

**Pollen Compatibility Studies of Some Commercially
Important Pear Varieties (*Pyrus communis* L.)**

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(2005-A-785-M)



**DIVISION OF POMOLOGY
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SHER-E-KASHMIR UNIVERSITY OF AGRICULTURAL SCIENCES &
TECHNOLOGY OF KASHMIR**

2007

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Important Pear Varieties (*Pyrus communis* L.)**

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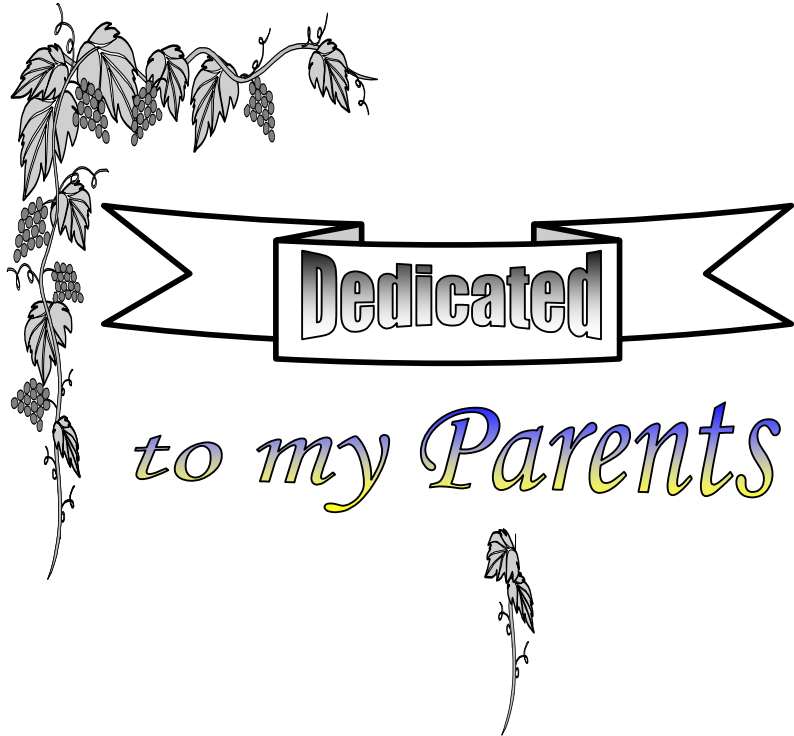
THESIS

Submitted to

**The Faculty of Postgraduate Studies
Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir in
partial fulfilment of requirement for the award of the degree of**

**MASTER OF SCIENCE IN AGRICULTURE
(Pomology)**

2007



Dedicated

to my Parents

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Pomology, Shalimar Campus, Srinagar

-::o::-

Certificate – I

This is to certify that the thesis entitled “**Pollen Compatibility Studies of Some Commercially Important Pear Varieties (*Pyrus communis* L.)**” submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Pomology)**, to the Faculty of Postgraduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, is a record of bonafide research work carried out by **Mr. Shahnawaz Qadir (Regd. No. 2005-A-785-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation have duly been acknowledged.

(K.D. Farooqui)
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Certificate – II

We, the members of the Advisory committee of **Mr. Shahnawaz Qadir (Regd. No. 2005-A-785-M)**, a candidate for the degree of **Master of Science in Agriculture (Pomology)**, have gone through the manuscript of the thesis entitled, **“Pollen Compatibility Studies of Some Commercially Important Pear Varieties (*Pyrus communis* L.)”** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of degree.

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Title of the Thesis : **“Pollen Compatibility Studies of Some Commercially Important Pear Varieties (*Pyrus communis* L.)”**

ABSTRACT

The present investigation were carried out at Fruit Research Station, Shalimar of Division of Pomology SKUAST-K on six fruit bearing cultivars of pear (*Pyrus communis* L.) namely “William Bartlett”, “Vicar of Winkfield”, “Gent Drouard”, “Flemish Beauty”, “Fertility” and “Chinese Sandy pear”. The design of experiment was RBD with four replications and the number of cross combination were 21. Significant variations among cultivars were observed for all the traits except duration a flowering, number of flowers/spur, pollen germination and pollen viability. The bloming pattern of cultivars under study revealed that Chinese sandy pear was first to come into flowering followed by Flemish beauty, William Bartlett and Vicar of Winkfield. Where as, Gent Drouard and Fertility were observed to be late bloomers. Among cultivars mean number of flowers spur⁻¹ ranged from 7.50 (Vicar of Winkfield) to 7.00 (William Bartlett, Chinese sandy pear and Fertility). Average number of stamens flower⁻¹ ranged from 21.75 (Vicar of Winkfield) to 18.00 (Flemish beauty and Chinese sandy pear). Highest floral density was noticed in Vicar of Winkfield (53.50) to low in Chinese Sandy pear (44.25). Anthesis of flowers and dehiscence of pollens peaked between 12 noon to 2 pm in all cultivars. Studies revealed that stigma receptivity to be highest on the day of anthesis or a day after. Significant variation in the magnitude of compatibility among pear cultivars under study was observed by initial fruitset per cent. William Bartlett shows highest compatibility with pollinizers Fertility (59.64%), Flemish Beauty (43.93%), Gent Drouard (34.55%), Chinese Sandy pear (33.69%). Where as, it showed partially compatible with Vicar of Winkfield (26.58%) and very low compatibility when selfed (13.51%). As recipient parent Vicar of Winkfield showed high degree of compatibility with Flemish Beauty

(58.4%) and Fertility (54.41%) where as they are partially compatible with pollinizer Gent Drouard (26.50%), Chinese Sandy pear (25.10%) and when selfed (25.41%). As a recipient parent, Gent Drouard showed highest degree of compatibility with Flemish Beauty (55.61%) and Fertility (48.28%) where as it was partially compatible with Chinese Sandy pear (27.78%). However, it was completely incompatible when selfed. Flemish Beauty as female parent was most compatible with Fertility (54.47%) and with Chinese sandy pear (34.76%). However, it is partially compatible with its own pollens. Fertility showed complete incompatibility with Chinese Sandy pear and when selfed. Chinese Sandy pear exhibited limited compatibility with its own pollens. Thus, it may be concluded that Flemish Beauty and Fertility were good pollinizers for the cultivars William Bartlett, Vicar of Winkfield, Gent Drouard and Flemish Beauty.

Key words : Cultivar, Compatibility, Fruitset, Pear, Pollen

Signature of Student
Dated : _____

Signature of Major Advisor
Dated: _____

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**IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST
BENEFICIENT AND THE MOST MERCIFUL**

With limitless humility, I seek forgiveness from the Great Allah, besides whom none is worthy for being worshipped. The living, The Eternal, The Exalted, The immense one, Who bestowed me with the health and courage to go through this crucial juncture.

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**“GLORY TO THEE MY LORD AND EXALTED ART THOU,
THE LORD OF MAJESTY AND BOUNTY”**

Shahnawaz Qadir

Place : Shalimar, Srinagar

Dated :

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner - Dr. D.B. Singh, Dean, Faculty of Agriculture, Allahabad Agricultural Institute, Allahabad during Viva-Voce examination held on March 25, 2008 have been incorporated in the manuscript entitled **“Pollen Compatibility Studies of Some Commercially Important Pear Varieties (*Pyrus communis* L.)”** submitted by **Mr. Shahnawaz Qadir (Regd. No. 2005-A-785-M)**.

K.D. Farooqui
Chairman
Advisory Committee

CHAPTER – 1

INTRODUCTION

Pear is grown in all temperate regions of the world. ‘Homer’ an ancient Greek poet praised pears as one of the ‘Gifts of God’. This pre-historic fruit has been under cultivation both in Europe and Asia for about 3000 years (Hedrick *et al.*, 1921; Kikuchi, 1946). The European pear is considered by many to be the most delectable of all tree fruits, whereas, the oriental pears which arose independently in China and Japan are preferred; pears are consumed as fresh, dried, cooked or as preserves. In Europe some are used for making Perry or wine (Rathore, 1990). Pear is next only to apple in importance, acreage, production and varietal diversity in the world.

According to Layne and Quamme (1975) and Bell and Hough (1986), the genus *Pyrus* has probably originated in the mountainous region of Western China where from, it moved both in East and West direction and evolution took place in different regions under geographical isolation, ecological tolerance, introgression and interspecific hybridization.

Vavilov (1951) proposed three centres of origin for the cultivated pears.

- a) Chinese centre, comprising of primary gene centre the region of North and central China, Japan and Korea.
- b) The Central Asiatic centre comprising, Western Tian-shan, Pamir-Alai, Tadjikistan, Uzbekistan, North West India and Afghanistan.
- c) Near Eastern centre comprising, Caucasus Mountains and Asia

Minor.

All pear cultivars belong to the genus *Pyrus*, which is a member of subfamily *Pomoideae*, family *Rosaceae* and order *Rosales*. The basic chromosome number is 17 and somatic number is 34, ($2n = 34$, $X=17$), (Westwood, 1993). Most pear cultivars are diploid, few are triploid and tetraploid. Triploid varieties like Beurre d' Ammanalis, Beurre Diel, Kantarishty, Marguerite marillot and Royal, set 21 to 49 per cent parthenocarpic fruits and are classified as partially self-fertile (Mischenko, 1987 and Ludnikova, 1985). Two cultivars of pear 'Improved Fertility' (a budsport of Fertility) is self-fertile and 'Double William' (a budsport of William Bon chretien) is reported to be self-incompatible (MAFF, 1973).

The highest production of pear in the world is in Italy (90,7458 MT) which exceeds the production of North America (770183 MT), South America (826513 MT), Africa (651086 MT) and Australia (142400 MT). Italy also is biggest exporter of pear (Anonymous, 2007).

In India, pear cultivation is restricted to selected hilly areas of J&K, Himachal Pradesh and Uttarakhand. The J&K state has very good potential for cultivation of pears. In spite of the fact that out of introduced material some of the cultivars are popular among fruit growers. The cultivation of this kind of fruit is still spread over limited area of 10994 ha, out of total fresh fruit area of 172233 ha (Anonymous, 2006).

The pear germplasm in Kashmir Himalayas is replete with tremendous genetic diversity and bestowed with superior traits such as pest and pathogen resistance and high yield potential. It promises a strong edifice on which ambitious breeding programmes can be launched. A comprehensive multidimensional programme is needed not only to salvage this important genetic resource but also to improve and upgrade it. This goal can be achieved only when the genotypes we already have are censused, evaluated and standardized. In the absence of knowledge about their diversity of habit, fruit quality, flowering behaviour and breeding system, planning, conservation strategies and genetic improvement is a task difficult to achieve. The popularity of pear is known worldwide besides under diversified horticulture programme pear growing assumes tremendous significance in our state where it meets ideal agro-climatic conditions for its cultivation.

Pear fruits constitute 65-75 per cent reducing sugars out of the total carbohydrates. The predominant sugars are fructose, glucose and sucrose (Farooqui and Happa, 1990). A protein content of 0.6 per cent recorded in pear fruit is rather low (Gopalan *et al.*, 1987). However, all the essential aminoacids except tryptophan have been identified in the fruit (Anonymous, 1969).

Pear can be grown in a wide range of climatic conditions, as it can tolerate as low as -26°C temperature when dormant and as high as 45°C during growing period. A large number of pear cultivars require about 1200 hours below 7°C during winter to complete their chilling period. The popularity of pear is known worldwide. Besides under diversified horticulture programme, pear growing assumes tremendous significance in our state where it meets the ideal agro-climatic conditions for its cultivation (Rathore, 1990).

Incomplete pollination is a principal barrier to minimize pear productivity. Self-incompatibility and cross incompatibility of pear cultivars is thus of common occurrence in pear varieties the interplanting of suitable varieties for providing effective cross-pollination assumes significant importance. In view of the fact that besides compatibility, bloom overlap of cultivars is a pre-requisite for effective pollination, thereby necessitating the identification/evaluation of suitable compatible pollinizers to do a way with the menace of low and erratic yields in pears. The present study was conducted on six commercially important cultivars with following objectives :

1. To identify the pollen compatible genotypes among different pear varieties.
2. To identify the combination of pear varieties that bloom and harvest in sequence.
3. To identify the combination of pear varieties that bloom together and harvest together.

CHAPTER – 2

REVIEW OF LITERATURE

2.1 Time and duration of flowering

Study of periodicity phenomena of fruit crops e.g. time of flowering in relation to climate has received a considerable attention of the researchers, as flowering time and production are highly correlated. Pear bloom appears early in the season. In the valley, rain, wind and low temperature are common during pear blossom, affecting the production adversely. Temperature is the most important environmental factor affecting pollination and fertilization. Temperature affects the rate of pollen tube growth of Bartlett pear taking 12 days at 5°C while 2 days at 15°C, viability of ovule is also affected by temperature and lower temperatures prolong the viability of the ovule but the effect is not as significant as on pollen tube growth as reported by Lombard *et al.* (1972a). In Oregon (USA), these weather conditions have been observed to restrict pollen tube growth and pollination in cherry (Brown, 1973; Stephen *et al.*, 1977).

Studies in England and Oregon (USA) showed that cultivars namely Bartlett, Conference, Bosc, Packham's Triumph had an extended effective

pollination period of 6 to 10 days during normal spring temperatures while Comice had only 1-2 days (Lombard *et al.*, 1973b). This cultivar was having low fruit set which could be due to short effective pollination period. Pollen tube growth for more than 8 days would indicate reduced fruit set because of limiting effective pollination period of any cultivar.

Aulakh *et al.* (1981) designated six developmental stages of pear flower bud viz., I, II, III, IV, V, VI and indicated that almost all the cultivars took nearly the same number of days (13-14days) for flower bud-development, thus showing no varietal difference. They also found that flowering of cultivar Patharnakh and Smith commenced in the third week of February, in Kieffer and LeConte on the first week of March and in Baggugosha in the second week of March. The duration of flowering in different cultivars varied from 21 days in Baggugosha to 29 days in Smith. The effective blooming period however, was found to be much shorter in LeConte (4days) and Patharnakh (7days).

Floral bud differentiation in pear takes place in July while bloom occurs next years spring (Jaumien, 1983a). The flower initiation depends on the level of organic and inorganic storage compounds and endogenous growth regulators, notably cytokinins and gibberellins (Banno *et al.*, 1985; Jaumien, 1983b). Spring frost are detrimental to pear production and temperatures at -3.3°C or lower kill the open blossoms. Pear begin flowering at the age of 5-8 years mostly on spurs and terminal shoots (Rathore, 1990). Dilbuz (1996) while working on the type of the sequence of blooming in the inflorescences of 77 pear varieties during 1984 and

1991. He observed that the centripetal successional order of flowering in the inflorescences was characteristic in 59 per cent of the pear cultivars. A quarter of the cultivars were centrifugal order was found.

Sandhu *et al.* (2002) while working on performance of Asian pear varieties under Punjab conditions during 2000 and 2001 observed that bud sprouting in some Asian pear cultivars under Punjab and in all cultivars took place in the first fortnight of March during both the years. The sprouting was earliest in YaLi, 4-6 March in (2000) and 1-3 March (2001). Whereas, it was late in Kosui, 17-23 March (2000) and 9-11 March (2001). The period of full bloom varied among all cultivars, earliest being in YaLi and late Kosui during both the years. However, end of flowering also showed similar pattern. Flowering period ranged from 13 day in YaLi to 15 day in Nijisseiki during (2000) and from 10 days in YaLi to 17 days in Nijisseiki during (2001).

2.2 Floral biology

2.2.1 Number of flowers per spur and flowering density

Aulakh *et al.* (1981) reported that average number of flowers per spur in five pear cultivars viz. Patharnakh, Keiffer, Smith, Baggugosha and LeConte. Varied from 7.5 in Patharnakh to 9.2 in Baggugosha. They also reported that density of flowering spurs per metre shoot length was ranged from 11.10 in Baggugosha to 8.5 in Keiffer. However, in both cases data was found to be non-significant statistically for this parameter. Paramar *et al.* (1982) while studying on *Pyrus pashia* (sp) reported that number of flowers per spur was ranged from 3 to

11.

Sandhu *et al.* (2002) reported the flowering behaviour of five pear cultivars viz., YaLi, Shinseiki, Hosui, Nijisseiki and Kosui during 2000 and 2001 observed that flower number per metre shoot length was found to be ranged from 25.50 in YaLi to 49.50 in Hosui during 2000 whereas, it ranged from 17.25 in Shinseiki to 47.50 in Kosui during 2001.

2.2.2 Number of stamens per flower

Aulakh *et al.* (1981) reported average number of stamens per flower in five pear cultivars varied from 18.5 to 22.2 in Smith and Baggugosha respectively. Parmar *et al.* studied that number of stamens per flower in *Pyrus pashia* (sp) ranged from 26 to 42.

2.3 Anthesis and Anther dehiscence

Anthesis is the opening of flower i.e. when all the floral parts are visible and Anther dehiscence is discharging pollen grains from the anthers. Mukherjee and Rana (1966) reported that peak period of anthesis in pear was between 12 noon to 2 pm. Josan and Chohan (1979) reported that in peach cultivars the maximum flower anthesis occurred between 12 noon and 2 pm. They also reported that dehiscence of anthers started just after anthesis and was completed within 3-4 hours after opening of the flowers. Chitkara and Kartar (1979) reported that in peach maximum anthesis and dehiscence occurred between 12 noon to 2 pm. They further observed that though some anthesis was recorded between 6 am to 10 am and from 4 pm to 6 pm, yet, no dehiscence occurred before 10 am.

Aulakh *et al.* (1981) while investigating on floral biology in sub tropical pear reported that in pear cultivars viz., Patharnakh, Smith, Keiffer, Baggugosha and LeConte temperature was positively correlated and inversely related with the opening of flowers. They found continuous anthesis from 10 am to 4 pm and peak period of anthesis is 10 am to 12 noon. While studying the dehiscence of pollen in different cultivars, it was noticed that the dehiscence started along with the opening of flowers and it continued for 2 to 4 hrs after opening of the flowers. The

maximum proportion of pollen dehiscence was recorded between 12 noon to 2 pm in all the cultivars under study.

2.4 Stigma receptivity

Bini (1972) reported that the stigma remained receptive for 5-10 days depending on environmental conditions in pear cultivars viz., Mirando Rosso, Conference, Clapp's Favourite, Kaisser, Passe Crassane and William, by fruit set method. Nyeki (1973) while working on dynamics of blossoming and fertility of pistils in 12 pear varieties reported that the stigma receptivity remains for 2-3 days.

Dhaliwal *et al.* (1982) while studying floral biology in subtropical pears observed the stigma receptivity in terms of fruit set. Highest fruit set was observed when pollination was carried out on the day of anthesis, followed by one day before anthesis. Davarynejad *et al.* (1997) while studying on micropheonology of flowers of pear cultivars viz., Dargazi, Sebri, Shahmiveh, Natanz and Bartlett concluded that most of the pear cultivars were self incompatible therefore it is necessary to determine the most suitable pollinizer. They worked over a four year period (1993 – 1996) and the phenological stages of the flower development were determined at hourly intervals from the late balloon stage until browning of the stigmas and petal fall. Results showed that air temperature, humidity, sunshine and wind all affected stigma receptivity.

