below 10° C and increase their activity as temperature increases around 19°C. As temperature increases, ovule senescence become faster in 'Italian' than in 'Brooks' cultivar of plum. At 15°C, only one ovule per flower remains viable by 8 DAFB for Italian, whereas for 'brooks' cultivar, higher temperature results to a decrease in ovule longevity (Moreno et al., 1992). The polythene cage induced a mean increase in the maximum temperature of 7.6°C (warm treatment). Rodrigo and Herrero (2002) observed that in the control treatment, most of the flowers (92%) had morphologically well-developed pistil, while in warm treatment, 33% of the flowers had pistils that are not completely developed and 13% of the flowers shows short styles and unswelled ovaries in Apricot cv. Moniqui.

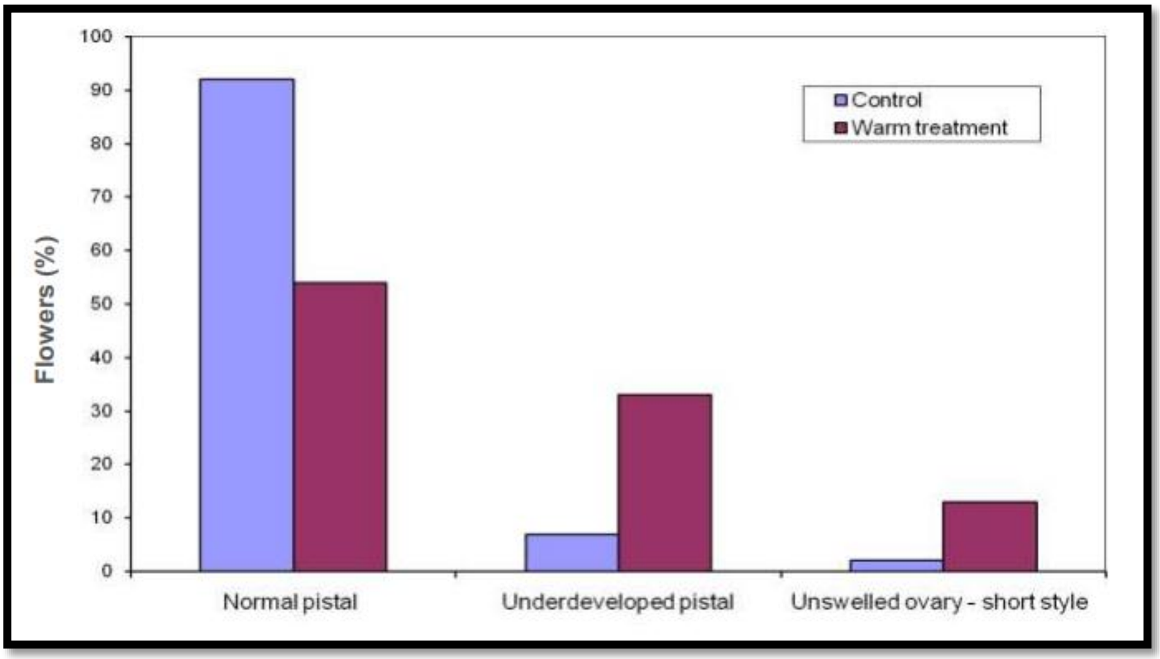


Figure 4. Percentage of flowers with different pistil morphology in Apricot cv. Moniqui in control and warm temperature

8.2.2. Humidity

Low atmospheric humidity causes drying of stigmatic secretions. Wet and humid weather favours anthracnose and poor fruit set in mango. The poor germination of pollen in almonds is attributed to damp weather during fruit set.

8.2.3. Rain

It directly affects fruit setting by distributing the process of pollination and germination of pollen grains and staminal fertilization. Rains at the time of blooming period causes unfruitfulness by washing pollen grains, inhibit pollinators and cause spread of diseases and pests. Every fruit species need a specific time period without rains at the time of blooming for successful pollinations. In almond, rain decreased the number of germinated pollen grains on the stigma and affected adhesion in forthcoming pollinations (Ortega *et al*., 2007).

8.2.4. Light

Light affects fruitfulness indirectly by its effect on photosynthesis. Light is a pre-requisite for photosynthesis and low light intensity or its duration reduces the carbohydrates reserves in the trees. In addition to this, poor light conditions promote fruit abscission.

8.2.5. Wind

Wind also affects the fruitfulness indirectly by its effect on the pollinating agents, that is, it controls pollination either by promoting wind pollination or by checking insect pollination. Bees travel shorter distances during windy weather (Warmund, 1914). Speedy winds cause ovary abortion and also make the stigma dry (Gardner, 1952).

