Studies on Floral Biology, Pollination and Fruit Set in Strawberry (*Fragaria* × *ananasa* L.) Under Hilly Conditions of Uttarakhand

Thesis

Submitted to the

College of Horticulture,

VCSG Uttarakhand University of Horticulture & Forestry

Bharsar-246123, Pauri Garhwal (Uttarakhand) INDIA

By

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IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

Master of Science

Horticulture (Fruit Science)

JULY, 2016

Acknowledgements

I am most indebted to the grace of ***one Universal Being****. His image of universal teacher, who constantly inspire entire humanity towards the knowledge, truth and eternal place. So, I would like to consecrate myself before the* ***Supreme Being*** *for the mental strength. He bestowed on me to go through the ups and downs of my life.*

*Every effort is motivated by an ambition and all ambitions have inspirations behind. I owe this pride place to ideal person of my life grandmother (****Lt. Chandra devi*** *), my ever loving papa (****Mr. Par singh kandwal)*** *and Mummy (****Mrs. Rukma devi****), Brothers (****Chandrakant and Suryakant)*** *and sister* ***(Pramila)*** *for their oceans of love and moral support bestowed upon me which steered the life of this cipher to the present shape.*

It is my profound privilege to express deep sense of gratitude and regards of my esteemed teacher and my Advisor ***Dr. Manju Negi*** *(Department of fruit science) for his inspiring guidance, constant encouragement, valuable suggestions, logical and necessary criticism, innovative ideas, indefatigable supervision throughout the course of this investigation and preparation of manuscript which made this endeavor a complete success.*

I emphatically extend my heartiest thanks to the worthy members of my Advisory Committee ***Dr. B .P Nautiyal*** *(Chairman),* ***Dr. Ajaya Paliwal*** *(Assistant Professor),* ***Dr. Nidhika thakur*** *(Assistant Professor) and* ***Dr. Pankaj Bhaghuna*** *(Assistant Professor) for their valuable suggestions and guidance with their scientific acumen during the investigation and manuscript preparation.*

Nevertheless, my successful accomplishment of the tasks at hand also owes much to the cooperation, personal inspiration, unfailing encouragement and moral support of Dr. B.P Nautiyal and Dr. Manju Negi.

I can never forget the kind bless of God who is not seen to anybody but remain with us at every breath of our life, I am completely overwhelmed by his generous support to me, which brought me up from dark of light.

I record my sincere thanks to all the beloved and respected people who helped me directly and indirectly, but could not find separate mention.

It's my fortune that I have been blessed with long lasting memorable company my friends and classmates ***Neema Pawar, Chetan Chidambar NM, Chinmay Hegde, Priyanka Malasi, Monika Bhatt, Deeksha Semwal, Kanchan Chauhan, Neelam Devrari, Priya Negi, Ekta Negi, Pragya Rawat, Mekap Bengia, Hemawati, Gaurav Kumar, Kulveer Singh and all my friends*** *who made my every moment enjoyable.*

I shall always remember the jovial company of my juniors for boosting up my spirits.

Library will always remain a luscious remembrance for furnishing my studies with endless and invaluable information.

I own entire responsibility for all the errors and omissions.

Place: Bharsar, Pauri Garhwal.
Date: July 2016.

(Madhuri Kandwal)

CERTIFICATE

This is to certify that the thesis entitled **"Studies on floral biology, pollination and fruit set in Strawberry (*Fragaria* × *ananassa*) under hilly conditions of Uttarakhand"** submitted in partial fulfilment of the requirements for the degree of **Master of Science (Horticulture)** with major in **Fruit Science** of the College of Horticulture**,** VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, is a record of *bonafide* research carried out by **Madhuri Kandwal Id. No. 14104,** under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been acknowledged.

Prof. B. P. Nautiyal
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CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Ms. Madhuri Kandwal Id. No. 14104,** a candidate for the degree of **Master of Science (Horticulture)** with major in **Fruit Science** agree that the thesis entitled **"Studies on floral biology, pollination and fruit set in Strawberry (*Fragaria* × *ananassa*) under hilly conditions of Uttarakhand"** may be submitted in partial fulfilment of the requirements for the degree.