Sanzol *et al.* (2003) studied stigma receptivity of 'Agua de Aranjuez' pear to evaluate the duration of 'stigma receptivity', stigmas of flowers pollinated at 0, 2, 4, 6, 8 and 10 day after anthesis were observed. It was apparent that not all the stigmas in a flower were at the same developmental stage. In both years, the duration of stigmatic receptivity was different, lasting upto six days for first year and two days for the second. They also reported that two days later, the number of receptive stigmas was slightly higher than at anthesis, probably because of a faster development from immature to mature stigmas than from mature to degenerative. They also observed complete flower fertility for just two days after anthesis in 'Agua de Aranjuez' pear in both the years under study and reported that stigmatic receptivity was clearly the limiting factor of flower receptivity and crop performance.

Herrero (2003) estimated effective pollination period in Agua De Aranjuez pear and observed that fruit set decreased if pollination occurred three days after anthesis which showed scarce stigma receptivity during the short effective pollination period.

2.5 Pollen viability and pollen germination

Initial fruit set depends upon pollination and fertilization of egg cells. For fertilization of egg cells, besides the compatibility factors, pollen should be viable

i.e., living and should have capacity to germinate on stigmatic surface so that pollen tube elongates sufficiently and fertilise egg cells. Therefore, to obtain higher fruit yield, the knowledge of pollen viability and germinability is very important. Nyeki (1972) observed that pollens of two cultivars 'Clapp's Favourite' and 'Williams' germinated best in 15 per cent sucrose solution. Clapp's Favourite reached a maximum germination per cent in 120 minute, and in William's in 160 minute. The optimum temperature for pear germination in these two cultivars were 23 °C and 25 °C, respectively. Ifteni *et al.* (1972) while working on aspects of pollen biology in some pear cultivars reported that the optimum temperature for germination was 22 - 25 °C in a 10-15 per cent solution of sucrose or glucose. Germination did not occur below 9°C, or in distilled water.

Duganova (1972) while working on characteristics of flowering and pollination in pear and quince observed the pollen germination in sucrose solution of 36 pear varieties and classified them into groups with high, medium and low percentage. He further reported that pollen retained viability for 12-15 days.

Filiti and Marcucci (1982) studied the *in vitro* germination of pear pollen keeping in view the effect of various cultural factors. They took pollen from pear anthers of Butirra Precoce Morrettini and William cultivars held them 30 cm apart from a 60-watt lamp for 36 h and stored at -25°C before study. It was then kept at 50 and 100 per cent relative humidity for 30 minutes at 26 to 50°C to give partially or fully rehydrated pollen. Both types of pollen showed higher germination ratio in the presence of boron. Addition of 0.1 per cent yeast extract

to the medium increased per cent germination of the partially rehydrated pollen only. Calcium (as nitrate) inhibited pollen germination and pollen tube growth. Both percentage germination and pollen tube growth of partially and fully rehydrated pollen occurred in medium containing 1.5 per cent sucrose, 20 ppm H_3BO_3 and 1 per cent agar.

Eti *et al.* (1997) reported that Turkey pear cv. Santa Maria had higher rates of pollen viability, germination and production than cultivar June Beauty. Singh *et al.* (2004) studied pollen characteristics and pollination in relation to fruit set in different pear cultivars during the year 1997 and 1998 at RFRS, Bahadungarh of P.A.U., Ludhiana. The pollen viability of cultivars LeConte, Kieffer, Baggugosha, Smith and Patharnakh was tested with 2 per cent acetocaramine solution. Observation on pollen germinability was recorded by using 'hanging drop method' in 15 per cent sucrose solution after 24 hours incubation. The pollen viability in different pear cultivars ranged from 88.0 per cent in Patharnakh to 81.7 per cent in LeConte during 1997. Similar trends were observed in the second year, however, the data were found to be non-significant.

Jiang *et al.* (2006) observed the pollen germination rate of 43 pear cultivars the pollen viability of pear cultivars Imamu Raaki, Xuehuali, Gold Nijisseiki, Hosui, Quigsong and Mantianhong was also determined using KI, blue ink, MTT and peroxide enzyme staining. The average germination rate of pear cultivars tested was 66.15 per cent, with 84 per cent of the cultivars recording a germination per cent higher than 60 per cent. The pollen of most cultivars tested

were viable. IKI staining detected the lowest, whereas MTT staining detected the highest pollen viability. Peroxide enzyme staining showed that the pollen viability of cultivar Gold Nijisseiki was markedly different with that of the control. Blue ink staining was the best method for lasting pollen viability.

2.6 Pollination and incompatibility

Crane and Lawrence (1929) and Crane and Lewis (1940) described the genetic basis of self and cross-incompatibility in temperate tree fruits. They demonstrated that incompatibility in pear is due to 'S' genes which prevent the normal growth of pollen tube into the floral styles, thus prohibiting fertilization. They found that incompatibility exists when the specific 'S' gene that is carried by a pollen grain is the same as one of the two specific 'S' genes carried by the somatic tissue of the receptor pistil.

Ascher (1966) proposed a gene action model to explain the biochemical basis of gamatophytic self-incompatibility and observed that if the pollen and style 'S' genes are identical, molecules from each unite to form a repressor which prevented normal metabolism and growth of the pollen tube. If the S alleles are not identical, the repressor molecules are not formed. Sedgley and Griffin (1989) during their investigations on incompatibility in pear cultivars suggested that incompatibility, a genetically controlled character manifested by the presence of multiple alleles at a single locus results from non-germination of functional pollen on the stigmatic surface, inhibition of pollen tube growth in the style and degeneration fertilized ovule.

Hiratsuka *et al.* (2001) re-examined self-incompatibility genotypes (S-genotypes) in the Japanese pear cultivars Choju, Kimizukawase, Meigetsu and Ichiharawase. The S-genotypes of first two cultivars were designated as S_2S_5 where those of the other two cultivars were S_1S_5 they also observed that pollen tube growth in style may be an unclear test, Ovule observation at the microscope for the presence of pollen tube in the nucellus is a proper method to test incompatibility in this crop. They, thus suggested that determination of S-genotypes will facilitate the characterizations of self and cross incompatibility.

Zuccherelli (2002) while studying on S-allele characterization in self-incompatible pear and bio-chemical, molecular and field analysis concluded that Gamatophytic self-incompatibility is a natural mechanism in flowering plants, including pear and other fruits tree species, to prevent inbreeding and promote out-crossing. It is usually under the control of one locus with allelic variants. The study was employed on biochemical (iso

electric focussing) and molecular (S-PCR) bases to determine S-allele composition of 10 European cultivars. The S-locus composition of the cultivars was determined via S-PCR. To verify the S-PCR assay two putative S-allele DNA fragments of Japanese pear were isolated and their relative sequences proved to be identical to the ones already reported in the data bank. While field data confirmed the molecular results.

Tassinari *et al.* (2004) investigated that Rosaceous gamatophytic self-incompatibility is genetically controlled by single S-locus. In European pear (*P. communis* L.) cultivars exhibit different types of self-incompatibility. They assessed the self-fertility on the basis of number of seeds per fruit produced by self-fertilization. They studied the SI mechanism in pear cultivars using a genetic approach. The tendency of pear cultivars for self-pollination was checked by calculating the self-pollination and Fertility index (ratio of seed number/flowers number). Self-pollination revealed a varying range of self-fertility in pear cultivars. The same cultivars were used in controlled crosses. Again, the fertility index reflected degree of self-fertility of the female parents. Even if the S-locus determined SI specificity, experimental evidences suggested the involvement of other unknown factors. These later included 'modifier' factors which interact with the proteins coded by the 'S' locus.

2.7 Pollination, pollinizers and fruit set

Pollination stimulates the development of ovary and the surrounding tissue leading to the formation of fruit, this is termed as fruit set. In case of pear self and cross incompatible pear cultivars need cross-pollination from compatible pollinizers, coupled with proper tree management and favourable climate for commercial yields. The major role of insects especially honeybees has long been recognised in pollination of fruit crops. Placement of minimum 2 hives per hectare has been suggested by various workers (Teskey and Shoemaker, 1972; Callan and Lombard, 1978) in order to increase fruit set percentage in pear.

Extensive research work done in Europe has suggested William as good polliniser for Conference cultivar and vice-versa (Verma and Jindal, 1997). Binij (1972) reported that for Doyenne du Comice, Conference and Clapp's Favourite

cultivars are to be effective pollinizers.

Gurnevskii (1977) reported that Beurre Giffard and Bartlett were best pollinizers for Beurre Hardy cultivar as this resulted in increased fruit set and larger fruit size. However, more hives are commonly recommended to ensure highest number of flowers to be pollinated (Simidchiev, 1978).

In another investigation, Seth and Kukshal (1981) while concluding the results of average fruit setting in different cross combinations observed that Thumb Pear and Victoria were the best pollinizers for each other. They further observed that Doyenne Du Comice is a good pollinizer for Beurre Hardy as well as for William Bartlett. For Winter Nelis, Victoria is best pollinizer. These findings, therefore, clearly showed that the use of suitable pollinizer was essential for all the pear cultivars because higher fruit setting was recorded even in particularly self-fruitful varieties.

Dhaliwal *et al.* (1982) made all cross combinations in between five-pear cultivars viz., Patharnakh, Kieffer, LeConte, Smith and Baggugosha and reported that in reciprocal cross between Keiffer x LeConte the fruit set percentage was highest (69.7%) which revealed that LeConte is best pollinizer for Kieffer as compared to other cultivars followed by Kieffer x Baggugosha (51.7%). For improving fruit set for better yields Jankovic and Kulincevic (1985) suggested the placement of beehives at a distance of 50-100 m from tree.

Oh *et al.* (1989) reported improved fruit set, yield and better fruit quality

of pears when pollinated by insects. Ketchie *et al.* (1995) reported that *P. callereyana*, Bartlett and Bosc could be best to cover the entire flowering period of 'Beurre d'Anjou' and to provide good pollination. Liu (2000) conducted an experiment of pollination for new pear varieties viz., 'Jinxiangshui' and 'Hongjinqiu' reported that in both pear cultivars, the fruit set percentage following self pollination was zero. However, under natural open pollination conditions fruit set percentage were 43.18 and 34.89 per cent, respectively. Further investigations revealed that the fruit set percentage varied greatly when pollinated by different varieties or selections. He reported that best pollinizer 'Jinxiangshui' was 1-7 selection, resulting upto 76.19 per cent fruit set. The fruit set percentage 'Hongjinqiu' pollinated by Youyi 91, Pingguoli and 11-11 were 92.48, 69.09 and 38.18 per cent, respectively.

Franchie *et al.* (2002) studied application of artificial pollen on nashi cultivar 'Housui'. Pollen was applied to bagged 'Housui' flowers during 1998, 1997 and 2000. Pollen type used were a range of fresh and frozen Asian pear, European pear pollen, apple pollen, crab apple pollen and crushed bee-collected pellets. Fruit set due to bee pollination of unbagged flowers decreased each year from 1998-2000. Fruit increased upto >20 per cent than bee pollination when either fresh or frozen pollen were applied. 'Kousui' pollen collected in the high crop load year had the highest viability and significantly better fruit set than any other pollen type (58%). The other fresh/frozen nashi pollen and European pear pollen had significantly lower fruit set (37%). The lowest fruit set was obtained

from apple, crab-apple, bee collected pellets, pollenaïd and Housui. Fruit set from these pollens was similar to self-pollination (<20%), suggesting that suitable pollen for artificial application would be 'Kousui'.

2.8 Fruit maturity

Accumulation of heat units and number of days after full bloom to harvest are the main criteria in making such estimates. Fazekas and Graeza (1970) reported that sugar content increased throughout the growth period, being maximum nearing the maturity and then drop in ripe fruits. Length, diameter and weight of pear fruits increased from fruit set to maturity in sigmoidal pattern (Mann and Singh, 1988). Further investigations carried out during (1986) by them revealed that biochemical changes also occurred during the growing period of the pears.

Farooqui and Happa (1990) while studying fruit maturity of 12 pear cultivars observed significant variations in their maturity period and therefore grouped them in early, mid and late season cultivars of pears and therefore enhance the availability of fruit and for the purpose of marketing. The period of fruit maturity in cultivars Doyenne Bussoch, Monarch and Flemish Beauty ranged between 29-119 days from end of bloom. This group can therefore, placed in early season.

Similarly, cultivars Beurre Giffard, Devoc and Merry Red Bartlett ranged between 120-130 days and was therefore mid-season in ripening. Cultivar William Bartlett, China pear, Vicar of Winkfield, Beurre-de-Amanalis and Fertility ranged between 137-148 days. These cultivars were late season in maturity. Kings pear however, took 170 days to mature.

Rachna *et al.* (2004) studied fruit development in low chilling semi-soft pear selection Punjab Nectar. They observed that fruits of Punjab Nectar took 130days from fruit set to harvest maturity. Fruit growth parameters (length, diameter and weight) increased from fruit set to harvest maturity.

2.9 Physico-chemical characters (fruit diameter, fruit volume and fruit firmness)

Azzouni *et al.* (1974) while working on ripeness determination of pear cultivars Hood and Kieffer observed that firmness varied from 11.4-12.1 lb/inch² in Hood fruits and for Kieffer the firmness ranged from 12.3 – 12.9 lb/inch². Since fruits are usually harvested at mature green stage, third phase of growth does not occur (Westwood, 1993). Length, diameter and weight of pear fruits increased from fruit set to maturity in sigmoidal

pattern (Mann and Singh, 1988). Mann and Singh (1990) studied developmental physiology of Patharnakh pear and found that Patharnakh pear took 150 days to mature. Physiological development was followed by measuring changes in size, specific gravity, skin colour, pigment, TSS, phenolic content and fruit firmness. They reported that fruit growth showed 3 phases active, very active and slow as measured by size i.e. length and diameter and weight. They also reported that fruit firmness decreased during the final 50 days to harvest. Fruit firmness decreased between 105 and 150 days from 24.56 to 16.48 lb/inch². Farooqui and Happa (1990) while determining physico-chemical characters of 12 pear varieties reported that fruit diameter varied from 3.73 cm (China pear) to 7.50 cm (Merry Red Bartlett). Similarly, fruit volume reported to be varied from 50 g (Fertility) to 300 g (Merry Red Bartlett). Fruit weight and volume advance with corresponding decline in specific gravity during fruit growth. Hong *et al.* (1991) reported variability among pear cultivars 'Whangkeumbae', 'Chuwangbae', 'Yeongsanbae' in respect of fruit weight and concluded that fruit weight differences were attributed to difference in seed production rather than metaxenia. Koksai and Yilmaz (1992) while studying physical and chemical changes during development and ripening of some pear cultivars viz., William and Ankara found that the physical characteristics such as fruit diameter and fruit weight of all fruits increased regularly until harvest. Sandhu *et al.* (2002) observed that fruit diameter varied from 4.99 to 5.96 cm in Nijisseki and YaLi during 2000 and 5.44 to 6.16 cm in Hosui and YaLi during 2001, respectively. Fruit weight varied from 53.71 g (Kosui) and 117.25 g (YaLi) during 2000 and 79.97 g (Kosui) and 127.42 g (YaLi) during year 2001. Similarly, fruit firmness (lb/inch²) was also different 6.49 (Kosui) and 11.94 (Shinsoiki) during 2000 and during year 2001 it was 6.91 (Nijisseki) and 9.55 (Shinsoliki).

Rachna *et al.* (2004) studied fruit development in low chilling semi-soft pear selection Punjab Nectar. They reported that fruit growth parameter like length, diameter and weight increased from fruit set to harvest maturity in three distinct phases. Fruit volume also increased upto last picking with a corresponding decrease in specific gravity. Fruit firmness decreased rapidly as fruits reached harvest maturity.

2.10 Chemical characteristics (TSS, acidity, reducing sugar, non-reducing sugar and total sugars)

Fazekas and Graeza (1970) reported that sugar content increased throughout the growth period maximum nearing the maturity and then drop in ripe fruits.

Azzouni *et al.* (1974) investigated ripeness determination in the pear cultivars 'Hood' and 'Kieffer'. They reported that total soluble solids content for 'Hood' cultivar ranged between 12.5-12.7 per cent, total acid

varied between 0.19-0.20 per cent and total sugars from 6.3-6.9 per cent. For Kieffer the corresponding values were 12.3-12.8 per cent for total soluble solids, 0.203-0.212 per cent for acids and 5.0-5.5 per cent for sugars.

Mann *et al.* (1978) while working on developmental physiology of Patharnakh pear observed that acidity showed a declining trend during most of the stages of fruit growth of pear. Singh *et al.* (1983) studied physico-chemical characteristics of three pear cultivars viz., Gola, Naga and Tumanier and observed that total soluble solids ranged from 12° (Gola) to 13.2 °Brix (Naga). Similarly, acidity was found to be highest in 0.96 (Gola) and lowest in 0.64 (Tumanier). Reducing sugar was found to varied from 9.43 per cent (Naga) to 7.33 per cent (Gola) whereas, total sugars varied between 10.31 per cent (Naga) to 9.54 per cent (Gola). Minhas *et al.* (1988) while working on variation in fruit size and its effect on fruit quality in pear cultivar Baggugosha observed that fruits belonging to A grade had maximum TSS (13%) which was closely followed by B (12.8%) and (12.7%), respectively. However, the lowest TSS (11.2%) was found in D grade fruits. Similar work was carried out by Grewal *et al.* (1988) on pear cv. Patharnakh. They, therefore concluded that fruit size effect the fruit quality.

Mann and Singh (1990) studied some developmental physiology of Patharnakh pear and found that total soluble solids showed continuous increase during development (from 7.8 to 13.53%). This increase was most rapid between 15 and 30 days after fruit set and again between 75 and 90 days after.

Reducing sugars and total sugars both increased continuously until harvest. The increases were most rapid during 120 to 150 days after. Farooqui and Happa (1990) while investigating chemical characteristic of 12 pear varieties reported that fruit TSS varied from 10.5 (Beurre-de-Amanalis) to 18.2 (Flemish Beauty). They also reported that reducing sugar varied from 1.89 (Beurre-de-Amanalis) to 13.88 (Flemish Beauty) and similarly, total sugars were found to be highest in Flemish Beauty (15.82) to lowest in Beurre-de-Amanalis (2.12). However, acidity varied between 11 per cent (Fertility) to 0.67 per cent (King's pear).

Koksal and Yilmaz (1992) determined that chemical changes occurred during developmental and ripening of some pear cultivars viz., William and Ankara. They found that chemical properties showed irregular changes until harvest and during 10 days of post harvest ripening. Hong *et al.* (1998) while studying the changes in contents of soluble sugars, organic acids and the fruit taste of early season pear cultivars viz., Chojuro, Kosui and Shinsui found that fruits at harvest had highest soluble sugar content (5.4, 12.9 and 14.3%) in Chojuro, Kosui and Shinsui,

respectively and malic acid content decreased during fruit maturation.

Hudina and Stampar (2000) studied the sugars and organic acid contents in pear fruits of 18 European (*Pyrus communis*) and 4 Asian (*Pyrus serotina*) cultivars. Fructose varied in the European pear cultivars from 23.7 g/kg in 'Conference' to 66.1 g/kg in 'Clapp's Favorite' and in the Asian cultivars from 27.9 g/kg in 'Sinseiki' to 45.7 g/kg in 'Koshui'. They concluded that Asian pears contain more sugars than European ones.