9. Pollen compatibility

Varieties that are closely related (i.e., with similar parentage) are not the most effective pollinizers for each other. For example, Cripps Pink is only a fair to average pollinizer of its parents, Lady Williams and Golden Delicious. Varieties that are sports (derived from mutations) of the same parent variety are considered to have incompatible pollen and cannot be used to pollinate one another. For example, Royal Gala will not pollinate Gala or Galaxy. Triploid varieties such as Mutsu, Jonagold, Gravenstein and Baldwin have sterile pollen and cannot be used as pollinisers and therefore they must be pollinized with viable pollen from diploid variety (Way, 1978).

10. Compatible varieties and pollinizers for apple

Pollination is one of the keys to profitable apple production. Therefore it is important to select a pollinizer variety which has compatible pollen and an overlapping flowering period. Apple varieties are generally self-unfruitful and do not fruit by their own pollen due to the antagonism that prevents pollen grains from growing on to stigmas of the same variety.

Genetically apples show gametophytic self-incompatibility which necessitates the pollen transfer from another pollinizer variety to set fruit in marketable quantities. For cross pollination to be effective it is very important that the cultivars bloom at approximately the same time, produce the sufficient quantity of viable, compatible pollens. Although some apple varieties, such as Lodi, Liberty, Empire, Winesap, Jonathan, Jonagold, Gala, Golden Delicious, Rome and Granny Smith may be listed as self-fruitful, they will set more fruit if they are cross-pollinated. Some apple varieties such as Winesap, Stayman, Mutsu and Jonagold, produce sterile pollen and therefore cannot be used to pollinate other apple varieties (Warmund, 1914).

Season	**Main Variety**	**Pollinizers**
Early season	Irish Peach, Early Shanburry, Mollies Delicious, Early Red One	Tydeman's Early Worcestor, Summer Queen
Mid season	Oregon Spur, Red Chief, Red Spur, Top Red, Vance Delicious	Sparten, McIntosh, Lord Lambourne
Late season	Royal Delicious, Red Delicious, Ambri, Rich-a-Red, Lal Ambri	Golden Delicious, Golden Spur, Granny Smith

Table 2. Compatible apple pollinizers for commercial apple varieties

10.1. Evaluation of crab apples for apple production in high-density apple orchards

(Kwon *et al*., 2015)

'Fuji', 'Hongro', and 'Tsugaru' apple cultivars were used in this study along with three blooming crab apples ('Maypole', 'Tuscan', and 'Manchurian') were selected. Their cultivar characteristics were compared with those of the known pollinizer cultivar, 'Manchurian'.

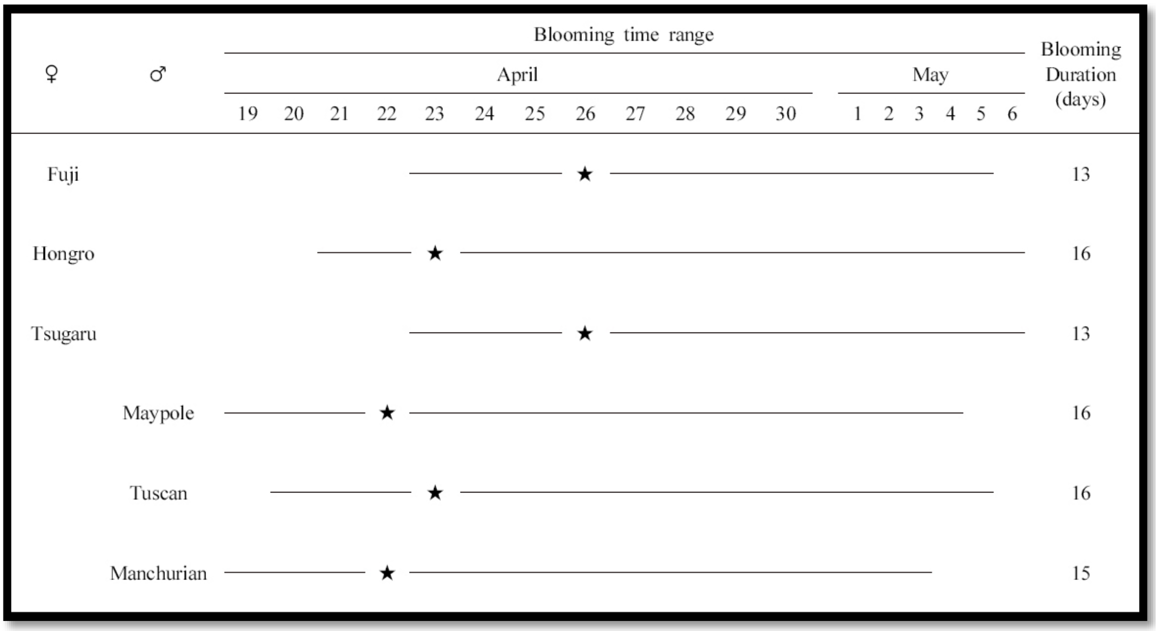


Figure 5. Flowering time for crab apples and major apple cultivar

A solid line (-) indicates blooming time period. Stars (★) indicate the date of full bloom