Prof. B. P. Nautiyal
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ABBREVIATIONS

am	:	Ante meridiem
cm	:	Centimeter
CRD	:	Completely randomized design
CD	:	Critical difference
^{0}C	:	Degree Celsius
etc.	:	Etcetera
gm	:	Gram
L	:	Length
µ	:	Micron
mm	:	Millimiter
MT	:	Metric tones
no.	:	Number
/	:	Per
%	:	Per cent
Pm	:	Post meridiem
±	:	Positive negative
RH	:	Relative humidity
i.e.	:	That is
viz	:	Videlicet (namely)
w	:	Width

CHAPTER 1

INTRODUCTION

Strawberry (*Fragaria* × *ananasa*) is a soft fruit crop which belongs to the family Rosaceae and genus Fragaria. The fleshy fruit of strawberry is classified as an aggregate fruit (Green 1971) one of the youngest domesticated plant. In Europe, *F. vesca* has been grown in gardens at least since the time of the Romans, and *F. moschata* since the 16th century (Wilhelm *et al*., 1974). The modern cultivated strawberry, *Fragaria* × *ananasa* originated in the 18th century in Europe from hybridization between two species imported from North and South America. The parental species, *F. virginiana* and *F. chiloensis,* also hybridize naturally in North America (Luby *et al.,* 1992), but there is no evidence that they were ever cultivated by the native Americans in this area. Global strawberry production is twice the amount of all other berry crops combined (Stewart, 2011). Ananasa, is eaten by millions of people and is cultivated from the arctic to the tropics.

China is the largest producer with production of 2,997,504 metric tonnes followed by United States 1,360,869 metric tonnes (FAOSTAT data, 2016). In India it is commercially grown in Kerela, Haryana, Mizoram, Meghalaya, Himachal Pradesh and Jammu and Kashmir. The area under strawberry cultivation in India is 1.00 thousand hectares with an annual production of 5.00 thousand tonnes. (NHB, 2015). However, in Uttarakhand, its area is limited to Dehradun, Udham Singh Nagar and Nainital districts.

Today, fresh consumption of strawberries trails only banana, apple, watermelon, and grape. While primarily valued for their flavour, strawberries also have potential health benefits. Strawberries are high in the nutrients vitamin C, folate, and Manganese. They are also rich in phenolic compounds, including anthocyanins, hydrolyzable tannins, and phenolic acids (Giampieri *et al*., 2012). The strawberry occupies a unique position among the cultivated fruits. The plant itself is herbaceous and consequently requires different cultivation from bush and tree fruits. It is a specialized crop which has wide adaptation and can be grown in a wide range of soils and geographical regions. It gives the quickest returns in the shortest possible time. Its fruit is very attractive, has very distinctive and pleasant aroma and delicate flavor and is a good source of vitamin C. All these attributes make it an excellent table fruit. It also makes excellent ice creams and exquisite quantity jam and lends itself well to canning. Because of its highly perishable nature, it needs to be

moved into consumption channels very quickly once it is harvested, else the fruit is apt to deteriorate to a point where it has little commercial value.

The cultivated strawberry, *Fragaria×ananasa,* is grown extensively in most temperate and in some subtropical countries. Some cultivars are adapted to septentrional culture, i.e., short days in autumn and hard winter, or to meridional conditions, i.e., long days in autumn and moderate winter. The cultivars Gorilla, Redgauntlet, Senga Sengana grow under septentrional conditions while Tioga is an important cultivar of meridional regions. Flower buds are not initiated unless the daily dark period is greater than a certain minimum, although this may be less necessary at low temperature (Cooke, 1969). Under normal conditions flowers are, therefore, initiated in autumn, and often the first truss which is initiated under marginally short days is inferior to trusses formed later during subsequent shorter days. A day temperature of about 22º to 23º C is considered optimum for maximum growth rate. Strawberry prefers light soil as heavy soil inhibits root development of runners. Most of the roots of strawberry were found in the top 15 cm of soil (Mann and Ball, 1927), while lateral root spread ranged from 30 to 100 cm. Strawberry prefers 4.6 to 6.4 pH.