Hudina *et al.* (2003) reported that internal fruit quality was effected by climate and soil factors. They studied influence of location on fruit quality of pear (*Pyrus communis*) cv. 'Williams' under 4 growing regions of Slovenia i.e. in Krsko, Bistrica ob Sotli, Kammik and Sentjur Pricelju. The highest content of individual sugars (glucose, fructose and sirbitol), total sugars and soluble solids in fruits were recorded in Bistrica ab Sotli. The difference between the location were statistically significant.

2.11 Juice (%)

Singh (1998) while working on performance of Asian pears under Punjab conditions recorded highest juice percentage in YaLi compared to other Asian pears under study. Sandhu *et al.* (2002) also estimated juice per cent of five pear cultivars viz., YaLi, Shinseiki, Hosui, Nijisseiki and Kosui. They found that all varieties had high percentage of juice content, maximum being (72.93%) in YaLi and minimum (57.08%) in Shinseiki.

2.12 Number of seeds per fruit

Formation of seeds and development of fleshy fruits, tissue of the fruit are found to be distinctly correlated; larger fruits usually have greater number of seeds. Successful pollination followed by the germination of pollen induces ovary growth and good seed setting. Nyeki (1977) studied fructification and number of seeds per fruit in 12 pear varieties. They crossed twelve varieties during year 1968, 1969 and 1970 and reported that number of seeds/fruit varied with year and combination and were not correlated with each other. Parthenocarpy was observed in Nemes Krasszan [noble Crassone] x Beurre Diel, Oliver de Serres x Beurre Diel and Teli esperes [Winter Esperon] x PCP (Priest). As seed parents, Clapp's Favourite, Beurre Hardy and Pringalle lended to give high number of full seeds/fruit and as a pollen parents, Harden Pont, Duperit Assozny (Madauk Dupalit], Pringalle and Beurre Bose. However, Beurre Bose (female) x Pringalle (male) and Oliver de Serres (female) x Beurre Hardy (male) were incompatible but the reciprocal were not.

In an another investigation Frimanslund (1984), while working on the effect of pollination period in some pear cultivars viz., Bonne Louise, Clara Frijs, Moltke, Amanalis, Keisarinne and BP 1575. The reduction in

fruit set and yield were less marked in the more parthenocarpic varieties BP1575 (Clapp's Favorite x Conference), Amanalis and Keisarinne and the reduction were generally greatest in Bonnecouise, which generally had the largest number of seeds per fruit and the fewest parthenocarpic fruits. They also reported that parthenocarpic fruits required early pollination for the best set of seeded fruit, seeded fruits being better in shape than seedless fruits.

Hiratsuka *et al.* (1985) while investigating on self incompatibility reactions of Japanese pear in various stages of Floral development. they made cross between *P. serotina* cv. *Chojura* which was used as female parent and crossed with Japanese pear cv. Nijisseki. They found that number of seeds were higher in cross-pollination than self-pollination. Similarly, Hong *et al.* (1991) while working on selection of suitable pollinizers for new released pear cultivars viz., Whang Kumbae, Chuwhangbae and Yeongsambae reported that source of pollen affected number of seeds per fruit, when they crossed 3 new *Pyrus pyrifolia* cultivars with 9 other cultivars of pears during 1989-1990 reported that in WhangKumbae, pollen source affected core size and number of seeds. In Chuwhangbae and Yeongsambae, pollen source affected fruit weight and the number of seeds. Nyeki *et al.* (1994) reported variation in number of seed under different combinations.

The variation in seed content of fruits in pear varieties was also a function of different conditions of fertilization, such as open pollination, natural autogamy and allogamy. Nyeki *et al.* (1998) reported that natural autogamy occurred with very few viable seeds (0.4-1.9/fruit). The mean rate of the number of seeds per fruit was longer as the result of purposeful allogamy i.e. cross-pollination than on open pollinated flowers from the same variety. Varieties known as good pollen producers resulted in higher seed content (6.6-6.7) in fruits pollinated by them.

CHAPTER – 3

MATERIALS AND METHODS

Investigation on “Pollen compatibility studies of some commercially important pear varieties (*Pyrus communis* L.)” were carried out in the Division of Pomology, Sher-e-Kashmir University of Agricultural Science and Technology, Shalimar, Srinagar during the year 2006-2007. Materials

used and methods employed are detailed below.

3.1 Materials

Full bearing pear cultivars, uniform in age were selected for experimentation in pear orchard at Shalimar Campus, Srinagar, Kashmir. The orchard had proper air drainage. The soil was moderately deep, having medium fertility status. The trees were spaced at 6m x 6m and received uniform recommended cultural practices during the studies.

3.2 Treatments

Six commercially important cultivars of pear viz., 'William Bartlett' (Awal No.), 'Vicar of Winkfield' (Satarwati Kalan), 'Gent Drouard', 'Flemish Beauty', 'Fertility' (Mishri Tang) and 'Chinese Sandy pear' (Nakh Kashmiri) were used in the present studies. Single tree in each cultivar constituted an experimental unit and each cultivar was replicated four times.

3.3 Methods

3.3.1 Time and duration of flowering

3.3.1.1 Initial bloom

This parameter was observed visually. The date of occurrence for each tagged tree was recorded when about 10 per cent of the flowers opened. The dates thus recorded were converted to days after reference date (DARD) fixed arbitrarily as 1st March.

3.3.1.2 Full bloom

This parameter was also observed visually. The date of occurrence of full bloom was recorded when experimental unit exhibited about 90 per cent of open flowers. The dates recorded were again converted to days after reference date as for initial bloom (Plate 1 and 2).

3.3.1.3 End of flowering

The date of occurrence was recorded when experimental unit exhibited 100 per cent of open flowers. The dates recorded were again converted to days after reference date as in initial bloom and full bloom.

3.3.1.4 Duration of flowering

The duration of flowering was worked out as the difference between the days taken to reach Initial bloom and end of flowering in each tagged tree of each cultivar under study.

3.3.2 Floral biology

3.3.2.1 Location of flower buds

Four branches from each cultivar were visualised and location of floral buds were observed on each tagged trees for each cultivar.

3.3.2.2 Number of flowers per spur

Thirty spurs on each tagged tree, on two or three year old wood were chosen at random. The total number of flowers were counted and averaged to the number of flowers per spur.

3.3.2.3 Floral density

Four branches, each one metre down from the base of one-year-old wood, on each tagged tree were selected. The number of flowers were counted and averaged to the flowering density i.e. number of flowers/metre shoot length.

3.3.2.4 Number of stamens per flower

Twenty spur borne flowers chosen at random on each tagged tree in all six cultivars were studied for number of stamens per flower.

3.3.3 Flower anthesis and anther dehiscence

3.3.3.1 Flower anthesis

In order to obtain daily periodical progress of anthesis, forty flowers likely to open next day were tagged and on the day of anthesis data was recorded at two hourly intervals from 8 am to 6 pm. The anthesized flowers after each interval of two hours were counted. The study was conducted for a week.

3.3.3.2 Anther dehiscence

Ten flowers ready to open were observed for recording the data on the dehiscence of anthers in each variety. The dehisced anthers were counted at an interval of two hours from 8 am to 4 pm, daily. The study was carried out for 3 days.

3.3.3.3 Receptivity of stigma

To assess the receptivity of stigma, controlled pollination was done on emasculated flowers at different stages of flower development viz., two days prior to anthesis, one day prior to anthesis, on the day of anthesis, one day after anthesis and two day after anthesis in each cultivar. The fruit set was recorded twenty days after pollination. The fruit set was used as an index of stigma receptivity following controlled pollination and receptivity of stigma were also measured by visual observation.

3.4 Pollen studies

3.4.1 Pollen collection

In each variety a few branches with good number of healthy closed flowers at balloon stage were removed. After discarding already open

flowers and late buds, the pollen was obtained by removing the anthers with the help of sterilized forceps on a white sheet paper. The anthers were dried for a while so that pollen from anther come out and then debris were removed.

Pollen sample of each cultivar was stored separately in sterilized and labelled glass vials capped with cotton. The pollen sample were then preserved in anhydrous CaCl_2 packed dessicator covered airtight, at ambient temperature.

3.4.2 Pollen germination

For *in vitro* pollen germination analysis, two methods were employed for this, in first method sucrose nutrient medium at 10 per cent concentration was prepared. Besides sucrose, the nutrient medium contained 0.025 g of boric acid and 1 g of agar per 100 ml of distilled water. The pollen of each cultivar was dusted with fingertip on the nutrient medium. Separately, the cultured pollen contained in petridish covered with lids was kept for 24 hours under laboratory conditions and then examined under microscope. Another method employed was hanging drop method in which only 10 per cent sucrose was used and pollens were dusted in same manner as in agar plate method and then incubated for 24 hours under laboratory conditions. They were then examined under microscope.

3.4.3 Pollen viability

For *in vitro* pollen viability analysis Acetocarmine solution was prepared besides 1 g of Acetocarmine, 40 ml of 95 per cent ethanol and 60 ml of distilled water was taken to make volume 100 ml. Then pollens were sowed for 1 hour for staining and examined under microscope.

3.5 Pollination studies

3.5.1 Emasculation

This consisted of removal of stamens from the female or seed parent before the anther dehiscence. For each cultivar, four branches on each tagged tree with most of flowers at popcorn stage were selected. Open flowers and late buds were removed. The selected flowers were counted and after emasculation i.e. removal of stamens, covered with muslin bags to avoid cross pollination (Plate 3).

3.5.2 Hand self-pollination

The bagged flowers were then hand pollinated, 24 hours after emasculation, with the preserved pollen of same cultivar. The pollinated flowers were labelled and again covered with muslin bags for 10 days after pollination.

3.5.3 Open pollination

Two branches on every tagged tree of each cultivar having healthy flowers were tagged after counting the flowers. They were left as such for open pollination.

3.5.4 Hand cross-pollination

The emasculated flowers were crossed (pollinated) by dipping a small, soft brush into a glass vial/tube containing the pollen on to the stigma. Pollination can be done equally well by dipping the finger tip into the pollen vial. Both methods were quick and effective. Flowers at popcorn stage i.e. likely to open next day were selected and emasculated. Open flower as well as late buds were removed. The emasculated flowers were covered with bags. They were then pollinated, 24 hours after emasculation with the pollen of the parent as per the crossing plan (Appendix-I). The pollinated flowers were labelled and again covered with muslin bags which were removed after 10 days of pollination (Plate 4).

3.6 Fruit set

3.6.1 Initial fruit set

Twenty days after cross-pollination, the percentage of fruit set on the basis of total number of flowers pollinated under different modes of pollination was recorded (Plate 5).

3.6.2 Fruit retention (at weekly intervals)

The fruits retained after initial fruit set were counted at weekly interval and the percentage of fruits retained was calculated. The study was conducted for three weeks after fruit set.

3.6.3 Fruit carried to maturity

The number of fruits carried to maturity were counted and expressed in percentage on the basis of number of flowers pollinated.

3.6.4 Number of days taken upto Harvest of pear cultivars

The date of harvesting was recorded when fruit had attained proper size and developed colouration.

3.6.5 Fruit characteristics

One random composite representative sample of 48 fruits (i.e, 24 big and 24 small) from each tagged tree of each cultivar was drawn at harvesting stage (Plate 6). These samples were collected in labelled polythene bags and carried to the laboratory for further investigation.

3.7 Physical characteristics

3.7.1 Fruit diameter

The random samples from each experimental unit of each cultivar was measured separately with the Digital Vernier Caliper in (mm) and then converted into (cms). The average fruit diameter was determined by dividing the total diameter obtained (cm) by the number of fruits in the sample.

3.7.2 Fruit volume

The random sample from each experimental unit of each cultivar were analysed for fruit volume (cc) by displacement method which was determined by dropping the fruit into the displacement jug, the volume of water over flown into the measuring cylinder was the volume of fruit and the average volume (cc) of fruit was the volume obtained (cc) by the number of fruits in sample.

3.7.2 Fruit shape

Fruit shape was observed visually and categorised by comparison with descriptor of pear.

3.7.3 Fruit firmness (lb/inch²)

The firmness of representative fruit samples was measured using Digital Pentrometer.

3.8 Analytical method

3.8.1 Total soluble solids

The hand refractometer of range (0-32) °Brix (Erma make Japan) was used to determine total soluble solids of fresh fruit samples. The values were corrected at 20°C (Ranganna, 1997).

3.8.2 Titrable acidity

Titration acidity (%) was determined by titration and values were expressed as percentage of malic acid (Ranganna, 1997). 10 ml sample of filtered juice extracted from 500gm of pear fruit was taken and volume made upto 100ml with distilled water. Then 3 samples each of 10ml from this make up volume were taken and titrated against standard 0.1 N NaOH using phenolphthalein as indicator till light pink colour (end point) was obtained and volume used was noted. The percentage acidity was evaluated using following formula:

$$\text{Titration acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of NaOH} \times \text{Volume makeup} \times \text{Eq. Wt. of acid}}{\text{Vol. of sample} \times \text{Volume of aliquot taken for estimation}} \times 100$$

3.8.3 Sugars

Total and reducing sugars were estimated by using Lane and Eynon method (Ranganna, 1997).

3.8.4 Total sugars

Juice was extracted from the pear fruits of respective cultivar using juicer (Philips). 10 ml sample of juice was taken and 5ml of concentrated HCl was added to it, then left undisturbed for 24 hours. It was then neutralized with sodium hydroxide using phenolphthalein as indicator. 2ml of 45 per cent lead acetate was added to it and left undisturbed for 10 minutes after which 2ml of 22 per cent potassium oxalate was added. Volume was made upto 250ml and then filtered. The make up volume was then titrated against 5ml Fehling A and Fehling B with 25ml of distilled water on continuous heating. After appearance of light red colour, 4 to 6 drops of methylene blue were added to it and then titrated again till brick red colour (end point) appeared. The volume consumed was measured and the total sugar was calculated by using following formula:

$$\text{Reducing or total sugars} = \frac{0.05 \times \text{Volume make up}}{\text{Titre value} \times \text{Weight of sample}} \times 100$$

For estimation of reducing sugar, the procedure followed was same as for total sugars without adding 5ml of concentrated hydrochloric acid, and waiting period of 24 hrs. Titration performed was same as for total sugars.

3.9 Number of seeds/fruit

Random samples from each cross combination of each cultivar were observed for number of seeds. The average number of seeds/fruit was determined by dividing total number of seeds by number of fruits observed in a sample.

3.10 Juice (%)

The volume of juice obtained by juicer from fruits of each cultivar of pear was measured to obtain the per cent of juice recovery. The juice per cent was measured volumetrically and expressed as juice per cent as per equation :

$$\text{Juice (\%)} = \frac{\text{Volume of juice (L)}}{\text{Weight of fruit (kg)}} \times 100$$

3.11 Sensory evaluation

Sensory quality attributes such as skin colour, flesh odour, flavour and overall acceptability of pear fruit were evaluated by 10 semi-trained panellists. The pear fruit for organoleptic evaluation were presented to the panellists in coded form and then were requested to note their sensory responses on the basis of skin colour, flesh colour, flavour and overall acceptability on 4 point hedonic scale.

4	=	Excellent
3	=	Good
2	=	Fair
1	=	Poor

3.12 Statistical analysis

For statistical analysis Randomized Block Design was followed. Cultivars and cultivar combinations were considered as variants for assessing initial fruit set, fruit retention and fruit carried to maturity under different modes of pollination. Whereas, for other traits only cultivars were considered as variants.

Chapter – 4

Experimental Findings

The present investigation was undertaken to generate information on pollen compatibility in some commercially important pear cultivars. The important experimental findings (character-wise) are described in present chapter.

4.1 Time and duration of flowering

The average number of days taken to reach first bloom, full bloom and end of flowering by six cultivars of pear are presented in Table 1. The values represent the average number of days taken to reach the particular phenological stage from 1st March, that was taken as the reference date.

4.1.1 Initial bloom

It is evident from Table 1, that cultivar ‘Fertility’ took maximum number of days (32.75 DARD) to reach initial bloom as against minimum of (26.75 DARD) required by ‘Chinese Sandy pear’. However, differences between one set of varieties viz. ‘Gent Drouard’, ‘Vicar of Winkfield’ and ‘William Bartlett’ and the other set viz. ‘Flemish Beauty’, ‘William Bartlett’ and ‘Vicar of Winkfield’ were statistically *at par* with each other.

4.1.2 Full bloom

The perusal of Table 1 also revealed, that cultivar ‘Chinese Sandy pear’ required significantly minimum number of days (32.50 DARD) to reach full bloom. However, the cultivar ‘Fertility’ required maximum number of days (37.75 DARD) to reach this stage as against other cultivars. The cultivars

‘Flemish Beauty’, ‘Gent Drouard’ and ‘William Bartlett’ took (35.50, 36.25 and 36.25 DARD), respectively to attain this stage. However, these cultivars were found to be statistically *at par* with each other. Furthermore, cultivar ‘Vicar of Winkfield’ took 34.75 DARD to reach full bloom stage, which was statistically *at par* with cultivar ‘Flemish Beauty’.

4.1.3 End of flowering

It is evident from Table 1, that on an average ‘Chinese Sandy pear’ required minimum number of days (35.05 DARD) to complete its flowering as against other cultivars. However, the cultivars ‘Fertility’ (40.75 DARD) and ‘Vicar of Winkfield’ (40.75 DARD) took appreciably more number of days to complete its flowering than other cultivars except ‘Gent Drouard’ (40.25 DARD). However, cultivar ‘William Bartlett’ took 39.25 DARD for end of flowering which was found to be statistically *at par* with ‘Gent Drouard’ (40.25 DARD).

4.1.4 Duration of flowering

Maximum effective blooming period (10.00 days) was observed in ‘Vicar of Winkfield’ as compared to other cultivars under study (Table 1). Other cultivars were statistically *at par* with each other in this regard.

4.2 Floral biology

4.2.1 Location of flower buds

Location of flower buds of six pear cultivars under study were found to be on spurs and laterals.

4.2.2 Number of flowers/spur

It is evident from the Table 2, that average number of flowers/spur in different pear cultivars was in the range from 7.00 to 7.50 and no significant statistically differences was observed in this character.

4.2.3 Flowering density

Maximum density of flowering per meter shoot length was significantly higher in ‘Vicar of Winkfield’ (53.50) as compared to other cultivars, except ‘Fertility’ (51.00) and ‘Gent Drouard’ (50.50). Where as, minimum density of

flowering was observed in 'Chinese Sandy pear' (44.25) which was statistically *at par* with 'Flemish Beauty' (47.00) and 'William Bartlett'. However, density of flowering per meter shoot length in 'Fertility', 'Gent Drouard' and 'William Bartlett' (51.00, 50.50 and 48.25), respectively was *at par* statistically with each other (Table 2).

4.2.4 Number of stamens/flower

Number of stamens per flower was observed significantly higher in 'Vicar of Winkfield' (21.75) which was significantly higher than other cultivars except 'Fertility' (21.00) (Table 2). However, number of stamens in cultivar 'Chinese Sandy pear' (18), 'Flemish Beauty' (18), 'Gent Drouard' (19) and 'William Bartlett' (19.50) were found to be statistically *at par* with each other.