The flowering periods of the ‘Maypole’ and Tuscan’ cultivars lasted 16 days, which was one day longer than that of the well-known pollinizer cultivar ‘Manchurian’, because ‘Maypole’ and ‘Tuscan’ exhibited flowering times similar to or faster than those of common apple cultivars, these two crab apple cultivars are good pollinizer candidates for ‘Fuji’, ‘Hongro’, and ‘Tsugaru’.

10.1.1. Pollen properties of the flowering crab apples

Crab apple cultivar (Pollinizer)	**Anther number per flower**	**Pollen germination rate (%)**
Maypole	16.0	52.5
Tuscan	17.8	59.5
Manchurian	18.5	80.6

Table 3. Pollen properties of three different crab apple pollinizers

According to Florin's classification (1927) 30-70% is considered as good. 'Maypole' and 'Tuscan' are good pollinizers for major apple cultivars, as their pollen germination rates are both over 52%.

10.1.2. Fruit set rate of the apple cultivar by the flowering crab apple

♀ / ♂	Fruit set rate (%)		
	Fuji	Hongro	Tsugaru
Maypole	78	70	71
Tuscan	67	77	64
Manchurian	74	80	68

Table 4. Fruit set rate of different apple varieties by three different pollinizers

Ha and Shim (1995) reported that when pollinizers produced a fruit set rate of about 60%, it can be considered high enough for agricultural purposes, as 30-40% of fruit are pruned away after fertilization. Thus, with respect to fruit set rate, 'Maypole' and 'Tuscan' are both suitable pollinizers for the 'Fuji', 'Hongro', and 'Tsugaru' cultivars.

'Maypole' and 'Tuscan' crab apples could meet the pollinizer requirements suggested by Dennis (2003), including synchronized flowering time and cross-compatibility with cultivars. Thus the use of the pollen of these crap apples in commercial production will improve fruit quality and promote sustainable and robust fruit production.

11. Compatible pollinizers for pear

Sl. No.	Cultivars	Pollinizers
1	Bartlett	Anjou, Bosc, Comice, Conference
2	Bosc	Anjou, Bartlett, Comice, Seckel

3	Comice	Anjou, Bartlett, Bosc, Seckel
4	Anjou	Bartlett, Bosc, Comice, Seckel
5	Seckel	Bosc, Comice
6	Conference	Anjou, Bosc, William, Jules Guyot

Table 5. Pollinizers for different pear varieties

12. Compatible pollinizers for plum

Sl. No.	Cultivars	Pollinizers
1	Burbank	Satsuma, Shiro, Santa Rosa
2	Santa Rosa	Satsuma, Shiro, Burbank
3	Satsuma	Santa Rosa, Shiro, Burbank

Table 6. Pollinizers for different plum varieties

13. Compatible pollinizers for sweet cherry

Sl. No.	Cultivars	Pollinizers
1	Bing	Sam, Van, Montmorency, Rainer, Stella
2	Lambert	Sam, Van, Stella, Compact Stella
3	Rainer	Sam, Van, Bing, Lambert, Montmorency, Stella

Table 7. Pollinizers for different sweet cherry varieties

14. Pollinizers for almond varieties

Sl. No.	Cultivars	Pollinizers
1	Makhdoom	Shalimar and Waris
2	Shalimar	Makhdoom and Waris
3	Waris	Shalimar and Makhdoom
4	Parbat	Makhdoom
5	Peerless	Non-Pareil

Table 8. Compatible pollinizers for different almond varieties

15. Pollinizers for kiwifruit

Sl. No.	Pollinizers
1	Tomuri, Matua
2	Allison, Chico Male
3	Blake (Hermaphrodite cultivar)

Table 9. Compatible pollinizers for kiwifruit varieties

15.1. The effect of pollen donor on fruit weight, seed weight and red colour development in *Actinidia chinensis* 'HORT22D'

(Seal *et al*., 2016)

Kiwifruit cultivars may be diploid, tetraploid or hexaploid. Kiwifruit vine produces either male or female flowers so the planting of both male and female vines in the field for pollination is very important. Pollination of kiwi strictly depends on vectors like honey bees and wind. Kiwifruit produces no nectar and requires a high level of pollen transfer to produce a properly sized and shaped fruit. Another problem is that female flowers produce 'fake' pollen to attract insects. It is not the same as male pollen because it does not contain genetic material or food.