Modern Strawberries, mostly octaploids, have been regrouped as *F. ananassa*. In the USA, *F. virginiana* has been used in breeding programme because of its resistance to drought and low temperature. Similarly f. chiloensis and f. virginiana are resistant to red stele, aphids and verticillium wilt. Hybridization is successful between some of the diploid species like *Fragaria. virginiana, Fragaria chiloensis, Fragaria ananasa* and *Fragaria moschata*. The objectives of strawberry breeding includes yield, runner production, extension of fruiting time, adaptability to particular growing environment, resistance to pests and diseases and characters that facilitate mechanical harvest. The size of fruit is inherited quantitatively. The cultivar Gorella showed high combining ability for fruit size.

Important strawberry varieties cultivated in India are Chandler, Tioga, Torrey, Selva, Belrubi, Fern and Pajaro. Other varieties include Premier, Red cost, Local Jeolikot, Dilpasand, Bangalore, Florida 90, Katrain Sweet, Pusa Early Dwarf and Blakemore. For the hilly areas, varieties Royal Sovereign, Srinagar and Dilpasand are suitable. Some of the introductions from California, such as Torrey, Toiga and Solana may prove even more successful. The variety found successful in Bangalore has been named Bangalore and which has performed well at Mahabaleshwar also. For the north indian plains, Pusa Early Dwarf which has dwarf plants, large film wedge-shaped fruits, has been recommended.

Another variety with rich aroma but softer fruits is Katrain Sweet. In hilly condition of Uttarakhand, where strawberry is a very recent introducted have great potentials for its cultivation exist in the valley areas and mid hills. There is a lack of suitable hybrid varieties for the hilly conditions of Uttarakhand and therefore there is an urgent need to select and evolve new varieties that are suitable for cultivation in these regions.

Information on the various indices of floral biology, pollination and fruit setting is an essential pre-requisite of any hybridization programme. Studies on these aspects are also helpful in revealing the fundamental causes of low fruit set and yields. It provides useful information for taxonomical studies. Studies on flowering behavior, flower opening (anthesis), anther dehiscence, pollen morphology, respectively of stigma, pollination also give an indication of the relationship between different varieties by providing useful information on pollen sterility and varietal incompatibility. The present investigation taking into cognizance of the above facts, the present investigation on the floral biology, pollination and fruit setting of strawberry was conducted at the Veer Chandra Singh Garhwali, College of Horticulture, Bharsar, during the year 2015-16 with the following objectives:

- To study the various components of floral biology in strawberry.
- To study the effective mode and time of pollination in the fruit setting of strawberry under hilly conditions of Uttarakhand.

CHAPTER 2

REVIEW OF LITERATURE

The pertaining literature related to various aspects of the study on floral biology, pollination and fruit set in strawberry (*Fragaria* × *ananasa*) is reviewed as given below:

Valleau (1923) found that primary flowers of strawberry had the greatest percentage set and produced the greatest percentage of well-formed fruits and that both of these progressively decreased in the later flowers of an inflorescence. He supposed that lack of pollination and frost injury were not responsible for lack of set or the production of malformed fruits.

Gardener (1923) has shown that the more vigorous plant of the Dunlap variety of strawberry produced larger flower clusters than did the weaker ones. Because of the difference in vigour of the plants in any field, they expect and actually find differences in size from one flowered too many flower clusters. Waldo (1930) established the relationship between photoperiodism to fruit bud formation in the strawberry. They observed that the strawberry requires short days for flower bud formation and long days for subsequent flower development.

Hopper (1932) reported that the stigmas are receptive long before the anthers dehisce, so cross pollination by insects is favoured. Insects especially various Diptera's, visiting strawberry flowers. Swarbick and Thompson (1932) recorded that varieties like Howard 17, Robinson, Sioux and Royal Sovereign are self fruitful and varieties Jucunda and oberschlesien of strawberry are self unfruitful.

Darrow and waldo (1935) has reported that cultivated strawberries produced two general type of flowers: pistillate and hermaphrodite. Morrow and Darrow (1940) reported that leaf production in strawberry is directly related to the number of flower produced. Herold (1941) concluded that 15 to 20 percent raw sugar solution was the best germinating medium for strawberry pollen grains. Naik (1949) has reported that strawberry fruits are ready for picking from February to July in South India, from March to July in Mahabaleswar and from May to June in Punjab. Wedehouse (1935) and Ali (1962) are of the view that it is the effect of the stain which brings about change in the shape of the pollen grains.