4.3 Flower anthesis and anther dehiscence

4.3.1 Flower anthesis

The pear inflorescence is indeterminate type i.e., first and terminal flowers open last, whereas lateral and side flowers open first. The time of anthesis was studied in all cultivars. Normally the petals started opening from the top of the flower bud and assumed a round cup-like shape for sometime. At this stage the male and female organs of flower were visible. From this stage up to the final expansion of petals, the flower buds took 1-3 hrs to open depending upon humidity and temperature. This period was longer during the early and late hours of the day.

It is evident from the data presented in Table 3a to 3f and Fig. 1 that anthesis continued throughout the day but the peak period was observed from 12 noon to 2 pm followed by anthesis from 10 am to 12 noon in all cultivars. However, the maximum proportion of flowers opened from 12 noon to 2 pm in 'Fertility' (40.70%) followed by 'Gent Drouard' (37.50%). Similarly, anthesis of flowers ranged from (35.71%) in 'Fertility' to (23.21%) in 'Vicar of Winkfield' between 10 am to 12 noon. Anthesis of flowers declined sharply before 10 am and after 2 pm in all cultivars.

4.3.2 Anther dehiscence

The anthers were arranged in two whorls, dehiscence of anthers started from the outer whorl to inner. It took place by a longitudinal slit from the joint of the pollen sacs in each lobe. The dehiscence of anthers in the cultivars of pear studied was completed within 2 to 3 days from anthesis.

The data pertaining to anther dehiscence are presented in Table 4a to 4e and Fig. 2. The results indicate that maximum dehiscence occurred from 10am to 2pm in all cultivars. However, the peak dehiscence was observed between 10am to 12 noon for 'William Bartlett', 'Vicar of Winkfield' and 'Gent Drouard'. Peak period of anther dehiscence in 'Flemish Beauty', 'Fertility' and 'Chinese Sandy pear' was observed between 10 am to 2 pm.

4.3.3 Stigma receptivity

Five cultivars were studied for onset and duration of stigma receptivity and the results are presented in Table 5. The data revealed that different cultivars exhibited extreme variability in the degree of stigma receptivity depending upon the source of pollen used.

In this study, the cultivar 'William Bartlett' was found receptive to 'Vicar

of Winkfield', 'Gent Drouard' and 'Chinese Sandy pear' for very short period (upto 1 days after anthesis). Whereas, this cultivar exhibited maximum duration of receptivity for 'Flemish Beauty' and 'Fertility' (upto 3 days after anthesis). Similarly, 'Vicar of Winkfield' was receptive for 'Gent Drouard' upto 2 days after anthesis and for 'Chinese Sandy pear' only a day after anthesis whereas, the receptivity for 'Flemish Beauty' and 'Fertility' was comparably higher (upto 3 days after anthesis). Furthermore, in cultivar 'Gent Drouard', as a female parent, stigma receptivity lasted upto 3 days for 'Flemish Beauty' whereas, for 'Chinese Sandy pear' and 'Fertility' it was only upto 2 days after anthesis. Similarly, receptivity of stigma for 'Flemish Beauty' was observed to be higher for 'Chinese Sandy pear' and 'Fertility' upto 3 days after anthesis. The cultivar 'Fertility' was not receptive to any pollen.

These investigations further revealed that the stigma became receptive 1 to 2 days before anthesis and receptivity lasted till 3 days after anthesis. The maximum receptivity of stigma in almost all the cultivars was on the day of anthesis. 'William Bartlett' exhibited higher receptivity for 'Fertility' 74.43 per cent followed by 'Flemish Beauty' (48.13%), 'Gent Drouard' (32.17%) and 'Chinese Sandy pear' (30.77%). However, comparatively low receptivity was observed for 'Vicar of Winkfield' (20.02%). 'Vicar of Winkfield' as female parent showed highest receptivity for 'Flemish Beauty' (72.99%) followed by 66.10 per cent stigma receptivity for 'Fertility' but comparatively low receptivity for 'Gent Drouard' (19.86%) and 'Chinese Sandy pear' (17.96%). 'Gent Drouard' also showed highest receptivity for 'Flemish Beauty' (68.11%) followed by 55.71 per cent for 'Fertility' and exhibited relatively lower stigma receptivity for 'Chinese Sandy pear' (21.73%). 'Flemish Beauty' recorded highest receptivity for 'Fertility' (66.22%) followed by 'Chinese Sandy pear' (32.53%). However, cultivar 'Fertility' did not show receptivity for cultivar 'Chinese Sandy pear'.

4.4 Pollen germination and pollen viability

The data pertaining to pollen germination in Table 6 revealed that pollen germination was highest in cultivar 'William Bartlett' (66.66%) and minimum in

'Fertility' (54.16%). However, the differences among all cultivars were statistically non-significant in this respect. From these observations it is also evident that the highest pollen viability was found to be in 'William Bartlett' (70.00%) whereas, minimum in 'Vicar of Winkfield' (61.66%). The data however, was found to be statistically non-significant in this respect.

4.5 Hand self-pollination

It is evident from the results (Table 7, Fig. 3) of hand self-pollination that initial fruit set was significantly higher in cultivar 'Vicar of Winkfield' (18.42%) as compared to other cultivars except 'Flemish Beauty' (17.62%). However, lowest initial fruit set was observed in 'William Bartlett' (5.46%). Furthermore cultivar 'Chinese Sandy pear' (8.02%) set higher initial fruit percentage (8.02%) than 'William Bartlett'. Cultivars, 'Fertility' and 'Gent Drouard' showed complete self-incompatibility.

4.6 Open pollination

The observations in open pollination revealed that initial fruitset was highest (63.28%) in 'Chinese Sandy pear' and lowest in 'Flemish Beauty' which recorded (51.35%) followed by 'Gent Drouard' (54.52%). Furthermore, cultivar 'Vicar of Winkfield' showed lowest initial fruitset (56.84%) than 'William Bartlett' (60.90%) and 'Fertility' (60.66%). These two cultivars were statistically *at par* (Table 7, Fig. 4-7).

4.7 Hand-cross pollination

The initial fruitset percentage of 60.90 per cent in 'William Bartlett' under open pollination significantly increased to 74.43 per cent when pollinated with 'Fertility' (Table 7, Fig. 4-7). The degree of compatibility was higher when 'Fertility' was used as a pollinizer as compared to other pollinizers (cultivars) than any other cultivar. This was evidenced from the significantly higher fruit set when 'William Bartlett' was crossed with 'Fertility'. Furthermore, 'Flemish Beauty' also showed good compatibility when used as pollen parent for 'William Bartlett', with (48.13%) fruit set followed by 'Gent Drouard' (32.17%) and 'Chinese Sandy pear' (30.77%). However, 'Vicar of Winkfield' showed low compatibility with (20.02%) fruitset when used as pollen parent for 'William Bartlett'.

Initial fruitset of 56.84 per cent in 'Vicar of Winkfield' under open pollination significantly increased to 72.99 per cent when pollinated with 'Flemish Beauty' and 66.10 per cent when crossed with 'Fertility'. However, when 'Gent Drouard' and 'Chinese Sandy pear' was used as pollen parent for 'Vicar of Winkfield' a significantly low fruitset percentage of 19.86 and 17.97 per cent, respectively was recorded as compared to 56.84 per cent fruitset recorded by the cultivar under open pollination. When cultivars 'Gent Drouard' and 'Chinese Sandy pear' were used as pollinizers for 'Vicar of Winkfield' the fruitset percentage was observed to be statistically *at par*.

When 'Gent Drouard' was crossed with 'Flemish Beauty' significantly higher initial fruitset (68.11%) was recorded as compared to

initial fruitset (54.52%) observed under open pollination conditions. However, (55.71%) initial fruitset was recorded when 'Gent Drouard' was crossed with 'Fertility' and was statistically *at par* with initial fruitset percentage observed under open pollination conditions. Further, significantly low fruitset (21.73%) was observed when crossed with 'Chinese Sandy pear' as compared to other cross combinations.

Significantly, higher initial fruit set (66.23%) was observed when 'Flemish Beauty' was crossed with 'Fertility' as compared to 51.35 per cent recorded under open pollination conditions. However, initial fruit set percentage was observed when pollinated with 'Chinese Sandy pear' (32.50%) as against other cross combinations. Complete lack of fruit set was observed in 'Fertility' when pollinated with 'Chinese Sandy pear'.

4.8 Fruit retention

4.8.1 Fruit retained upto 1st week after two months of fruitset

The results presented in Table 8 revealed that average percentage of fruit retained (on 21st June) in 'William Bartlett' x 'Fertility' combination was significantly higher (61.55%) as followed by 'William Bartlett' x 'Open' (45.58%), 'William Bartlett' x 'Flemish Beauty' (42.47%), 'William Bartlett' x 'Chinese Sandy pear' (24.45%) and 'William Bartlett' and 'Gent Drouard' (20.92%). Whereas, 'William Bartlett' x 'Vicar of Winkfield' (15.75%) retained significantly less fruit percentage than other cross combinations of this cultivar.

Among all cross combinations involving 'Vicar of Winkfield' as the female parent, the cross combination 'Vicar of Winkfield' x 'Chinese Sandy pear' retained significantly less fruits (11.92%) as compared to other cross combinations. Whereas, 56.90 per cent fruits were retained in cross combination of 'Vicar of Winkfield' x 'Flemish Beauty' and were significantly higher than all other cross combinations. Fruits retained in 'Vicar of Winkfield' x 'Fertility' were also significantly higher (54.11%) than the fruits retained in 'Vicar of Winkfield' under open pollination. However, significantly less fruits (16.50%) were retained in cross combination of 'Vicar of Winkfield' x 'Gent Drouard'. Percentage of fruits retained by 'Gent Drouard' when crossed with 'Flemish Beauty' was highest (54.00%) followed by 'Fertility' (44.35%) as compared to fruits retained by 'Gent Drouard' under open pollination (41.52%). However, 'Gent Drouard' x 'Chinese Sandy pear' retained less fruits (17.71%) as compared to other cross combinations. 'Flemish Beauty' retained significantly lesser percentage of fruits (39.73%) under open pollination and when crossed with 'Chinese Sandy pear' (28.38%) than when crossed with 'Fertility' (46.32%).

4.8.2 Fruit retained upto 2nd week after two months of fruitset

The results presented in Table 8 revealed that average percentage of fruit

retained (on 28th June) by 'William Bartlett' in cross combination 'William Bartlett' x 'Fertility' was significantly higher (42.90%) as compared to other cross combinations. However, less fruits (12.77%) were retained in cross combination of 'William Bartlett' x 'Vicar of Winkfield'. However, open pollinated 'William Bartlett' and 'William Bartlett' x 'Flemish Beauty' cross combination were statistically *at par* with each other.

Among cross combinations of 'Vicar of Winkfield', 'Vicar of Winkfield' x 'Fertility' retained significantly higher percentage of fruits (44.22%), followed by 'Vicar of Winkfield' x 'Flemish Beauty' cross combination (41.50%). 'Vicar of Winkfield' x 'Chinese Sandy pear' cross combination retained significantly less fruits (9.81%) as compared to other cross combinations. 'Gent Drouard' as pollen acceptor retained significantly higher percentage of fruits (42.70%) when crossed with 'Flemish Beauty', followed by 35.92 per cent when crossed with 'Fertility' and 35.05 per cent fruits under open pollination conditions, however, these two cross combinations were statistically *at par* with each other. Furthermore, significantly low fruits 14.45 per cent were retained on 2nd week in cross combination of 'Gent Drouard' x 'Chinese Sandy pear'.

'Flemish Beauty' retained significantly higher percentage of fruits (39.10%) when crossed with 'Fertility' followed when left for open pollination 36.64 per cent. In cross combinations of 'Flemish Beauty' x 'Chinese Sandy pear' also retained significantly (23.75%) of fruits. Among cross combinations of 'Fertility' as female parent retained highest percentage of fruits (41.11%) under

open pollination. Whereas, 'Fertility' did not showed any compatibility in other cross combinations as there were no initial fruitset.

4.8.3 Fruits retained upto 3rd week after two months of fruitset

Among different cross combinations fruits retained upto 3rd week after two months of fruitset (05 July) involving 'William Bartlett' as female parent, 'William Bartlett' x 'Fertility' cross combination retained significantly higher fruit percentage (38.02 %) as compared to other cross combinations. In cross combination of 'William Bartlett' x 'Vicar of Winkfield', retained significantly less (9.40%) fruits. Cross combination of 'William Bartlett' x 'Flemish Beauty' retained 27.05 per cent of fruits which were significantly higher than cross combination of 'William Bartlett' x 'Chinese Sandy pear' (13.82%). 'Vicar of Winkfield' as pollen acceptor in cross combination with 'Flemish Beauty' retained significantly higher percentage of (39.05%) fruits as compared to other cross combinations, followed by 'Vicar of Winkfield' x 'Fertility' cross combination (36.55%). In cross combination of 'Vicar of Winkfield' x 'Chinese Sandy pear' retained significantly lower percentage of (8.52%) fruits as compared to other cross combinations of this cultivar.

Fruit retained upto 3rd week after 2 months of fruitset in cross combination of 'Gent Drouard' x 'Chinese Sandy pear' were significantly less (12.54%) as compared to other cross combinations. However, the differences between one set of cross combination viz., 'Gent Drouard' x 'Flemish Beauty' and 'Gent Drouard' x 'Fertility' and other set of cross combinations 'Gent Drouard' x 'Fertility' and

‘Gent Drouard’, when open pollinated were statistically *at par* with each other.

‘Flemish Beauty’ as female parent, retained significantly higher percentage of fruits (35.22%) in cross combination of ‘Flemish Beauty’ x ‘Fertility’ as compared to other cross combination, followed when left open pollination (35.25%). However, cross combination of ‘Flemish Beauty’ x ‘Chinese Sandy pear’ retained significantly lower (20.85%) fruits (Table 8).

4.9 FRUITS CARRIED TO MATURITY

The fruits carried to maturity was highly variable depending upon the source of pollen and the results obtained in orchard pollination are given in Table 9. In cultivar ‘William Bartlett’ significantly higher percentage of fruits (38.02%) was carried to maturity when ‘Fertility’ was used as pollen parent in comparison to other cross combinations, followed by open pollination (28.77%). Combination of ‘William Bartlett’ x ‘Vicar of Winkfield’, carried significantly less percentage of fruits (9.40%) to maturity. ‘William Bartlett’ x ‘Flemish Beauty’ carried 27.05 per cent of fruits to maturity which were significantly higher than ‘William Bartlett’ x ‘Chinese Sandy pear’ combination (13.82%). ‘Vicar of Winkfield’ as pollen acceptor in combination, with ‘Flemish Beauty’ carried significantly higher percentage of fruits (39.05%) to maturity as compared to other combinations, followed by ‘Vicar of Winkfield’ x ‘Fertility’ combination (36.55%). ‘Vicar of Winkfield’ x ‘Chinese Sandy pear’ carried significantly lower percentage of fruits (8.52%) to maturity as compared to other combinations.

Fruits carried to maturity by 'Gent Drouard' x 'Chinese Sandy pear' were significantly lower (12.54%) as compared to other cross combinations. However, differences between one set of cross combinations viz., 'Gent Drouard' x 'Flemish Beauty' and 'Gent Droaurd' x 'Fertility' and another set viz., 'Gent Drouard' x 'Fertility' and 'Gent Drouard', under open pollination conditions were statistically *at par* with each other.

'Flemish Beauty' as female parent, carried significantly higher percentage of fruits (35.22%) to maturity in cross combination of 'Flemish Beauty' x 'Fertility' as compared to other cross combinations, followed by open pollination (32.25%). 'Flemish Beauty' x 'Chinese Sandy pear' carried significantly less percentage of fruits (20.85%) to maturity.

4.10 Number of days taken upto harvest

The data presented in Table 10 revealed that on an average cultivar 'Vicar of Winkfield' took significantly maximum number of days (176.50 DARD) to reach harvestable stage whereas, 'Gent Drouard' took significantly least number of days (131.75 DARD) to reach harvestable maturity as compared to other cultivars except 'Flemish Beauty' (136.25 DARD) and 'William Bartlett' (138.00 DARD). Time taken by 'Fertility' and 'Chinese Sandy pear' to reach harvestable maturity did not vary significantly, though both cultivars were harvested later than 'Flemish Beauty' and 'William Bartlett'.

4.11 Physico-chemical characteristics of pear cultivar

4.11.1 Physical characteristics

4.11.1.1 Fruit diameter

The data presented in Table 11a revealed that average fruit diameter of 6.92 cm in 'Flemish Beauty' was significantly higher than all other cultivars. The average fruit diameter of 3.86 and 3.96 cm was recorded in 'Fertility' and 'Chinese Sandy pear', respectively and were statistically *at par* with each other, however, their average fruit diameter were significantly lower than all other cultivars. The diameter of cultivar 'William Bartlett' (5.05 cm) and 'Gent Drouard' (5.40 cm) were *at par* with each other for fruit diameter.

4.11.1.2 Fruit volume

The data presented in the Table 11a revealed that average fruit volume of 120.25 cc in 'Flemish Beauty' was significantly higher than all other cultivars. The average fruit volume of 38.00 cc in 'Fertility' was significantly lower as compared to other cultivars except 'Chinese Sandy pear' with fruit volume as 40.75 cc. These cultivars were *at par* with each other in this respect. Fruit volume of cultivar 'Vicar of Winkfield' (89.25 cc), 'Gent Drouard' (92.50 cc) and 'William Bartlett' (99.25 cc) was lower than fruit volume of 'Flemish Beauty'. These cultivars were statistically *at par* with each other.

4.11.1.3 Fruit firmness

Data in Table 11a revealed that 'Chinese Sandy pear' had significantly highest fruit firmness (11.27 lb/inch²) as compared to other cultivars except 'Vicar of Winkfield' (10.66 lb/inch²). However, other cultivars were found to be statistically non-significant.

4.11.2 Chemical characteristics

4.11.2.1 Total soluble solids (TSS)

It is evident from Table 11b TSS was significantly highest in 'Flemish Beauty' (16.95%), followed by (14.63%) in 'Fertility'. However, significantly lowest TSS was found in cultivar 'Chinese Sandy pear' 10.52 per cent than other cultivars except 'William Bartlett' 11.36 per cent. Cultivars 'William Bartlett', 'Gent Drouard' and 'Vicar of Winkfield' was statistically *at par* with each other in this parameter.

4.11.2.2 Acidity

The data revealed (Table 11b) that 'Vicar of Winkfield' had highest acidity (0.5%) followed by 'Flemish Beauty' (0.45%) but these two were statistically *at par* with each other. Both these cultivars differed significantly

with other cultivars in respect to acidity. Cultivar 'William Bartlett' and 'Gent Drouard' had lower acidity (0.19%) among all the cultivars under study. 'Fertility' and 'Chinese Sandy pear' had significantly higher acidity 0.27 per cent and 0.32 per cent, respectively than 'William Bartlett' and 'Gent Drouard'.

4.11.2.3 TOTAL SUGARS

The experimental findings revealed (Table 11b) that 'Flemish Beauty' had significantly highest percentage (14.42%) of total sugars, followed by 'Fertility' (12.73%). Cultivar 'Vicar of Winkfield' had lowest percentage (9.42%) sugars which was statistically *at par* with 'Chinese Sandy pear' (9.64%) and 'Gent Drouard' (9.69%). However, cultivar 'William Bartlett' had significantly higher percentage of total sugar (10.97%) as compared to 'Vicar of Winkfield', 'Chinese Sandy pear' and 'Gent Drouard'.