The recent development of red-fleshed kiwifruit (Wang *et al*. 2003; Zhong *et al*. 2007) offers new opportunities to diversify and expand the market. A red-fleshed cultivar must produce fruit with a significant and consistent amount of red pigmentation, as well as meet all other commercial requirements in terms of fruit size, eating quality, yield, disease resistance and storage life to be successful.

Vines of red-fleshed diploid *A. chinensis* 'Hort22D' were hand pollinated with pollen from three males: 'Bruce' (diploid *A. chinensis*), M248 (tetraploid *A. chinensis*) and 'Chieftain' (hexaploid *A. deliciosa*). The resulting fruit were evaluated at four dates (77 days after pollination (DAP), 105 DAP, 131 DAP and 167 DAP) through the growing season and after storage.

15.1.1. Fruit weight

For all pollen treatments, the mean fruit weight increased steadily over the sampling period. By the final harvest date, fruit from pollination by 'Bruce' weighed 28 g (38%) more, and fruit from pollination by M248 weighed 15 g (21%) more, than those from pollination by 'Chieftain'.

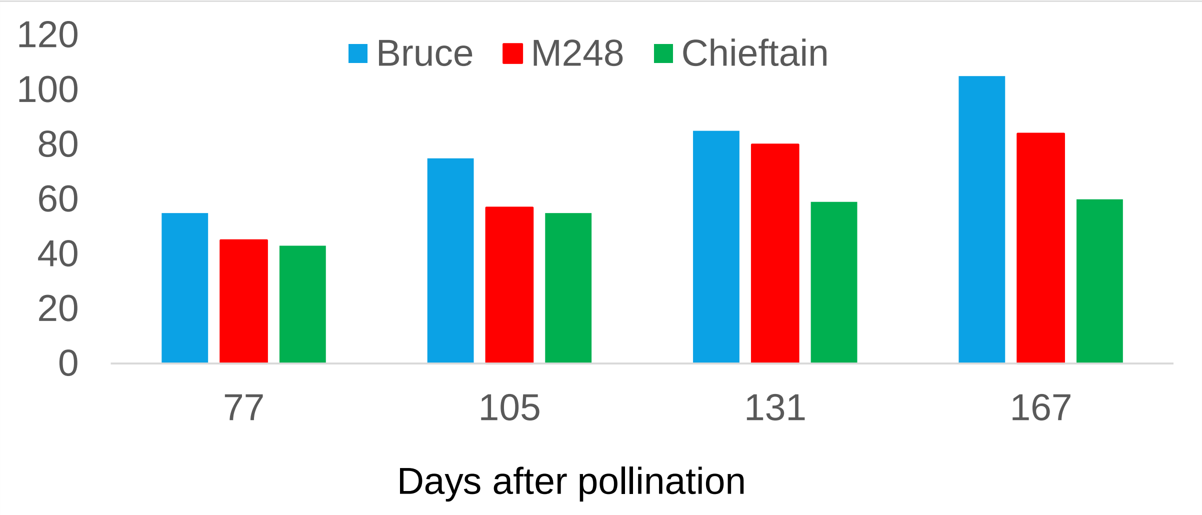


Figure 6. Effect of pollen donor on fruit weight in kiwifruit

15.1.2. Seed number, individual and total seed weight

Pollination by 'Bruce' pollen also produced the highest number of seeds per fruit, but the differences among pollen donors were not statistically significant.

Among the stored fruit, the mean total and individual seed weights were significantly higher following pollination by 'Bruce' than following pollination by M248 or 'Chieftain'

Pollen source	Seed number	Individual seed weight (mg)	Total seed weight (g)
Bruce	748	1.17	0.88
M248	626	0.30	0.17
Chieftain	660	0.13	0.09

Table 10. Effect of pollinizer on seed number and total seed weight in kiwifruit

15.1.3. Red pigment analysis

The total anthocyanin concentration increased, then declined through the sampling period. Pollen donors were most pronounced at the second sampling date (105 DAP), when the anthocyanin concentration of fruit from pollination by 'Bruce' was nearly four times that of fruit from pollination by 'Chieftain' and nearly twice that of fruit from pollination by M248. By the final harvest (167 DAP), these differences had diminished, but the anthocyanin concentration of fruit from pollination by 'Bruce' was still significantly higher (by 47%) than that of fruit from pollination by 'Chieftain'. After 24 weeks' storage at 1 °C, the intensity of red colour in fruit from 'Chieftain' pollination still appeared to be slightly weaker than that in fruit from pollination by 'Bruce' or M248.