Darrow (1937) has also reported that stigma was highly receptive on the day of anthesis. Hopper (1918) however has reported that in strawberry the anthers mature later than the stigma.

Nitsch (1950) reported that the growth of the receptacle is entirely dependent upon the presence of fertilized achenes, and has obtained evidence that this control was mediated through a mechanism involving auxin like growth substances. Guttridge (1952) found that in the Royal Sovereign the number of inflorescences varied between 2 to 3 percent crown. He further pointed out that the number of inflorescence initiated each year by each plant might be expected to depend upon the duration of the active growth period.

Guttridge (1955) reported that flower initiation in spring bearing strawberry cultivation begins in September under field conditions. Initiation is first indicated by broadening and flattening of the apex with the terminal flower appearing first. The flower develops centripetally the sepals appearing first followed by the petals, stamens and pistils. Secondary flowers appear in the axils of the inflorescence and are at a younger stage than the terminal flower.

Haskell and Williams (1954) studied the biometrical variation in the flowers of polyploidy series of strawberry. They observed that in octaploid Royal Sovereign the number of floral parts decreased from primary to lateral flowers. The number of bracts, petals and stamens were 22, 9, 48 respectively in primary flowers; 14, 7, 28 respectively in secondary flowers; 10, 5, 22 respectively in tertiary flowers and 12, 6, 24 respectively in quaternary flowers.

Guttridge (1955) reported that the growth in strawberry is sympodial and inflorescences are formed terminally. He observed that in the cultivars Royal Sovereign the inflorescences were found to be first initiated each year in early September. Further inflorescence were initiated terminally during the summer and autumn on the crown extension axis, which are subtended by leaves immediately below the inflorescences.

Skrebtsova (1957) concluded that the flowers of strawberry pollinated by honey bees at the time, their reproductive organs were fully developed, produced heavier berries than flower pollinated before, or after this time.

Went (1957) found that temperature can be as important as photoperiod in including flower formation and that temperature can be as important as photoperiod in including flower formation and that cool night temperature at 60ºF or less, even on long days, hastened flower bud initiation in strawberry.

Kronenberg (1959) reported that poor fruit set in strawberry may be caused by unfavorable weather condition including frost during flowering season, injury by insects, mites or fungi, insufficient pollination under cover beds and unfavorable soil structure, but inherent, genetically determined factor causing poor set are more serious.

Hughes (1961) reported that most modern strawberry varieties are self fertile, though exceptions either having no stamens or producing insufficient pollen are not rare.

Ali (1962) and Chauhan (1966) have reported that flowering season varies not only from place to place but also from year to year. This difference can be attributed to weather conditions, time of planting and cultural practices.

Hideo and Takasi (1962) reported that low temperature of about 9ºC is the critical for the flower bud formation in the strawberry plant. At 9ºC, the flower bud formation occurs under either short-day or continuous illumination. At 17º and 24ºC, photoperiods longer than 16 hours failed to induce the flower bud formation and short day in the range of 4 to 12 hours induces the flower bud formation. At 30ºC, even the short day treatment such as four or eight hours failed to induce the fiower bud formation. Desai (1963) has reported that the first flower of strawberry appeared in January and the fruit matured in about three weeks.

Chauhan (1966) observed the anthesis in Pusa early dwarf variety of strawberry to take place between 8 am to 10 am whereas in the other types the maximum number opened between 10 am to 12 noon. He also observed the stigma to be highly receptive on the day of the anthesis. He reported that maximum number of flowers (49.72) in Pusa early dwarf dehisced at 10 am whereas in Royal sovereign the maximum dehiscence (39.51) was recorded at 12 noon.

Rajput (1967) observed that the shape of the pollen grains in dry state was elliptical. In general there were a high percentage of viable pollen grains (75.7 – 95.4 %) in

the acetocarmine test, while the shape of the pollen grains was observed to be roundish when mounted in 2% acetocarmine. He also concluded that cross pollination resulted in the highest percentage of fruit set and self pollination in the lowest.