4.11.2.4 Reducing sugar

The data in Table 11b revealed that 'Flemish Beauty' had highest percentage of reducing sugar (12.63%) which differed significantly from other cultivars. 'Vicar of Winkfield' had lower percentage of reducing sugar (4.65%) followed by 'Gent Drouard' (5.00%). However, these two were statistically *at par* with each other. 'Chinese Sandy pear' had significantly higher reducing sugar (6.05%) than 'Vicar of Winkfield' and 'Gent Drouard' but lower than 'William Bartlett' (7.27%) and 'Fertility' (7.92%) which were statistically *at par* with each other.

4.12 Number of seeds per fruit

The number of seeds per fruit (Table 12) were non-significant in all cross combinations among different pear cultivars. There was no significant difference in respect of seed number per fruit in any cross combinations.

4.13 Juice percentage

JUICE PERCENTAGE WAS SIGNIFICANTLY HIGHER (TABLE 13) IN CULTIVAR 'WILLIAM BARTLETT' (61.62%) AS COMPARED TO OTHER CULTIVARS. 'VICAR OF WINKFIELD' RECORDED LOWEST

JUICE PERCENTAGE (45.45%). JUICE PERCENTAGE OF (55.59%) WAS RECORDED IN 'CHINESE SANDY PEAR' WHICH WAS SIGNIFICANTLY HIGHER THAN 'gENT DROUARD' (50.25%). HOWEVER, THIS CULTIVAR WAS FOUND TO BE STATISTICALLY AT PAR WITH 'FLEMISH BEAUTY' AND 'FERTILITY'.

4.14 ORGANOLEPTIC EVALUATION OF DIFFERENT PEAR CULTIVARS

There were significant differences in respect to organoleptic scores, which was evaluated in terms of various quality attributes including skin colour, flesh colour, texture, taste and aroma. The quality parameters are presented as under :

4.14.1 SKIN COLOUR

The data pertaining to skin colour score (Table 14) was found to be significantly higher in cultivar 'Chinese Sandy pear' (4.00) whereas, lowest mean skin colour score was recorded in 'Fertility' (1.60). Cultivar 'William Bartlett', 'Vicar of Winkfield' and 'Gent Drouard' were found to be statistically *at par* with each other.

4.14.2 FLESH COLOUR

The minimum average flesh colour score (Table 14) was found in 'Fertility' (2.20) which differed significantly among all other cultivars. However, other cultivars were found to be statistically *at par* with each other in this respect.

4.14.3 TASTE

The taste scores were found significantly minimum in cultivar ‘Vicar of Winkfield’ (2.30) among all other cultivars except ‘Gent Drouard’ (2.40). Maximum taste score was found in ‘Flemish Beauty’ (3.90) which was *at par* with cultivar ‘Chinese Sandy pear’ (3.70) and ‘Fertility’ (3.60) (Table 14).

4.14.4 TEXTURE

The texture score was significantly higher in ‘Chinese Sandy pear’ (3.70) among all the cultivars whereas, difference in texture score in other cultivars, was found to be statistically *at par* with each other (Table 14).

4.14.5 AROMA

The aroma among the cultivars studied was observed to be minimum in ‘Gent Drouard’ (1.90) as compared to other cultivars (Table 14). Other cultivars were statistically *at par* each other.

CHAPTER – 5

DISCUSSION

5.1 Time and duration of flowering

Significant variations were noticed in the occurrence of almost all the phenological stages from first bloom to end of flowering and also the duration of flowering.

First bloom stage was observed earlier in cultivar ‘Chinese Sandy pear’ and last of all in cultivar ‘Fertility’. Almost similar variations were observed in full bloom stage, ‘Chinese Sandy pear’ exhibiting this stage earlier and ‘Fertility’ last of all. Likewise, ‘Chinese Sandy pear’ attained end of flowering earlier while Fertility and Vicar of Winkfield last of all. The maximum spread of flowering span from first bloom to full bloom was observed in ‘Vicar of Winkfield’, whereas, all other cultivars showed non significant variation in this respect. Analogous variations in various flower bud developmental stages in pear have been noticed by many workers (Aulakh *et al.*, 1981; Farooqui and Happa, 1990; Sandhu *et al.*, 2002; Arzani *et al.*, 2003). Such variation in addition to being varietal characteristic may be due to variation in requirement of chilling hours below 7°C (Capellini *et al.*, 1978; Aulakh *et al.*, 1981; Mukherjee and Rana, 1966).

5.2 FLORAL BIOLOGY

The number of flowers per spur in different pear cultivars was found to be non significant. However, density of flowering per meter shoot length were varied among various cultivars.

Highest flower density was noticed in Vicar of Winkfield and minimum was observed in 'Chinese Sandy pear'. Such variations are controlled by polygenes and are also strongly influenced by agrotechnical factors. Similar variations have been observed by many workers (Sandhu *et al.*, 2002; Aulakh *et al.*, 1981). The studies revealed significant variability in the number of stamens/flower. Maximum mean number of stamens/flower was observed in 'Vicar of Winkfield' followed by "Fertility". The minimum mean number of stamens per flower was observed in 'Chinese Sandy pear' and 'Flemish Beauty'. Variation in the number of stamens/flower have been reported in pears by Aulakh *et al.* (1981) and such variations may be attributed to be a varietal character.

5.3 Anthesis and anther dehiscence

Anthesis continued throughout the day, peak anthesis occurred between 12 noon to 2 pm followed by anthesis between 10 am to 12 noon in all cultivars. Maximum proportion of flowers opened between 12 noon to 2 pm in 'Fertility' and minimum in 'William Bartlett'. Maximum number of flowers opened between 10 am to 12 noon in 'Fertility' and minimum in 'Vicar of Winkfield'. Dehiscence of anthesis was completed within two days of flower anthesis and maximum dehiscence occurred between 10 am to 2 pm in all cultivars. The peak

dehiscence between 10 am to 12 noon was observed in maximum 'William Bartlett' and minimum in Vicar of Winkfield. Similarly, peak dehiscence between 12 noon - 2 pm was observed in 'Flemish Beauty' followed by 'Chinese Sandy pear'. These results are in consonance with the findings of many workers (Mukherjee and Rana, 1966; Aulakh *et al.*, 1981; Josan and Chohan, 1979 ; Chitkara and Kartar, 1979). Flower anthesis and anther dehiscence besides being genetically controlled is strongly influenced by climatic conditions particularly temperature and relative humidity.

5.4 Stigma receptivity

The cultivars showed high variability in the degree of stigma receptivity and this was observed to be dependent on the pollinizer used as well. In most of the cases stigmas became receptive a day before anthesis and receptivity lasted till 3 days after anthesis. Most of the cultivars exhibited maximum stigma receptivity on the day of anthesis and some of the cultivars showed a day after.

Generally receptivity decreased rapidly after anthesis in all the cultivars. 'Fertility' showed zero receptivity for cultivar 'Chinese Sandy pear'. William Bartlett exhibited high stigma receptivity for 'Fertility' and 'Flemish Beauty', moderate receptivity for 'Gent Drouard' and 'Chinese Sandy pear' and very low receptivity for 'Vicar of Winkfield'. Vicar of Winkfield showed highest receptivity for 'Flemish Beauty' and lowest for 'Chinese Sandy pear'. 'Gent Drouard' exhibited low receptivity for cultivar 'Chinese Sandy pear' and

maximum receptivity for 'Flemish Beauty' followed by 'Fertility'. 'Flemish Beauty' exhibited high receptivity for pollinizer 'Fertility' and moderate receptivity for cultivar 'Chinese Sandy pear'. Comparable variation in degree and duration of stigma receptivity in pear have been reported by many workers (Sanzol *et al.*, 2003; Nyeki, 1971; Sanzol *et al.*, 2003; Herrero, 2003; Dhaliwal *et al.*, 1982).

Rapid decrease in stigma receptivity after anthesis in pear has been reported by Sanzol *et al.* (2003), Davarynejad *et al.* (1997) and Dhaliwal *et al.* (1982). Stigma receptivity in addition to being a varietal characteristic may also be influenced by temperature, humidity, sunshine and wind during pear bloom. Dhaliwal *et al.* (1982) and Davarynejad *et al.* (1997).

5.5 Initial fruitset

Lack of fruitset was observed in cultivar William Bartlett when self-pollinated. However, some cultivars were partially and others were self-fruitful. Significant variability was observed in fruitset in almost all the cultivars using different pollinizers. Cultivar 'William Bartlett' recorded highest fruitset per cent when crossed with 'Fertility' followed by open pollination. Lowest fruitset was observed when 'William Bartlett' was crossed with 'Vicar of Winkfield'. Vicar of Winkfield recorded highest fruitset when 'Vicar of Winkfield' was crossed with 'Flemish Beauty' followed by 'Fertility'. Lowest fruitset was observed when pollinated with 'Chinese Sandy pear'. 'Gent Drouard' recorded highest fruitset

when crossed with 'Flemish Beauty' and lowest when crossed with 'Chinese Sandy pear'. However, this variety was found to be completely self-incompatible. Flemish Beauty showed highest fruitset per cent when crossed with 'Fertility' followed by when open pollinated. Fertility as recipient parent showed complete incompatibility when cross-pollinated with 'Chinese Sandy pear' and also completely self incompatible. Analogous variations have been noticed in pear by many workers (Franchie *et al.*, 2002; Nyeki *et al.*, 1998; Arzani *et al.*, 2003; Dhaliwal *et al.*, 1982; Seth and Kukshal, 1978; Singh *et al.*, 2004). Lack of fruitset in some cultivars when self pollinated could be due to self-incompatibility which normally occurs within the stylar tissue. Shukla *et al.* (2004) concluded that mechanism of self-incompatibility could be due to pollen stigma interaction, pollen tube style interaction and pollen tube ovule interaction. Pollen stigma interaction occurs just after the pollen grains reach to the stigma and generally prevent pollen germination. In the gametophytic system, stigma surface is plumose having elongated receptive cells and is commonly known as wet stigma. Incompatibility reaction occurs at later stages. There are clear cut serological differences among the pollen grains with different 'S' genotypes, such differences have not been observed in sporophytic system.

Another cause of self-incompatibility could be due to the pollen tube style interaction. In most of the gametophytic systems, pollen grains germinate and pollen tube penetrates the stigma surface. But in the incompatible combinations, the growth of pollen tube is retarded within the stigma. In some cases pollen tube

reaches the ovule and affect fertilization. However, in incompatible combination, embryo degenerate at early stage of development. The biochemical basis for incompatibility is not known, but an antagonism exists between the pistil tissue and pollen germ tube which have the same specific S genes. Ascher (1966) proposed a gene action model to explain gametophytic self-incompatibility. He observed that when the pollen and style S gene are identical, molecules from each unite to form a repressor molecule which prevents normal metabolism and growth by the pollen tube. However, if the S alleles are not identical, the repressor molecules are not formed.

Difference in fruit set within the same variety using different pollinizers have also been reported by many workers (Franchie *et al.*, 2002). The variation in fruit set could probably due to the difference in pollen viability, more viable the pollen, more will be fruit set and can also probably be explained by the differences in temperature during bloom period. At high temperature the pollen grows faster than at low temperatures. The different growth rate of the pollen tube is function of the temperature grows may not be retained as the only explanation. Depending on the pollinizer, the pollen tube from a certain variety would be slowed down to an extent. Besides, the genetic factors which determine the extent of fruit set, the environmental factors also exercise a strong influence. These observations are further supported by the results of Brown (1973) and Stephen *et al.* (1977).

5.6 Commercial harvest

Harvest maturity of pear cultivars varied quite significantly in present investigation. The harvesting was recorded to be early in 'Gent Drouard', followed by 'Flemish Beauty', 'William Bartlett', 'Fertility', 'Chinese Sandy pear' and 'Vicar of Winkfield'. These variations in harvest maturity period could be attributed either due to genetic differences and may be due to the amount of heat units required for attaining maturity.

Variation in harvest maturity of various pear cultivars on the basis of days after full bloom have been noticed by Farooqui and Happa (1990), Azzouni *et al.* (1974), Hwang *et al.* (2005), Rachna *et al.* (2004), Sandhu *et al.* (2002) and on the basis of heat unit accumulation by Fisher (1962) and Anstey (1965).

5.7 Physico-chemical characteristics

5.7.1 Fruit diameter, Fruit volume and Fruit firmness

The studies revealed significant variation among the cultivars in respect of fruit diameter at harvest. Highest average fruit diameter was observed in 'Flemish Beauty' followed by 'Vicar of Winkfield' whereas, lowest average fruit diameter was noticed in 'Fertility'. Increase in fruit size from fruitset to harvest has been characteristic feature of pear cultivars and occurs in three distinct phases (Rachna *et al.*, 2004). In all *Pyrus* species the pattern of fruit growth follows sigmoidal pattern (Mann and Singh, 1988). Size being a quantitative character and

influenced by many environmental factors, there is much variability in this among the pear cultivars (Farooqui and Happa, 1990). High level of cytokinin occurs in fruits during the post fertilization period of cell division (Letham, 1963; Letham and Bollard, 1961). The variation in fruit diameter observed at harvest of the cultivars could be attributed to varietal characteristics, crop load and may also be due to variation in diurnal temperature (Endo, 1974). Almost similar variation has been reported in pear cultivars by many workers (Farooqui and Happa, 1990; Endo, 1974; Rachna *et al.*, 2004; Mann and Singh, 1988, Koksai and Yilmaz, 1992, Mann and Singh, 1990).

5.7.2 FRUIT TSS, REDUCING SUGAR, NON-REDUCING SUGAR AND TOTAL SUGAR

Biochemical changes in the growing pear fruits have been investigated by Mann and Singh (1986). Sugar content increases throughout the growth period, being maximum nearing the maturity and then drop in ripe fruits (Fazekas and Graeza, 1970). Acidity showed declining trend during most of the stages of fruit growth (Mann *et al.*, 1978). Significant variation was observed among cultivar in respect of fruit TSS. Highest TSS was observed in 'Flemish Beauty' and lowest in Chinese Sandy pear.

Similarly, acidity was found to be highest in cultivar 'Vicar of Winkfield' and in William Bartlett and Gent Drouard. As far as reducing sugar is considered the highest reducing sugar was found to be in Flemish Beauty followed by

Fertility and lowest in Vicar of Winkfield. Similarly, non-reducing sugar was found to be highest in cultivar Vicar of Winkfield and lowest was found to be in Flemish Beauty. Significant variation was found to be among pear cultivars in respect to total sugars however, in present investigation highest total sugars was found to be in cultivar Flemish Beauty and low being in cultivar Vicar of Winkfield. Increase in chemical constituents in pear fruit during development except acidity which showed no significant change have been reported by various workers (Fazekas and Graeza, 1970; Rachna *et al.*, 2004; Hong, 1998; Yoo *et al.*, 2002).

The variation in chemical characters might chiefly be due to varietal influence and period of interval available from fruitset till maturity, resulting in the breakdown of more starch to simpler forms. Similar variation in fruit quality characters have been reported in pear cultivars by various workers (Hudina and Stampar, 2000; Hudina *et al.*, 2003; Hong *et al.*, 1998; Farooqui and Happa, 1990; Sandhu *et al.*, 2002; Mann and Singh, 1990; Azzouni *et al.*, 1974).

5.7.3 FRUIT VOLUME

Studies revealed significant variation among the cultivars in respect of fruit volume at the time of harvest. Highest fruit volume was observed in 'Flemish Beauty' followed by 'William Bartlett' whereas lowest fruit volume was observed in cultivar 'Fertility'. As in case of fruit diameter, fruit volume also showed increase in fruit size from fruit set to harvest in three different phases (Mann and

Singh, 1988). Fruit diameter was directly proportional to fruit volume and the variation among different cultivars were observed by many workers (Farooqui and Happa, 1990; Sandhu *et al.*, 2002; Mann and Singh, 1990; Koksai and Yilmaz, 1992; Hong *et al.*, 1991; Endo, 1974). The variation in fruit weight/volume may be attributed due to difference in seed production rather than metaxenia (Hong *et al.*, 1991), temperature fluctuation (Endo, 1974) and genetic character.

5.7.4 FRUIT FIRMNESS

Data revealed significant variation among the cutlivars studied in respect of fruit firmness. Fruit firmness was observed to be highest in ‘Chinese Sandy pear’ followed by Vicar of Winkfield and lowest fruit firmness was noticed in ‘William Bartlett’. Mann and Singh (1990) reported that fruit firmness decreased between 105 and 150 days from 24.56 to 16-48 lb/inch² in Patharnakh cultivar of pear. Physical characteristics of all fruits increased regularly until harvest except fruit firmness (Koksai and Yilmaz, 1992). Variation among cultivar in respect of fruit firmness was worked out by many workers (Azzouni, 1974; Westwood, 1993; Rudic *et al.*, 1977; Sandhu *et al.*, 1990). The firmness range from optimum maturity varied with the cultivar, climate, rootstock and the utilisation of the fruit (Westwood, 1993; Rudic *et al.*, 1977).

5.7.5 Number of seeds per fruit in each cross-combination

‘William Bartlett’ as a female parent set maximum number of seeds/fruit

when 'Fertility' was used as pollen parent and minimum when 'Chinese Sandy pear' was used as pollinizer for this cultivar. 'Vicar of Winkfield' as pollen acceptor set maximum number of seeds/fruit when 'Flemish Beauty' was used as pollinizer and minimum seeds were recorded when 'Chinese Sandy pear' was used as pollen parent for this cultivar. Similarly, 'Gent Drouard' as female also set maximum number of seeds when 'Flemish Beauty' was used as pollinizer. Minimum number of seeds/fruit was recorded when 'Chinese Sandy pear' was used as pollinizer for 'Flemish Beauty' and maximum when 'Fertility' was used as pollinizer. The variation in number of seeds/fruit using different pollen donors was also found by some workers (Nyeki, 1977; Frimanslund, 1984; Hiratsuka *et al.*, 1985; Nyeki *et al.*, 1994 and Nyeki *et al.*, 1998). The variation in seed number may be attributed due to successful fertilization of the ovules more the ovules fertilize more will be number of seeds.

Chapter – 6

Summary and conclusion

The present investigations were carried out in the Pear Collection Block of Division of Pomology at the Main Campus, Shalimar during 2006-2007 with the following objectives :

1. To identify the pollen compatible genotypes among different pear varieties.
2. To identify the combination of pear varieties that bloom and harvest in sequence.
3. To identify the combination of pear varieties that bloom together and harvest together.

The results obtained during the course of these studies are summarised below :

- The cultivar ‘Chinese Sandy pear’ exhibited early blooming while as cultivars ‘Fertility’ and ‘Vicar of Winkfield’ found late bloomers.
- Flowering period was observed greater in ‘Vicar of Winkfield’ than other cultivars.