16. Pollinizers for Avocado

Cultivar	Pollinizer
Hass	Fuerte, Sir Prize
	Nobel, Marvel
	Bacon, Ettinger

Table 11. Compatible pollinizers for Avocado cv. Hass

16.1. Selection of potential pollinizers for 'Hass' avocado based on flowering time and male–female overlapping

(Alcaraz *et al*., 2009)

Avocado is an evergreen subtropical fruit tree that has protogynous diurnally synchronised dichogamy breeding system that promotes cross pollination. Each perfect flower opens twice, the first functionally as a female flower; then the flower closes and the following day the flower reopens functionally as a male flower with the stigmas no longer receptive and dehisced anthers (Davenport, 1986). The most widely grown cultivar worldwide is 'Hass' and 'Fuerte' is the most commonly used as pollen donor. However, 'Fuerte' is currently of less commercial interest. Hence it is necessary to find an alternative pollinizer for 'Hass'.

Pollinizer used in the study were 'Nobel', 'Marvel' (selected on the basis of monitoring) and 'Fuerte' (most common cultivar used as pollen source)

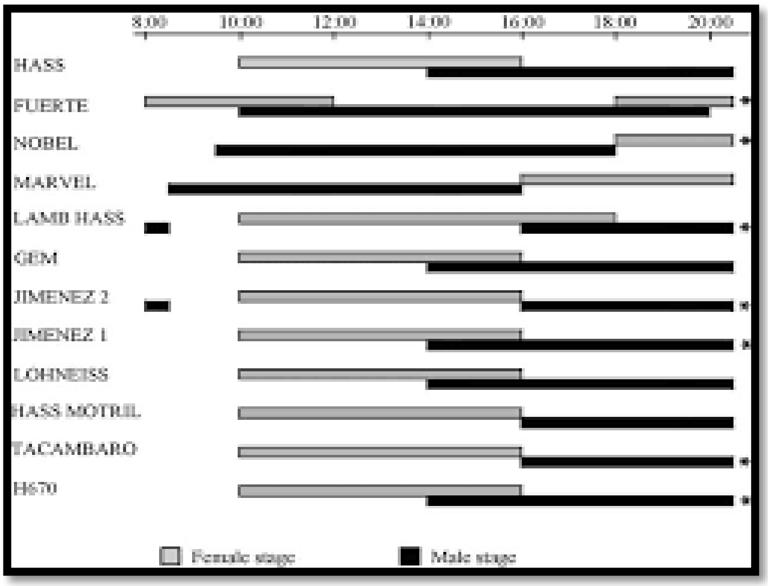


Figure 7. Daily flowering cycle of different genotypes of avocado

16.1.1. Flowering phenology

Full bloom for most genotypes occurred during April, displaying a good overlapping with 'Hass'. However, full bloom of 'Fuerte', the most commonly used pollinizer for 'Hass' in Spain, only showed a good overlapping with 'Hass' during the first half of 'Hass' full bloom; consequently it will be of interest to find additional pollinizers for the second half of the 'Hass' flowering period.

When compared with ‘Hass’, ‘Marvel’ had a similar blooming season and an overlapping with ‘Hass’ flowers could be observed during the first morning hours

16.1.2. Fruit set in avocado

The final fruit set was 2.8%, 7.4% and 8.4% for ‘Fuerte’, ‘Marvel’ and ‘Nobel’ respectively.