Kurgaceva ((1968) distinguished three types of shoots carrying two types (terminal and axillary) of inflorescence in strawberry. Varieties were classified by the earliness of shoot formation, which was found to be related to the start of inflorescence initiation.

Shanks (1969) observed in raspberry that without any additional pollination a berry developed frequently, although it was be relatively small and may had a tuft of unpollinated pistils at its center in strawberry. Insect activity helped to spread pollen over the pistils and to increase the set of drupelets. The extent of this increase seemed to vary with the cultivar. Sharma (1970) reported in apple that the anthesis occurred between 6.00 am to 6.00 pm with gradual increase up to 12.00 noon and then decreased slowly which ended by 6.00 pm. in apple cultivars.

Redalen (1976) found in raspberry that open pollination of emasculated Norna flowers after isolation for three to six days decreased drupelet set by 36 and 58 %, respectively. Drupelet set was also higher in a year when the flowers were pollinated two days after emasculation than in a year when they were pollinated after three days after emasculation. He also found that receptivity of Norna was higher when it was pollinated after three days rather than six, and showed evidence that pollination after two days was more effective than three. The flowers of cv. Willamette were receptive for at least three days under field conditions. Hand pollination for only one day at the peak of the receptivity period was as effective as pollination for more than one day.

Bekey (1985) reported that anther dehiscence began in a few of the anthers of a flower almost immediately after the split of the calyx. At field temperatures dehiscence was heaviest on the first three days and nearly ceased by the fourth day. Thus 26 pollen were available during the first two days, the time of maximum bee visitation of the flowers. The peak period of receptivity of raspberry flowers lasted from 2 to 3 days after anthesis.

Bist (1985) obtained as much as 22.40 % fruit retention upto maturity under cross pollination in apple cultivar. Further, 3.87 % and 0.49 % fruit retention was recorded under hand self pollination and selfing by bagging.

Bist and Sharma (1986) found that the fresh pollen grains of apple were elliptic and tricolpate and in acetocarmine solution the pollen grains assumed the triangular shape. The average length of fresh pollen ranged from 33.96 to 47.95 microns in different cultivar, whereas the breadth ranged from 23.97 to 29.97 microns. The average length and breadth of pollen grain in aniline oil ranged from 38.29 to 47.95 microns and 21.31 to 26.64 microns respectively in some low chilling cultivars of apple.

Tamura *et al.* (1987) reported seven bud development stages in apple. He suggested that the diameter of flower primordial was a suitable indicator of the stage of flower bud development. Asada (1987) reported that the morphological development of flower bud in early spring with various apple cultivars that L/D ratio (length/diameter) was similar for all the cultivars rising from 0.25 at dormancy to 0.65 at flowering.

Jenning (1988) observed that raspberry flowers were white, 1-1.5 cm in diameter, a few to many in terminal panicles or bunch of axillary inflorescences or solitary. Pedicels were hairy; 4-6 mm bracts were narrow and hairy. The calyx was covered with yellow tomentose or thorny hairs, ovoid sepals with yellow tormentors. The pistils were pointed, erect in the fruit period spoon like petals with hairs, teeth at the edge, white or pale red claw at the base wide flat filaments shorter than the style. The styles were glabrous and ovary was tormentose. The fruits were yellow in color, nearly spherical about 1 cm in diameter, not hairy or fine hairs at the apices. The gynoecium consisted of 60 to 80 ovaries, each of which develops into a drupelet. There are 60 to 90 stamens. The flowers of *Rubus* are structurally rather similar to those of strawberries with five sepals, five petals, a very short hypanthium, many stamens and an apocarpous gynoecium of many carpels on a cone like receptacle. Raspberries were an aggregate fruit, composed of individual drupelets, held together by almost invisible hairs. The one seeded drupelets were set together on a small conical core. Kumar (1988) observed the maximum fruit set in cross pollination whereas, minimum fruit set obtained with hand self pollination.