- Number of flowers per spur did not vary significantly in the cultivars studied.
- Highest number of stamens per flower were noticed in ‘Vicar of Winkfield’ followed ‘Fertility’. However, other cultivars did not vary in this respect.
- Highest number of flowers per metre shoot length was noticed in cultivar ‘Vicar of Winkfield’ followed by ‘Fertility’ and ‘Gent Drouard’ whereas minimum density of flowering was observed in ‘Chinese Sandy pear’.
- Peak anthesis of flowers in all cultivars occurred between 12 noon to 2 pm. This was followed by anthesis between 10 am to 12 noon.
- Dehiscence of anthers was maximum between 10 am to 12 noon for cultivar ‘William Bartlett’, ‘Vicar of Winkfield’ and ‘Gent Drouard’, whereas peak dehiscence of anthers for cultivar ‘Flemish Beauty’, ‘Fertility’ and ‘Chinese Sandy pear’ was observed between 12 noon – 2 pm.
- Stigma receptivity spanned from 1 to 2 days prior to anthesis to 3 days after anthesis. All cultivars exhibited peak receptivity on the day of anthesis whereas, ‘Vicar of Winkfield’ and ‘Flemish Beauty’ exhibited peak stigmatic receptivity a day later as well. The cultivar ‘William

Bartlett' and 'Flemish Beauty' exhibited highest stigma receptivity for 'Fertility' whereas 'Vicar of Winkfield' and 'Gent Drouard' exhibited highest receptivity for 'Flemish Beauty'.

- Maximum pollen germination was found in 'William Bartlett' and minimum in 'Fertility'. However, the data was found to be statistically non-significant.
- Pollen viability was found highest in 'William Bartlett' and minimum in 'Vicar of Winkfield'. However, data was statistically non-significant.
- The cultivars 'Gent Drouard' and 'Fertility' were found completely self incompatible. However, cultivars 'William Bartlett' and 'Chinese Sandy pear' set very low fruits under self-pollination, whereas, 'Flemish Beauty' and 'Vicar of Winkfield' were found self-compatible.
- 'William Bartlett' recorded highest initial fruitset when cross-pollinated with 'Fertility', followed by fruitset which occurred under open pollination conditions. Fruit setting was low when 'Vicar of Winkfield' was used as its pollinizer.
- Highest initial fruitset percentage was noticed when 'Flemish Beauty' was used as pollinizer for 'Vicar of Winkfield' and 'Gent Drouard'. However, low initial fruitset was observed when 'Chinese Sandy pear' was used as

pollinizer for 'Vicar of Winkfield' and 'Gent Drouard'.

- 'Flemish Beauty' set higher initial fruitset percentage with 'Fertility' as pollinizer followed by when left open and moderate initial fruitset when crossed with 'Chinese Sandy pear'.
- 'Fertility' did not set any fruit when pollinated with 'Chinese Sandy pear', however, good fruit setting was recorded when this cultivar was observed under open pollination conditions.
- Maximum fruit drop occurred after 2 months of fruitset (between 21 June to 05 July) in 'William Bartlett' and 'Vicar of Winkfield'.
- Final fruitset varied with the pollen parent used. The trend of initial fruitset was comparable to that of final fruit retention. 'William Bartlett' registered highest final fruit retention when pollinated with 'Fertility' 'Vicar of Winkfield' retained maximum fruit when 'Flemish Beauty' was used as pollen parent. 'Gent Drouard' retained highest final fruit retention when 'Flemish beauty' was used as pollen parent, followed when crossed with 'Fertility. However, 'Flemish Beauty' retained maximum fruits when fertility was used as pollen donor.
- The cultivar 'Gent Drouard' attained harvest maturity significantly much earlier than all other cultivars except 'Flemish Beauty'. Cultivar 'Vicar of Winkfield' significantly took highest number of days upto harvest among

all other cultivars. However, one set of cultivars 'Flemish Beauty and 'William Bartlett' and the other set viz., 'Fertility' and 'Chinese Sandy pear were harvested nearly at the same time.

- Maximum fruit diameter was noticed in 'Flemish Beauty' which was significantly higher than all other cultivars. Whereas, 'Fertility' had significantly lowest than all cultivars except 'Chinese Sandy pear'. The cultivar 'William Bartlett' and 'Gent Drouard' were statistically at par with each other.
- Highest fruit volume was noticed in 'Flemish Beauty' whereas lowest was noticed in 'Fertility' except 'Chinese Sandy pear'. Cultivar 'Vicar of Winkfield', 'Gent Drouard' and 'William Bartlett' were statistically at par with each other.
- Maximum fruit firmness was noticed in 'Chinese Sandy pear' as compared to other cultivars except 'Vicar of Winkfield'. However, cultivar 'William Bartlett', 'Flemish Beauty', 'Fertility' and 'Gent Drouard' were found to be statistically at par with each other in this parameter.
- Highest TSS per cent was observed in cultivar 'Flemish Beauty' followed by 'Fertility' whereas lowest TSS per cent was recorded in cultivar 'Chinese Sandy pear'. 'William Bartlett', 'Gent Drouard' and 'Vicar of Winkfield' were found to be statistically at par with each other in this trait.

- Highest total sugar was observed in ‘Flemish Beauty’ and lowest in cultivar ‘Vicar of Winkfield’ except ‘Chinese Sandy pear’ and ‘Gent Drouard’ which were at par in this regard.
- Maximum reducing sugar was also observed in cultivar ‘Flemish Beauty’ and lower in ‘Vicar of Winkfield’.
- Highest number of seeds were found in cultivar ‘William Bartlett’ when ‘Fertility’ was used as pollen parent and lowest when crossed with ‘Chinese Sandy pear’. In cultivar ‘Vicar of Winkfield’, highest number of seeds were noticed when ‘Flemish Beauty’ was used as pollen parent and lowest number of seeds were observed when ‘Chinese Sandy pear’ was used as pollen parent. Cultivar ‘Gent Drouard’ exhibited highest seed setting when ‘Fertility’ was used as pollen donor. Similarly, ‘Flemish Beauty’ exhibited highest number of seeds when ‘Fertility’ was used as pollen parent.
- Highest percentage of juice was observed in ‘William Bartlett’ whereas, lowest percentage of juice was recorded in ‘Vicar of Winkfield’. ‘Fertility’, ‘Flemish Beauty’ and ‘Gent Drouard’ were found to be statistically at par with each other in this respect.

Based on the observations recorded from the investigation the following conclusions are drawn :

- i) The cultivar 'Chinese Sandy pear' behaved as early bloomer, 'Flemish Beauty', 'William Bartlett' and 'Vicar of Winkfield' mid bloomers whereas, 'Gent Drouard' and 'Fertility' as late bloomers.
- ii) All the cultivars showed that peak period of flower anthesis during the mid of day between 12 noon to 2 pm depending upon the temperature. Whereas, peak period of anther dehiscence for cultivar 'William Bartlett', 'Vicar of Winkfield' and 'Gent Drouard' was between 10 am to 12 noon. However, peak period of anther dehiscence for cultivar 'William Bartlett', 'Fertility' and 'Chinese Sandy pear' was between 12 noon to 2 pm.
- iii) Almost all the cultivars showed highest receptivity of stigma on the day of anthesis. However, cultivar 'Gent Drouard' and 'Flemish Beauty' showed a day after also. However, average receptivity of stigma remained upto 2 to 3 days after anthesis.
- iv) The cultivar 'Gent Drouard' and 'Fertility' showed complete self-incompatibility whereas, the cultivar 'William Bartlett' and 'Chinese Sandy pear' showed poor self-compatibility whereas, 'Vicar of Winkfield' and 'Flemish Beauty' showed good percentage of self-compatibility.

- v) 'William Bartlett' displayed high compatibility with 'Fertility', 'Flemish Beauty', 'Gent Drouard' and 'Chinese Sandy pear'. However, it exhibited poor compatibility when 'Vicar of Winkfield' was used as donor parent.
- vi) Poor compatibility was observed when 'Vicar of Winkfield' was used as recipient parent with 'Chinese Sandy pear' and 'Gent Drouard'. However, it displayed high compatibility when crossed with 'Flemish Beauty' and 'Fertility'.
- vii) The cultivar 'Gent Drouard' also observed complete compatibility with cultivar 'Fertility' and 'Flemish Beauty', however, poor compatibility with 'Chinese Sandy pear'. Similarly, 'Flemish Beauty' displayed high compatibility with both the pollen parents used i.e. 'Fertility' and 'Chinese Sandy pear'. No compatibility was observed in 'Fertility' when crossed with 'Chinese Sandy pear'.
- viii) On the basis of days taken to attain harvest maturity, the cultivar 'Gent Drouard' followed by 'Flemish Beauty' and 'William Bartlett' were found early maturing. Cultivar 'Fertility' followed 'Chinese Sandy pear' were found mid season maturing. However, 'Vicar of Winkfield' was found as late maturing.

- ix) 'Flemish Beauty' showed highest average fruit diameter and fruit volume.
- x) Fruit firmness was higher in cultivar 'Chinese Sandy pear'.
- xi) Highest TSS, reducing sugar and total sugar was observed in cultivar 'Flemish Beauty'.

Table-1. Time and duration of flowering in pear cultivars

Cultivar	First bloom (DARD)	Full bloom (DARD)	End of flowering (DARD)	Duration of flowering (days)
William Bartlett	30.50	36.25	39.25	8.75
Vicar of Winkfield	30.75	34.75	40.75	10.00
Gent Drouard	31.50	36.25	40.25	8.75
Flemish Beauty	29.75	35.50	38.05	8.75
Fertility	32.75	37.75	40.75	8.00
Chinese Sandy pear	26.75	32.50	35.05	8.75
LSD at 5%	1.1	0.99	0.99	0.99
SE_{diff.}	0.52	0.46	0.46	0.46

DARD = Days after reference date (March 1, 2006)

Table-2. Floral biology of pear cultivars

CULTIVAR	NO. OF FLOWERS/SPUR	NO. OF STAMENS/FLOWER	Flowering density (No./m shoot length)
William Bartlett	7.00	19.50	48.25
Vicar of Winkfield	7.50	21.75	53.50
Gent Drouard	7.25	19.00	50.50
Flemish Beauty	7.00	18.00	47.00
Fertility	7.25	21.00	51.00
Chinese Sandy pear	7.00	18.00	44.25
LSD at 5%	NS	1.82	4.90
SE_{diff.}	-	0.86	2.30

Table-3(a). Time of flower anthesis in pear cultivar 'William Bartlett'

NO. OF FLOWERS OPENED AT HOUR (24 HR CLOCK)

Date of observation	No. of flowers observed	NO. OF FLOWERS OPENED AT HOUR (24 HR CLOCK)					
		8 am	10 am	12 noon	2 pm	4 pm	6 pm
31.03.2006	40	2	8	14	11	4	1
01.04.2006	40	1	5	11	14	7	2
02.04.2006	40	1	5	12	16	5	1
03.04.2006	40	1	6	10	14	7	2
04.04.2006	40	2	5	13	14	5	1
05.04.2006	40	2	6	12	13	6	1
06.04.2006	40	3	6	12	14	4	1
Total	280	12	41	84	96	38	9
Percentage	100	4.28	14.60	30.00	34.28	13.57	3.21

Table-3(b). Time of flower anthesis in pear cultivar 'Vicar of Winkfield'

NO. OF FLOWERS OPENED AT HOUR (24 HR CLOCK)

Date of observation	No. of flowers observed	NO. OF FLOWERS OPENED AT HOUR (24 HR CLOCK)					
		8 am	10 am	12 noon	2 pm	4 pm	6 pm
30.03.2006	40	1	3	10	17	7	2
31.03.2006	40	2	6	9	16	6	1
01.04.2006	40	2	7	15	11	4	1
02.04.2006	40	1	4	13	14	6	2
03.04.2006	40	2	6	11	13	6	2
04.04.2006	40	1	3	11	17	6	2
05.04.2006	40	1	3	10	17	7	2
Total	280	10	32	79	105	42	12
Percentage	100	3.57	11.42	23.21	37.50	15.00	4.28

Table-3(c). Time of flower anthesis in pear cultivar 'Gent Drouard

NO. OF FLOWERS OPENED AT HOUR (24 HR CLOCK)

Date of observation	No. of flowers observed	NO. OF FLOWERS OPENED AT HOUR (24 HR CLOCK)					
		8 am	10 am	12 noon	2 pm	4 pm	6 pm
31.03.2006	40	1	5	13	16	4	1
01.04.2006	40	2	4	12	15	5	2
02.04.2006	40	1	6	13	14	5	1
03.04.2006	40	2	5	12	15	4	2
04.04.2006	40	1	5	12	14	6	2
05.04.2006	40	1	5	13	16	4	1
06.04.2006	40	2	4	13	15	5	1
Total	280	10	34	88	105	33	9
Percentage	100	3.57	12.14	31.42	37.50	11.78	3.21

Table-3(d). Time of flower anthesis in pear cultivar 'Flemish Beauty'

NO. OF FLOWERS OPENED AT HOUR (24 HR CLOCK)

Date of observation	No. of flowers observed	NO. OF FLOWERS OPENED AT HOUR (24 HR CLOCK)					
		8 am	10 am	12 noon	2 pm	4 pm	6 pm
29.03.2006	40	1	5	12	14	5	3
30.03.2006	40	2	4	14	15	4	1
31.03.2006	40	1	5	11	16	5	2
01.04.2006	40	1	6	13	15	4	1
02.04.2006	40	2	5	12	14	5	2
03.04.2006	40	1	5	13	15	5	1
04.04.2006	40	1	6	12	13	6	2
Total	280	9	36	87	102	34	12
Percentage	100	3.21	12.80	31.07	36.42	12.14	4.28

Table-3(e). Time of flower anthesis in pear cultivar 'Fertility'

NO. OF FLOWERS OPENED AT HOUR (24 HR CLOCK)

Date of observation	No. of flowers observed	NO. OF FLOWERS OPENED AT HOUR (24 HR CLOCK)					
		8 am	10 am	12 noon	2 pm	4 pm	6 pm
02.04.2006	40	2	7	15	17	6	1
03.04.2006	40	1	5	12	16	5	2
04.04.2006	40	3	4	14	16	6	1
05.04.2006	40	2	4	16	17	2	1
06.04.2006	40	2	5	15	15	6	3
07.04.2006	40	1	6	15	17	4	2
08.04.2006	40	1	7	13	16	2	1
Total	280	12	38	100	114	31	11
Percentage	100	4.29	13.60	35.71	40.70	11.07	3.92

Table-3(f). Time of flower anthesis in pear cultivar 'Chinese Sandy pear'

NO. OF FLOWERS OPENED AT HOUR (24 HR CLOCK)

Date of observation	No. of flowers observed	NO. OF FLOWERS OPENED AT HOUR (24 HR CLOCK)					
		8 am	10 am	12 noon	2 pm	4 pm	6 pm
26.03.2006	40	2	5	12	15	5	1
27.03.2006	40	1	4	13	16	4	2
28.03.2006	40	1	5	10	16	6	2
29.03.2006	40	2	6	11	15	5	1
30.03.2006	40	1	5	12	16	4	2
31.03.2006	40	1	7	12	14	5	1
01.04.2006	40	3	9	12	12	3	1
Total	280	11	41	82	104	32	10
Percentage	100	3.92	14.64	29.30	37.14	11.40	3.57

Table-4(a). Time of anther dehiscence in pear cultivar 'William Bartlett'

No. of flowers	DATE OF	No. and percentage of anthers dehisced at hour		Anthers dehisced per day

observed	OBSERVATION						Number	Per cent	
		8 am	10 am	12 noon	2 pm	4 pm			
10	31.03.2006	(No.)	0	14	54	64	3	135	67.50
		(%)	0	7	27	32	1.50		
	01.04.2006	(No.)	2	10	46	7	0	65	32.50
		(%)	1	5	23	3.50	0		
10	01.04.2006	(No.)	0	14	50	58	5	127	63.50
		(%)	0	7	25	29	2.50		
	02.04.2006	(No.)	4	12	39	18	0	73	36.50
		(%)	2	6	19.50	9	0		
10	02.04.2006	(No.)	0	15	36	52	0	103	51.50
		(%)	0	7.50	18	26	0		
	03.04.2006	(No.)	6	24	43	24	0	97	48.50
		(%)	3	12	21.50	12	0		
Percentage		100	2	14.83	44.60	37.16	1.33	-	-

Table-4(b). Time of anther dehiscence in pear cultivar 'Vicar of Winkfield'

No. of flowers observed	DATE OF OBSERVATION	No. and percentage of anthers dehiscid at hour					Anthers dehiscid per day	
		8 am	10 am	12 noon	2 pm	4 pm	Number	Per cent

10	31.03.2006	(No.)	2	17	55	49	3	126	57.27
		(%)	0.9	7.72	25	22.27	1.36		
	01.04.2006	(No.)	5	17	46	26	0	94	42.72
		(%)	2.27	7.72	20.90	11.80	0		
10	01.04.2006	(No.)	0	6	37	45	3	91	41.36
		(%)	0	2.72	16.80	20.45	1.36		
	02.04.2006	(No.)	12	19	48	43	7	129	58.63
		(%)	5.45	8.63	21.81	19.54	3.18		
10	02.04.2006	(No.)	2	11	38	45	0	96	42.50
		(%)	0.92	5	17.27	20.45	0		
	03.04.2006	(No.)	16	30	47	25	6	124	57.50
		(%)	7.27	13.63	21.36	11.36	2.72		
Percentage		100	5.60	15.15	41.06	35.30	2.87	-	-

Table-4(c). Time of anther dehiscence in pear cultivar 'Gent Drouard'

No. of flowers observed	DATE OF OBSERVATION		No. and percentage of anthers dehisced at hour					Anthers dehisced per day	
			8 am	10 am	12 noon	2 pm	4 pm	Number	Per cent
10	31.03.2006	(No.)	0	13	36	38	4	91	47.89
		(%)	0	6.84	18.94	20	2.10		

10	01.04.2006	(No.)	5	14	43	33	4	99	52.10
		(%)	2.63	7.36	22.63	17.36	2.10		
10	01.04.2006	(No.)	0	12	43	51	0	106	55.78
		(%)	0	6.31	22.63	26.84	0		
10	02.04.2006	(No.)	4	20	39	21	0	84	44.21
		(%)	2.10	10.52	20.52	11.05	0		
10	02.04.2006	(No.)	0	12	40	49	2	103	54.21
		(%)	0	6.31	21.05	25.78	1.05		
10	03.04.2006	(No.)	5	10	36	36	0	87	45.78
		(%)	2.63	5.26	18.94	18.94	0		
Percentage		100	2.45	14.21	41.57	40.00	1.75	-	-

Table-4(d). Time of anther dehiscence in pear cultivar 'Flemish Beauty'

No. of flowers observed	DATE OF OBSERVATION	No. and percentage of anthers dehiscid at hour					Anthers dehiscid per day		
		8 am	10 am	12 noon	2 pm	4 pm	Number	Per cent	
10	31.03.2006	(No.)	0	10	51	58	0	119	66.11
		(%)	0	5.55	28.33	32.22	0		
	01.04.2006	(No.)	4	15	33	9	0	61	33.88
		(%)	2.22	8.33	18.33	5	0		

10	01.04.2006	(No.)	0	11	41	51	0	97	53.88
		(%)	0	6.11	22.77	28.33	0		
	02.04.2006	(No.)	3	13	34	32	1	83	46.11
		(%)	1.66	7.22	18.88	17.77	0.50		
10	02.04.2006	(No.)	2	12	35	47	2	98	54.44
		(%)	1.11	6.66	19.44	26.11	1.11		
	03.04.2006	(No.)	4	13	30	35	2	82	45.55
		(%)	1.11	7.20	16.66	19.44	1.11		
Percentage		100	2.03	13.70	41.48	42.96	0.92	-	-