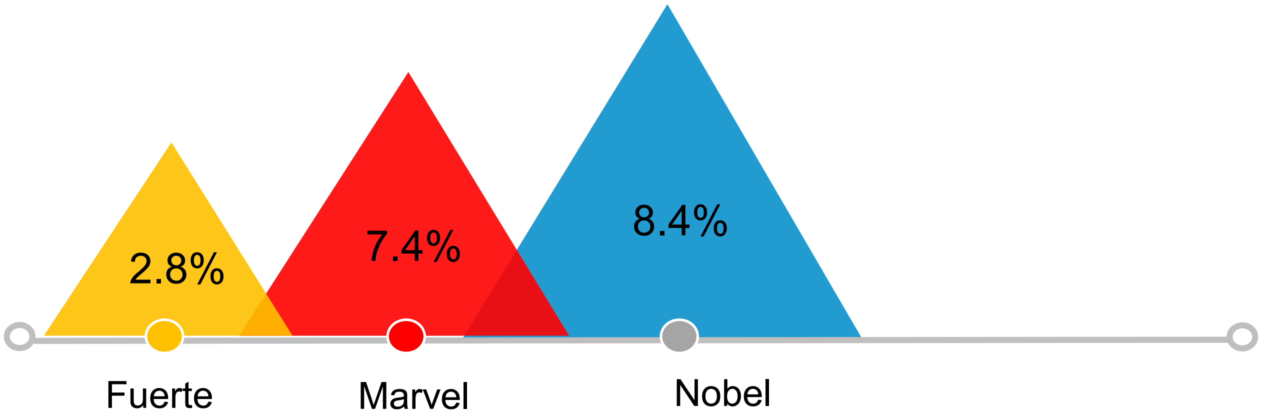


Figure 8. Effect of pollinizers on fruit set in avocado

The results reveal that ‘Fuerte’ is less efficient than the other two pollinizers for ‘Hass’ under our growing conditions. Taking the flowering phenology, the overlap in sexual stages and the fruit set obtained, an alternative to the current use of ‘Fuerte’ as main pollinizer in the avocado orchards would be to combine some ‘Fuerte’ trees which will pollinate during the first two weeks of the flowering of ‘Hass’, with other type B genotypes such as ‘Nobel’ and/or ‘Marvel’. This mixed plantation system of two or more genotypes would decrease the possible negative effect of a lack of synchrony between two genotypes depending on the environmental conditions. A similar approach could be used in other avocado growing regions to optimize ‘Hass’ cross-pollination.

17. Pollen flow and the effect on fruit size in an ‘Imperial’ Mandarin orchard

(Wallace *et al.*, 2002)

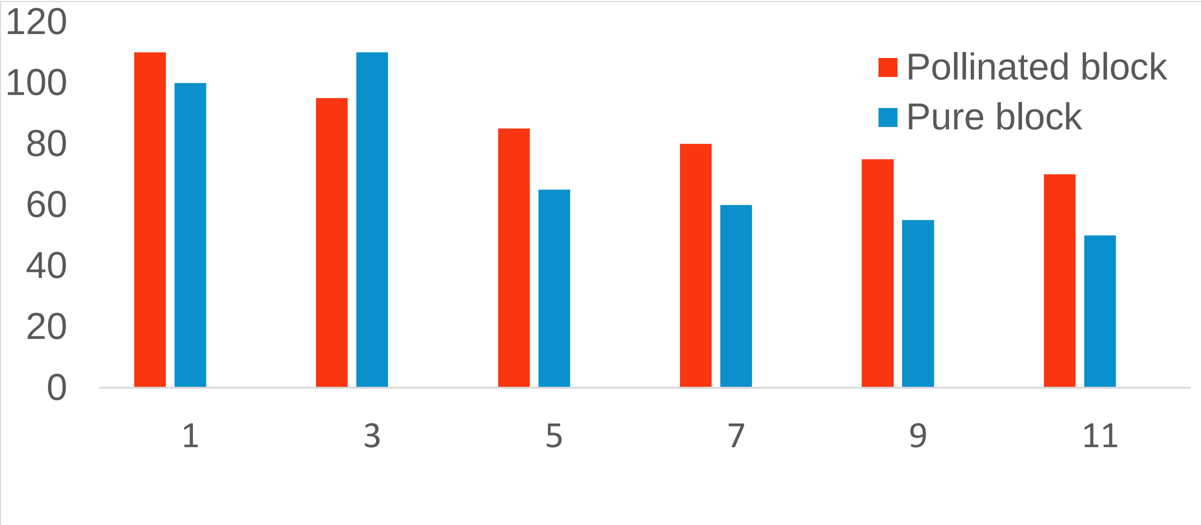
Adequate pollination is an important consideration in the management of commercial mandarin orchards. Pollen source is particularly important for self-incompatible cultivars like ‘Imperial’. In self-incompatible cultivars, the consequence of poor pollination or self-pollination may be low fruit-set, reduced fruit size and reduced sugar content (Lee and Wallace, 1999).