Table-4(e). Time of anther dehiscence in pear cultivar 'Fertility'

No. of flowers observed	DATE OF OBSERVATION		No. and percentage of anthers dehiscid at hour					Anthers dehiscid per day	
			8 am	10 am	12 noon	2 pm	4 pm	Number	Per cent
10	31.03.2006	(No.)	0	15	49	52	3	119	56.66
		(%)	0	7.14	23.30	24.76	1.42		
	01.04.2006	(No.)	2	17	33	36	3	91	43.33
		(%)	0.95	8.09	15.71	17.14	1.42		
10	01.04.2006	(No.)	0	11	31	43	3	88	41.90
		(%)	0	5.23	14.76	20.47	1.42		

10	02.04.2006	(No.)	8	17	47	43	7	122	58.09
		(%)	3.80	8.09	22.38	20.47	3.33		
	02.04.2006	(No.)	0	12	39	46	2	99	47.14
		(%)	0	5.71	18.57	21.90	0.95		
	03.04.2006	(No.)	11	25	38	33	4	111	52.85
		(%)	5.23	11.90	18.09	15.71	1.90		
Percentage		100	3.33	15.39	37.62	40.15	3.33	-	-

Table-4(f). Time of anther dehiscence in pear cultivar ‘Chinese Sandy pear’

No. of flowers observed	DATE OF OBSERVATION	No. and percentage of anthers dehiscid at hour					Anthers dehiscid per day		
		8 am	10 am	12 noon	2 pm	4 pm	Number	Per cent	
10	31.03.2006	(No.)	0	12	32	37	2	83	46.11
		(%)	0	6.66	17.77	20.55	1.11		
	01.04.2006	(No.)	7	14	39	34	3	97	53.80
		(%)	3.88	7.77	21.66	18.88	1.66		
10	01.04.2006	(No.)	0	9	25	28	4	66	36.66
		(%)	0	5	13.88	15.55	2.22		
	02.04.2006	(No.)	6	14	39	46	9	114	63.33
		(%)	3.33	7.77	21.66	25.55	5		

10	02.04.2006	(No.)	4	11	49	39	0	103	57.22
		(%)	2.22	6.11	27.20	21.66	0		
	03.04.2006	(No.)	3	14	28	32	0	77	42.77
		(%)	1.66	7.77	15.50	17.77	0		
Percentage		100	3.70	13.70	39.25	40.00	3.33	-	-

Table-5. Receptivity of stigma (% fruit set) in different pear cultivars

Female parent	Pollen parent		Pollination conducted					
			2 days before anthesis	1 day prior to anthesis	On day of anthesis	1 day after anthesis	2 days after anthesis	3 days after anthesis
William Bartlett	X	Vicar of Winkfield	0.00	0.00	20.02*	15.80	0.00	0.00
	X	Gent Drouard	0.00	5.50	32.17*	20.70	0.00	0.00
	X	Flemish Beauty	10.35	12.50	48.13*	27.90	20.10	10.50
	X	Fertility	11.50	15.50	74.43*	35.75	25.50	15.70
	X	Chinese Sandy pear	0.00	8.25	30.77*	10.78	0.00	0.00
Vicar of Winkfield	X	Gent Drouard	0.00	4.53	19.86*	12.70	8.75	0.00
	X	Flemish Beauty	5.00	6.57	72.99*	21.40	10.80	5.67
	X	Fertility	0.00	5.35	66.10*	25.53	17.85	8.78
	X	Chinese Sandy pear	0.00	4.70	17.97*	09.70	0.00	0.00
Gent Drouard	X	Flemish Beauty	0.00	28.78	68.11*	68.11*	10.70	09.50

	X	Fertility	0.00	20.70	55.71*	31.67	11.20	0.00
	X	Chinese Sandy pear	0.00	16.50	21.73*	05.78	0.00	0.00
Flemish Beauty	X	Fertility	6.87	19.54	66.23*	32.53	19.56	08.76
	X	Chinese Sandy pear	0.00	13.74	32.53*	32.50*	14.86	05.37
Fertility	X	Chinese Sandy pear	0.00	0.00	0.00	0.00	0.00	0.00

** PEAK RECEPTIVITY*

TABLE-6. POLLEN VIABILITY (%) AND POLLEN GERMINATION (%) IN PEAR CULTIVARS

CULTIVARS	Pollen germination (%)	Pollen viability (%)
William Bartlett	66.66	70.00
Vicar of Winkfield	55.00	61.66
Gent Drouard	55.83	64.16
Flemish Beauty	55.83	67.50

Fertility	54.16	65.00
Chinese Sandy pear	60.00	68.30
LSD at5%	NS	NS

Table 7. Fruit set in pear cultivar under open and controlled pollination

	Cultivar pollinated	Treatment	Initial fruitset (%)	
1.	William Bartlett	: Open	60.90	(51.30)
		: Self manual	5.46	(13.51)
		X Vicar of Winkfield	20.02	(26.58)
		X Gent Drouard	32.17	(34.55)
		X Flemish Beauty	48.13	(43.93)
		X Fertility	74.43	(59.64)
		X Chinese Sandy pear	30.77	(33.69)
2.	Vicar of Winkfield	: Open	56.84	(48.92)
		: Self manual	18.42	(25.41)
		X Gent Drouard	19.86	(26.50)
		X Flemish Beauty	72.99	(58.40)
		X Fertility	66.10	(54.41)
		X Chinese Sandy pear	17.96	(25.10)
3.	Gent Drouard	: Open	54.52	(47.59)
		: Self manual	0.00	(0.28)
		X Flemish Beauty	68.11	(55.61)
		X Fertility	55.71	(48.28)

4.	Flemish Beauty	X	Chinese Sandy pear	21.73	(27.78)
		:	Open	51.35	(45.77)
		:	Self manual	17.62	(24.82)
5.	Fertility	X	Fertility	66.23	(54.47)
		X	Chinese Sandy pear	32.53	(34.76)
		:	Open	60.66	(51.16)
6.	Chinese Sandy pear	:	Self manual	0.00	(0.28)
		X	Chinese Sandy pear	0.00	(0.28)
		:	Open	63.28	(52.70)
				8.02	(16.45)
LSD at5%					(1.26)
SE_{diff.}					(0.63)

Table 8. Fruit retention (%) at weekly intervals under open and controlled pollination in pear cultivars

Figures in parentheses are sine transformations

Cultivar pollinated	Treatment	21 June		28 June		05 July	
1. William Bartlett	: Open	45.58	(42.46)	33.94	(35.63)	28.77	(32.43)
	: Self manual	4.70	(12.52)	3.84	(11.30)	3.84	(11.30)
	X Vicar of Winkfield	15.75	(23.38)	12.77	(20.93)	9.40	(117.85)
	X Gent Drouard	20.92	(27.22)	14.50	(22.38)	11.29	(19.63)
	X Flemish Beauty	42.47	(40.67)	35.00	(36.26)	27.05	(31.33)
	X Fertility	61.55	(51.68)	42.90	(40.92)	38.02	(38.07)
	X Chinese Sandy pear	24.45	(29.63)	18.24	(25.28)	13.82	(21.82)
2. Vicar of Winkfield	: Open	47.42	(43.52)	38.56	(38.38)	31.72	(34.28)
	: Self manual	15.31	(23.03)	13.26	(21.35)	11.41	(19.75)
	X Gent Drouard	16.50	(23.96)	13.64	(21.67)	12.44	(20.65)
	X Flemish Beauty	56.90	(48.97)	41.50	(40.10)	39.05	(38.67)
	X Fertility	54.11	(47.36)	44.22	(41.68)	36.55	(37.19)
3. Gent Drouard	X Chinese Sandy pear	11.92	(20.20)	9.81	(18.25)	8.52	(16.96)
	: Open	41.52	(40.11)	35.05	(36.29)	24.58	(34.79)
	: Self manual	0.00	(0.28)	0.00	(0.28)	0.00	(0.28)
	X Flemish Beauty	54.00	(47.29)	42.7	(40.80)	34.55	(35.99)
	X Fertility	44.35	(41.75)	35.92	(36.82)	33.25	(35.20)
X Chinese Sandy pear	17.71	(24.88)	14.45	(22.34)	12.54	(20.74)	

4.	Flemish Beauty	: Open	39.73	(39.07)	36.64	(37.25)	32.25	(34.55)
		: Self manual	12.31	(20.53)	10.47	(18.87)	10.34	(18.75)
		X Fertility	46.32	(42.89)	39.10	(38.70)	35.22	(36.40)
		X Chinese Sandy pear	28.38	(32.03)	23.75	(29.17)	20.85	(27.17)
5.	Fertility	: Open	52.17	(46.24)	41.11	(39.87)	36.47	(37.15)
		: Self manual	0.00	(0.28)	0.00	(0.28)	0.00	(0.28)
		X Chinese Sandy pear	0.00	(0.28)	0.00	(0.28)	0.00	(0.28)
6.	Chinese Sandy pear	: Open	48.36	(44.05)	38.74	(38.49)	32.04	(34.47)
		: Self manual	3.42	(10.65)	0.00	(0.28)	0.00	(0.28)
LSD at5%			(0.97)		(0.81)		(0.87)	
SE_{diff.}			(0.49)		(0.41)		(0.44)	

Table 9. Fruit carried to maturity (%) in pear cultivar under open and controlled pollination

	Cultivar pollinated	Treatment	Fruit carried to maturity*	
1.	William Bartlett	: Open	28.77	(32.43)
		: Self manual	3.84	(11.30)
		X Vicar of Winkfield	9.40	(117.85)
		X Gent Drouard	11.29	(19.63)
		X Flemish Beauty	27.05	(31.33)
		X Fertility	38.02	(38.07)
		X Chinese Sandy pear	13.82	(21.82)
2.	Vicar of Winkfield	: Open	31.72	(34.28)
		: Self manual	11.41	(19.75)
		X Gent Drouard	12.44	(20.65)
		X Flemish Beauty	39.05	(38.67)
		X Fertility	36.55	(37.19)
		X Chinese Sandy pear	8.52	(16.96)
3.	Gent Drouard	: Open	24.58	(34.79)
		: Self manual	0.00	(0.28)
		X Flemish Beauty	34.55	(35.99)
		X Fertility	33.25	(35.20)
		X Chinese Sandy pear	12.54	(20.74)
4.	Flemish Beauty	: Open	32.25	(34.55)

		:	Self manual	10.34	(18.75)
		X	Fertility	35.22	(36.40)
		X	Chinese Sandy pear	20.85	(27.17)
5.	Fertility	:	Open	36.47	(37.15)
		:	Self manual	0.00	(0.28)
		X	Chinese Sandy pear	0.00	(0.28)
6.	Chinese Sandy pear	:	Open	32.04	(34.47)
		:	Self manual	0.00	(0.28)
LSD at 5%					(0.87)
SE_{diff.}					(0.44)

Figures in parentheses are arc sine transformations

Table 10. Number of days taken upto harvest of pear cultivars (Reference date 1st March, 2006)

Cultivar	No. of days
William Bartlett	138.00
Vicar of Winkfield	176.50
Gent Drouard	131.75
Flemish Beauty	136.25
Fertility	155.75

Chinese Sandy pear	157.75
LSD at5%	6.17
SE_{diff.}	2.90

Table 11(a). Fruit physico-chemical characteristics of pear cultivars

CULTIVAR	Fruit diameter (cm)	Fruit volume (cc)	Fruit firmness (lb/inch²)
William Bartlett	5.05	99.25	8.81
Vicar of Winkfield	6.06	89.25	10.66
Gent Drouard	5.40	92.50	9.72
Flemish Beauty	6.92	120.25	9.03
Fertility	3.86	38.00	9.57
Chinese Sandy pear	3.96	40.75	11.27

LSD at5%	0.82	9.65	1.14
SE_{diff.}	0.38	4.53	0.53

Table 11(b). Fruit chemical characteristics of pear cultivars

CULTIVAR	TSS (°Brix)	Acidity (%)	Reducing sugar (%)	Non-reducing sugar (%)	Total sugars (%)
William Bartlett	11.36	0.19	7.27	3.70	10.97
Vicar of Winkfield	12.15	0.5	4.65	4.76	9.42
Gent Drouard	12.11	0.19	5.00	4.69	9.69
Flemish Beauty	16.95	0.45	12.63	1.80	14.42
Fertility	14.63	0.27	7.92	4.71	12.73
Chinese Sandy pear	10.52	0.32	6.05	3.59	9.64
LSD at5%	1.02	0.06	0.75	1.10	0.62

SE_{diff.}**0.48****0.03****0.35****0.52****0.29**

Table 12. Number of seeds/fruit in each cross-combination

Female parent		Pollen parent	Mean no. of seeds/fruit
William Bartlett	X	Vicar of Winkfield	5.75
	X	Gent Drouard	7.00
	X	Flemish Beauty	7.00
	X	Fertility	7.50
	X	Chinese Sandy pear	5.50
Vicar of Winkfield	X	Gent Drouard	5.75
	X	Flemish Beauty	7.50
	X	Fertility	6.75
	X	Chinese Sandy pear	5.00
Gent Drouard	X	Flemish Beauty	7.25
	X	Fertility	7.50
	X	Chinese Sandy pear	5.50
Flemish Beauty	X	Fertility	8.50
	X	Chinese Sandy pear	6.75
LSD at 5%			NS

Table-13. Juice percentage of few cultivars

CULTIVAR	Juice (%)
William Bartlett	61.62
Vicar of Winkfield	45.45
Gent Drouard	50.25
Flemish Beauty	53.30
Fertility	53.03
Chinese Sandy pear	55.99
LSD at 5%	3.13
SE_{diff.}	1.47

Table 14 : Sensory evaluation (score)

CULTIVAR	Skin colour	Flesh colour	Taste	Texture	Aroma
William Bartlett	3.00	3.50	3.00	2.70	2.50
Vicar of Winkfield	3.00	3.00	2.30	2.90	2.40
Gent Drouard	2.40	3.00	2.40	2.30	1.90
Flemish Beauty	3.40	3.35	3.90	2.80	3.00
Fertility	1.60	2.20	3.60	2.50	2.40
Chinese Sandy pear	4.00	3.30	3.70	3.70	3.00
LSD at 5%	0.42	0.59	0.67	0.59	0.62
SE_{diff.}	0.18	0.20	0.31	0.27	0.29

APPENDIX - I

Representation of crossing without reciprocal

Pollen parent →	V₁	V₂	V₃	V₄	V₅	V₆
Female parent ↓						
V ₁	V ₁ V ₁	V ₁ V ₂	V ₁ V ₃	V ₁ V ₄	V ₁ V ₅	V ₁ V ₆
V ₂		V ₂ V ₂	V ₂ V ₃	V ₂ V ₄	V ₂ V ₅	V ₂ V ₆
V ₃			V ₃ V ₃	V ₃ V ₄	V ₃ V ₅	V ₃ V ₆
V ₄				V ₄ V ₄	V ₄ V ₅	V ₄ V ₆
V ₅					V ₅ V ₅	V ₅ V ₆
V ₆						V ₆ V ₆

V₁ : William Bartlett; V₂ : Vicar of Winkfield; V₃ :Gent Drouard; V₄ : Flemish Beauty; V₅ :Fertility; V₆ : Chinese Sandy pear