The pollen flow in ‘Imperial’ Mandarin, a mono embryonic cultivar in citrus known to be self-incompatible was studied. The Mandarin orchard was planted in two blocks

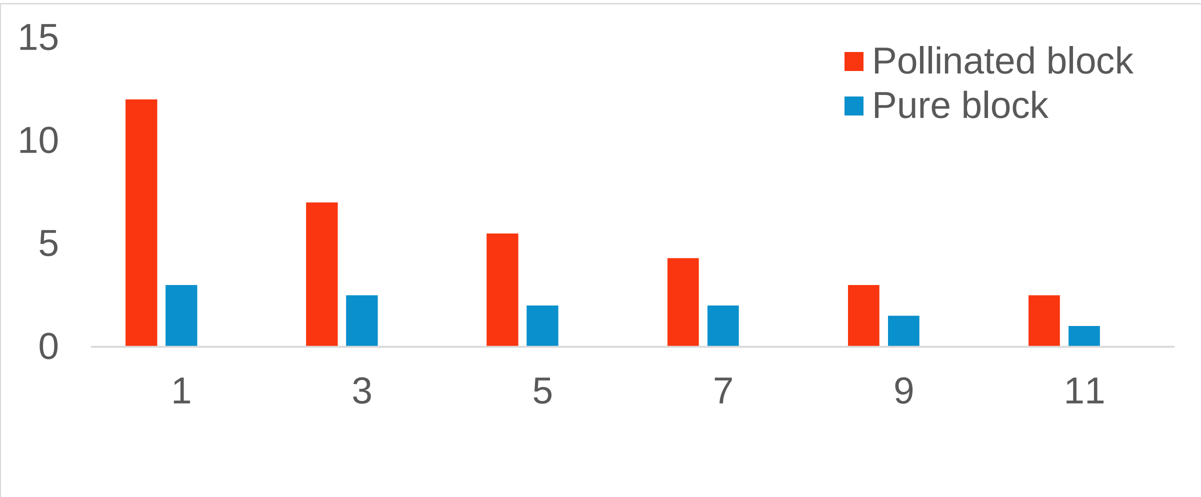
1) A ‘pollinated’ block planted 10 m from the pollinizer (Ellendale)
2) A ‘pure’ block isolated from the nearest pollinizer (Ellendale) by 500 m

Honey bees were introduced to the orchard 3 weeks prior to flowering, and placed in groups of 4-6 hives in both pure and mixed block.

The fruit weight and number of seeds observed from the two blocks are represented in a graph below.



(a)



(b)

Figure 9. Effect of distance from pollinizers in Mandarin (a) on fruit weight (b) on seed number

In the 'pollinated' block, fruit size and seed number decreased with increasing distance from the 'Ellendale' pollinizer row. Fruits from Row 1 had larger fruit than fruits from Row 5-15. A similar pattern was observed in seed number.

In the 'pure' block, only rows 1 and 3 produced commercially sized fruits (> 80g) and fruits from rows 5-11 were smaller.

18. Search of suitable pollinizers for mango

(Ram *et al*., 1976)

Pollination studies revealed the existence if self-incompatible varieties of Mango like Bombay Green, Chausa, Dashehari and Langra. The objective of the study was to find out most effective pollinizers for commercial cultivars of North Indian mangoes namely Dashehari and Chausa.

Pollinizer	**Year**	**Percentage of fruit set**			
		21 DAP	28 DAP	35 DAP	60 DAP
Dashehari (unpollinated)	1971	0.0	0.0	0.0	0.0
	1972	0.0	0.0	0.0	0.0
	1973	0.0	0.0	0.0	0.0
Chausa	1971	30.5	22.3	9.9	0.0
	1972	49.5	35.9	11.9	0.0
	1973	10.3	8.5	8.5	0.0
Bombay Green	1971	36.0	20.5	18.5	10.2
	1972	49.4	33.8	14.5	7.8
	1973	26.0	24.8	22.5	13.4

Table 12. Effect of pollinizers on fruit-set in mango cv. Dashehari

Pollinizer	Year	Percentage of fruit set			
		21 DAP	28 DAP	35 DAP	60 DAP
Chausa (unpollinated)	1971	0.0	0.0	0.0	0.0
	1972	0.0	0.0	0.0	0.0
	1973	0.0	0.0	0.0	0.0
Bombay Green	1971	44.1	33.5	12.1	3.7
	1972	43.7	36.7	16.9	1.6
	1973	42.2	30.0	8.1	7.0
Dashehari	1971	45.8	35.0	15.5	12.2
	1972	43.4	36.9	14.5	22.7
	1973	42.5	35.5	16.2	13.8

Table 13. Effect of pollinizers on fruit set in mango variety Chausa

Bombay Green and Dashehari were found to be the most effective pollinizers for Dashehari and Chausa respectively.