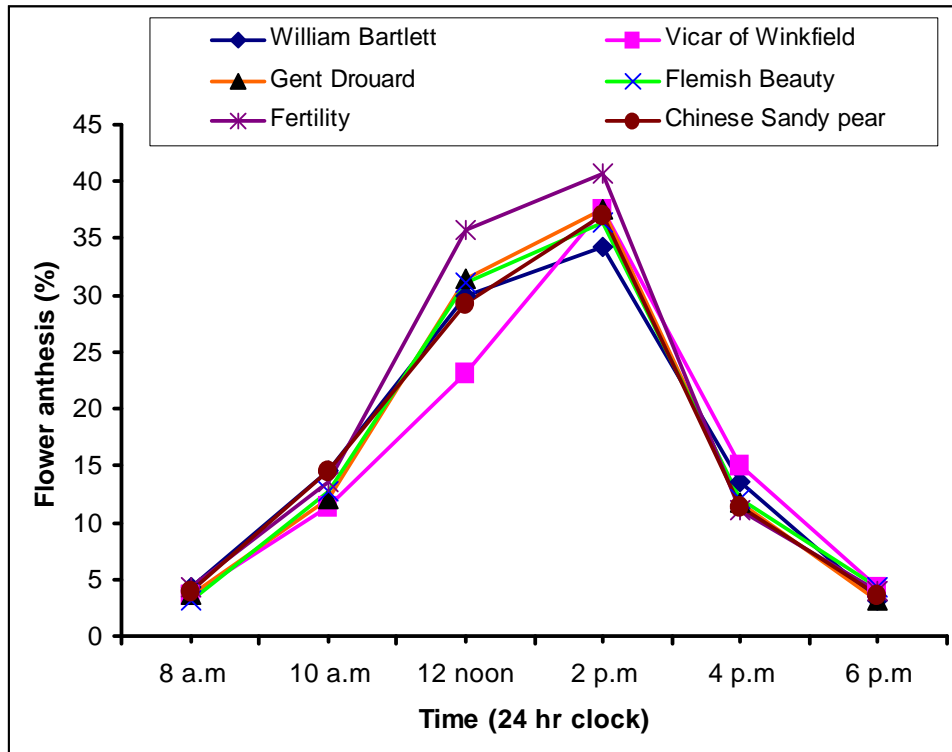


FIG. 1. FLOWER ANTHESIS AT TWO HOURLY INTERVALS IN PEAR CULTIVARS

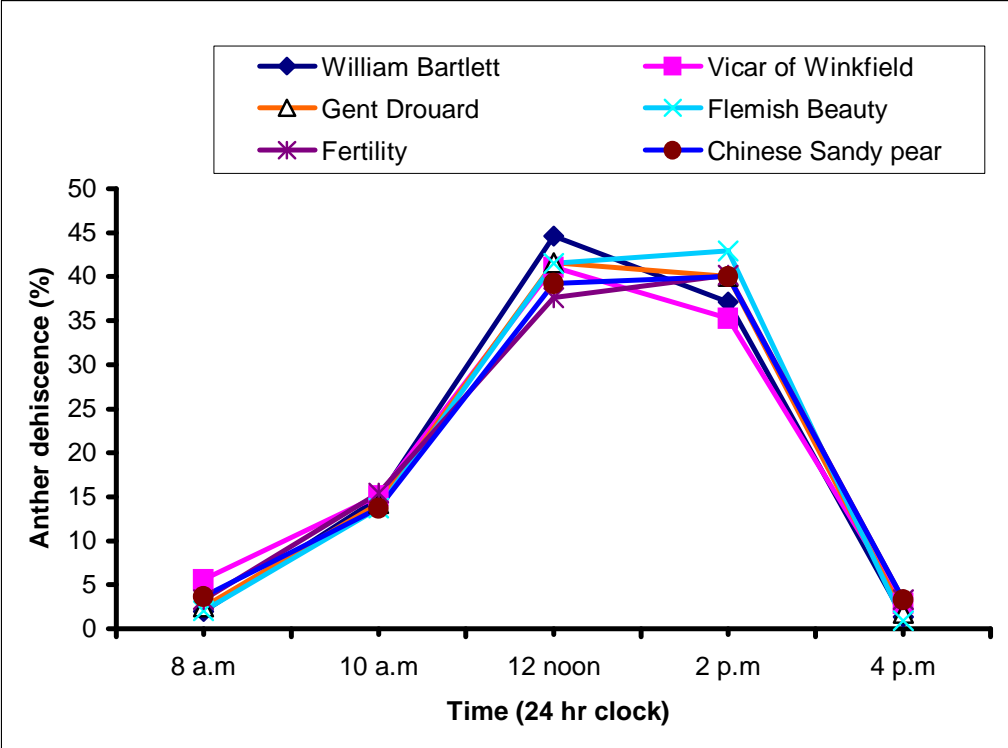


Fig. 2. Anther dehiscence (%) at two hourly intervals in pear cultivars

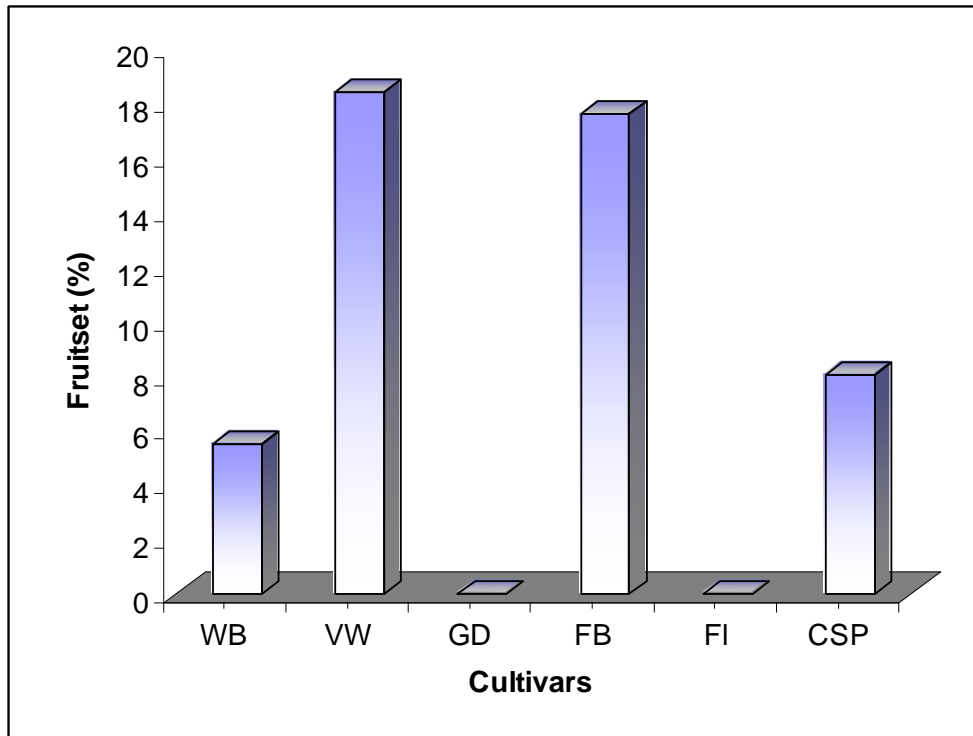


Fig. 3 : Fruit set percentage under self-pollination

WB = William Bartlett; VW = Vicar of Winkfield; GD = Gent Drouard;
FB = Flemish Beauty; FI = Fertility; CSP = Chinese Sandy pear

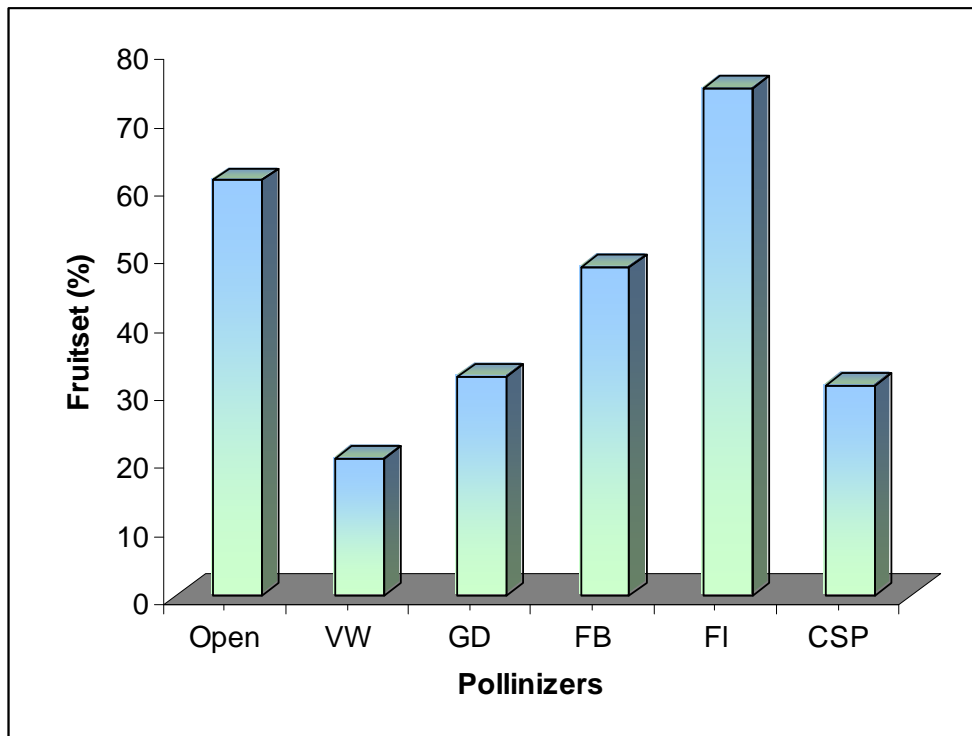


Fig. 4 : Fruit set percentage of William Bartlett under different cross combinations

VW = Vicar of Winkfield; GD = Gent Drouard; FB = Flemish Beauty;
FI = Fertility; CSP = Chinese Sandy pear

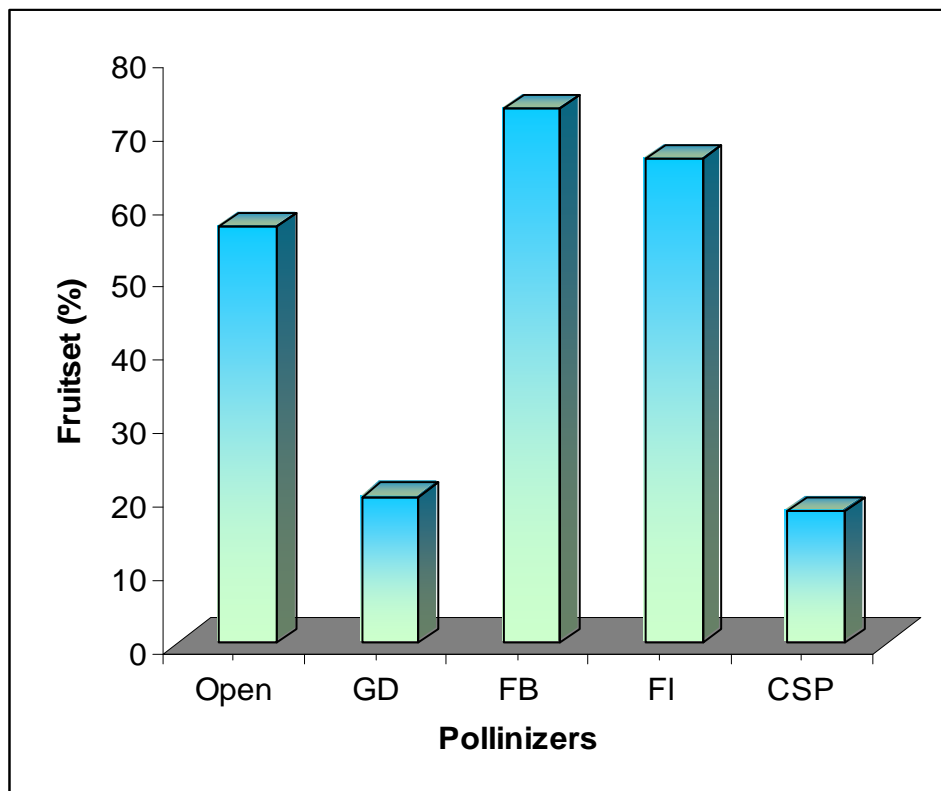


Fig. 5 : Fruit set percentage of Vicar of Winkfield under different cross combinations

GD = Gent Drouard; FB = Flemish Beauty; FI = Fertility; CSP = Chinese Sandy pear

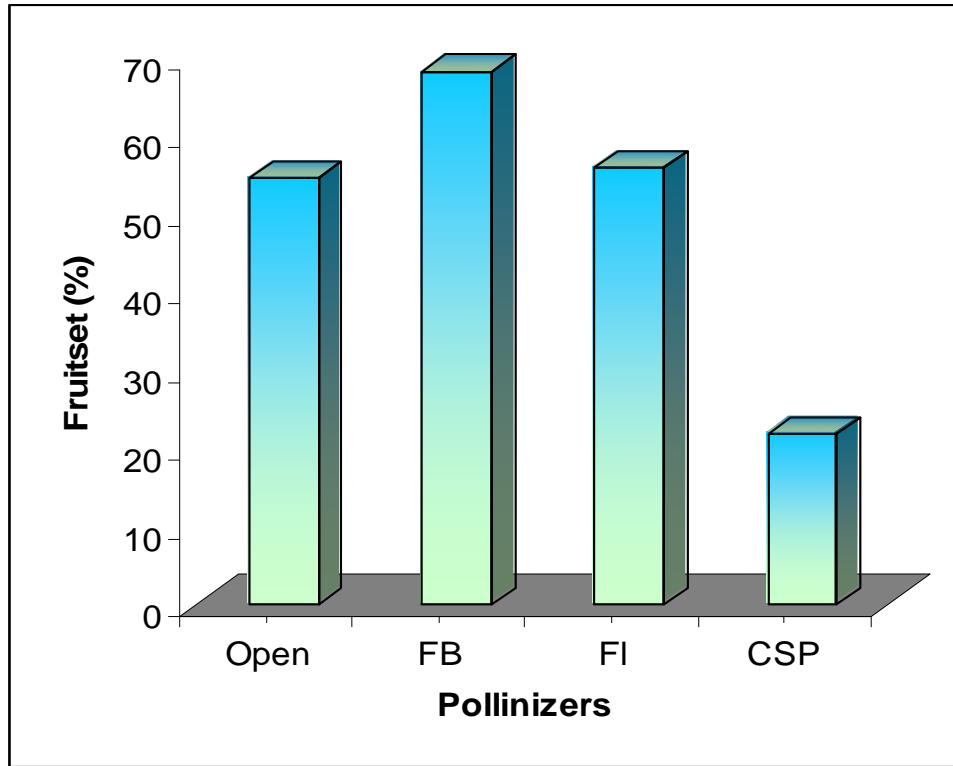


Fig. 6 : Fruit set percentage of Gent Drouard under different cross combinations

FB = Flemish Beauty; FI = Fertility; CSP = Chinese Sandy pear

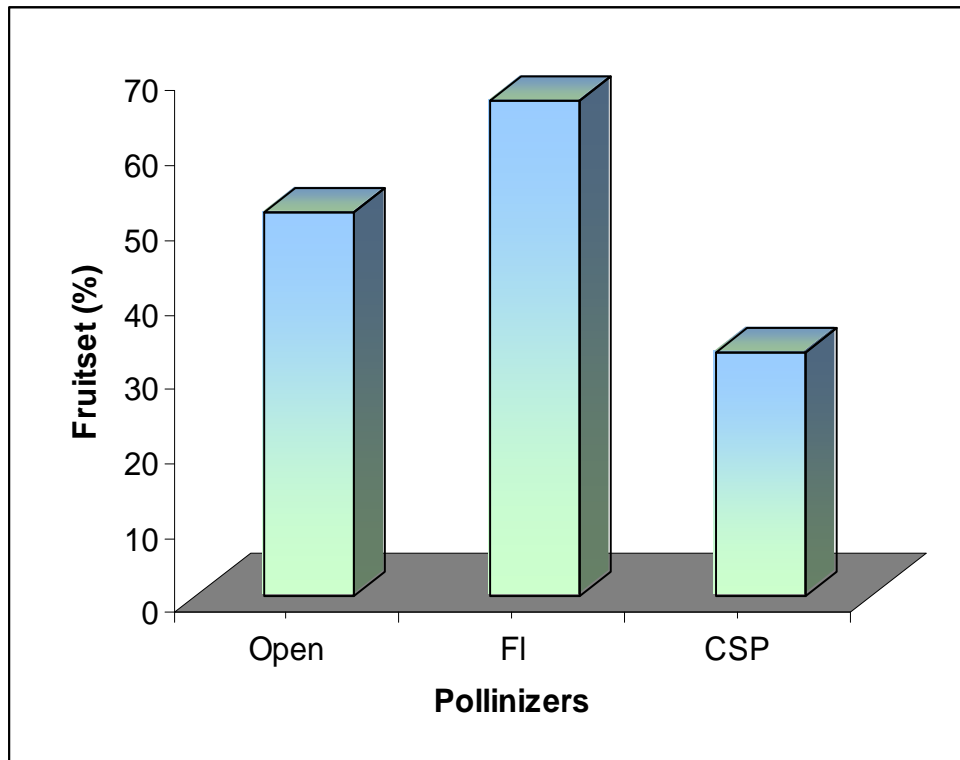


Fig. 7 : Fruit set percentage of Flemish Beauty under different cross combinations

FI = Fertility; CSP = Chinese Sandy pear



Plate-1 : Tight bud stage of pear

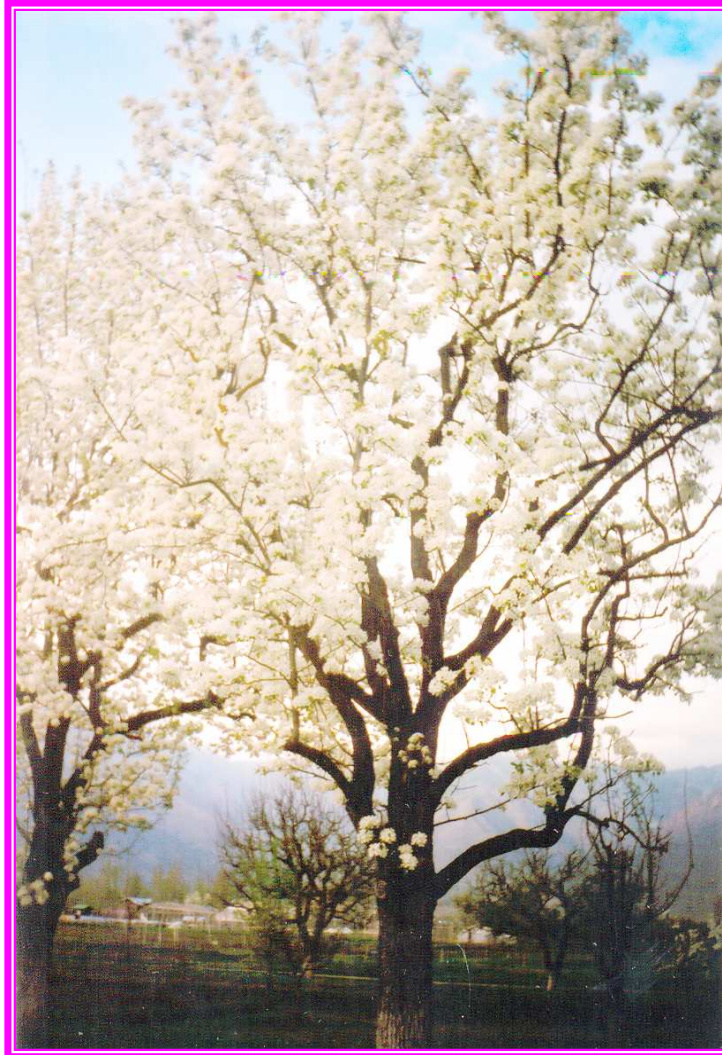


Plate-2 : Full bloom stage of pear





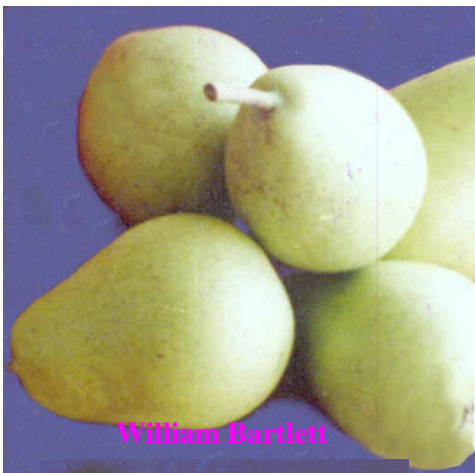
Plate-3 : Bagging of flowers to avoid cross contamination



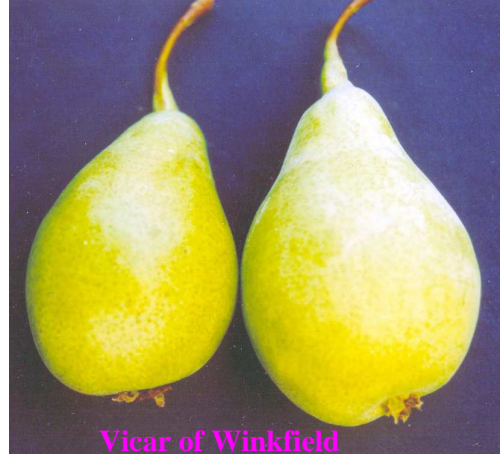
Plate-4 : Hand cross-pollination



Plate-5 : Initial fruitset of pear cultivars under different cross-combinations



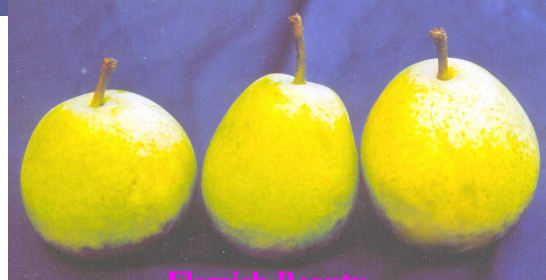
William Bartlett



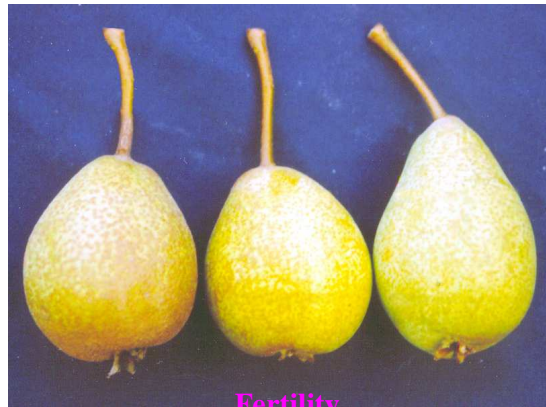
Vicar of Winkfield



Gent Drouard



Flemish Beauty



Fertility



Chinese Sandy pear

Plate-6 : Fruits of different pear cultivars

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* Original not seen.