19. Conclusion

Pollinizers are used for tropical, subtropical and temperate fruit crops. Pollinizers are essential for Apple, Pear, Plum, Sweet cherry, Kiwifruit, Almond, Avocado, Mandarin, Date palm, Mango *etc.* Receptivity and pollen viability has to be considered first during the selection of pollinizers. The effective integration of pollinizers and pollinators influence the yield as it increases fruit set in majority of fruit crops. Hence, it can be considered as a cornerstone in fruit crops.

20. Discussion

1. What are the internal factors that affects fruit set and pollination?

There are mainly two factors that affects fruit set and pollination namely internal and external factors. The internal factors that affects fruit set include stigmatic receptivity, incompatibility and non-viable pollen.

2. The honeybee population is declining drastically due to climate change and other activities. Is there any substitute for honeybees to carry out pollination?

Wild pollinators like bumble bee, Mason bee (*Osmia* spp.), stingless bee have been recently recognized for their role in increasing and stabilizing crop-pollination services. Wild bees are known to improve seed set, quality, shelf life and commercial value of a variety of crops.

3. What is the percentage of yield increase by placing pollinizer in the orchard?

In the case of avocado, studies have shown that under natural conditions, fruit set is only 0.15 per cent which is very low. According to Alcaraz et al. (2009) highest fruit set (8.4 %) was observed in avocado cv. Hass followed by 7.4 % by using Nobel and Marvel as pollinizers respectively.

4. What is the optimum humidity range for pollination?

The optimum humidity required for pollination lies in the range of 70 – 75 per cent.

5. Which is the best pollinizer suitable for apple?

Crab apple (*Malus sylvestris*) is the best pollinizer for apple because it satisfies all the features for a good pollinizer variety.

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22. Abstract

KERALA AGRICULTURAL UNIVERSITY

COLLEGE OF HORTICULTURE, VELLANIKKARA

Department of Fruit Science

FSC 591: Masters Seminar

Name	: Anju Jayachandran	Venue	: Seminar hall
Admission No	: 2018-12-008	Date	: 06-12-2019
Major Advisor	: Dr. K. Ajith Kumar	Time	: 10.00 am

Pollinizers – A cornerstone in fruit crops

Abstract

Pollination is a major phenomenon in flowering plants including horticultural crops which determine fruit-set intensity and production efficiency. The first step of successful pollination is the transfer of viable pollen from mature anther to receptive stigma. It involves effective integration of pollinator and pollinizer for sustainable crop production and diversity. A pollinator is an agent (bees, flies, birds, wind or water) that moves pollen from anther to the stigma of flower which leads to the development of fruits or seeds through fertilization. On the other hand, a pollinizer is a plant that serves as pollen source for related plants for effective fertilization (Haldhar *et al.*, 2018).

Some fruit trees may be considered as self-fruitful or self-pollinating (Apricot, Peach, Nectarine and Sour cherry). On the contrary, there are some trees that are self-unfruitful or self-incompatible (Apple, Pear, Plum, Sweet cherry, Mango and Mandarin). To overcome the problem of yield reduction due to self-incompatibility, trees require cross pollination which will be facilitated by the use of a suitable pollinizer (pollen source) that must be diploid, provides compatible, viable and plentiful pollen and also flower at approximately the same time as that of the main commercial variety along with the provision of honey bee colonies for effective pollination. Pollinizer placement is of great importance in an orchard and it is recommended that 11-33 per cent of pollinizer trees are necessary for regular cropping. A minimum of every third tree in every third row should be a pollinizer tree (Way, R. D. 1978).

Apple shows gametophytic self-incompatibility system and requires cross pollination by a suitable pollinizer. The selected pollinizer must have a compatible pollen and good

flowering overlap. Kwon *et al*. (2005) reported that the use of 'Maypole' and 'Tuscan' flowering crab apples as pollinizers will improve fruit quality and promote sustainable and robust fruit production under high density planting in apple. The recent development of red-fleshed kiwifruit offers new opportunities to diversify and expand the market. Seal *et al*. (2016) concluded that the use of 'Bruce' as pollen source in kiwifruit produced bigger sized fruit with highest number of seed per fruit and an increased anthocyanin concentration of fruit. The use of Bombay Green and Dashehari as pollinizers, has been reported to increase the percentage of fruit-set in Dashehari and Chausa cultivars of mango respectively (Ram *et al*., 1976).

The effective integration of pollinizers and pollinators has an influence on yield as it increases fruit-set in major fruit crops. Pollinizers are used for tropical, subtropical and temperate fruit crops. Hence it can be considered as a cornerstone in fruit crop production.

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