Marvin (1996) reported that the two types of bearing habits were found in commercial red raspberries. The first type is called summer bearing habit. Canes originated

from either crown buds or adventitious root buds in early spring. Canes elongated during the growing season, forming fruit buds in the axils of leaves in the autumn when temperatures decreased and day length was shortened. The plants became dormant for winter and then the buds on the cane grew the following spring once the chilling requirement was fulfilled. The chilling requirement varied considerably among summer bearing varieties, ranging from a few hundred hours to more than 1800 hours. The lateral axillary buds on dormant canes contained both leaf and flower primordial. At the onset of warm weather, buds break and flowering occured about 6-10 weeks later. Fruiting occured in early to late summer, depending on variety,then the entire cane senesced. While these second year canes i.e. floricanes were flowering, first year canes i.e. primo canes were growing from the crown or roots. These primo canes fruited the following year.

Ilieva (1996) studied the raspberry flower buds their morphologic characters were investigated in every 5 and 7 days. It was found that, the changing started on August and continued for 60 to 90 days. Floral axis was formed between October and mid April, terminal flowers started developing and dormant buds started activity. Petal, stamen and pistil started developing in mid-May and it took 2 to 3 days for anthesis takes place. A month later, buds developed a little on vegetative shoots with 35 nodes. It was observed that the changing started on August and then it was found that these buds went into resting phase.

Kumar (1998) reported the percentage anthesis increased gradually from 8:00 am to 2:00 pm., after which it decreased in all the cultivars of apple. Hancock (1999) reported that flower production started in early July during the first year of growth and by mid-May to early June in the next and subsequent years. Flowering was continuous during the summer and lasted until the first frosts in fall. The inflorescences showed many flowers and were placed at or above canopy. The flowers had five to seven petals, whereas normally five are typical in *Fragaria*.

Abdel (1999) reported 73.30 to 86.10 per cent pollen germination in 15 per cent sucrose solution in three apple cultivars. The best pollen tube length was observed with 25% sucrose + 0.4% boric acid solution which ranged from 26.66 µ to 284.37µ.

Carew *et al*. (2000) reported that the primocane raspberry cultivars showed some similarities with perpetual flowering roses and strawberries. They had annual canes which

were induced to flowering in summer and flowers grew out immediately so the fruiting occurs in the autumn.

Nielsen *et al*. (2000) reported that a set of morphological characters to uniquely identify strawberry cultivars (Nielsen and Lovell 2000) includes leaf morphology, leaf length and breadth, leaf base shape, teeth base shape, petal spacing, petal length and base, calyx: corolla (length ratio), fruit size, fruit length and breadth, fruit shape, band without achenes, insertion of achenes, insertion of calyx, and calyx size.

Gertcekcioglu *et al.* (2000) reported in strawberry that the in vitro pollen germination by hanging drop method using sucrose concentration 0, 10, 15, 20, and 25 per cent at 15, 20 and 25°C. Germination ability was 3 to 41.7 per cent. They further reported that the concentration of sucrose except for control i.e. zero per cent had no effect on germination. The best germination was observed at 20°C temperature.

Rawat *et al*. (2003) reported that the pollen grains of peach were large, equitriangular, tricolporate with thick exine. The highest pollen germination (83.78%) and pollen tube length (1259.01micron) was recorded in 10% sucrose solution after 24 hours.

Ariza *et al*. (2006) studied the effect of chilling on floral development in strawberry to evaluate the effect of chilling on male structures. The total numbers of pollen grains per flower, percentage of germinated of non viable pollen were recorded in control and chilled plants. Anthers from 5 to 10 flowers per treatment were placed in Petri dishes inside a sealed dry chambers containing silica gel for 24 hours to promote release of pollen grains. The pollen was placed in 1.5 ml vials and 150 µL of a germination medium consisting of 10 % glucose and 150 ppm boric acid.

Asma (2008) studied the pollen germination in apricot and found that the genotypes had their highest germination rates at 20°C, whereas Roksana and Levent had the lowest germination rates (46.8 and 48.5%). The germination rates were also affected by sucrose concentrations and media containing a 15% sucrose concentration had the highest germination rates, while Roksana again had the lowest germination rate (36.4%). While the differences in anther number/flower were not significantly different among genotypes, there were significant differences in pollen number for both anther and flower bases.

Sonsteby *et al.* (2009) reported that the inflorescence of red raspberries was cyme, in which the terminal flower developed first, followed by the sequential development of flowers further down the inflorescence axis. While the uppermost lateral buds produced only one to three inflorescences, the complexity of the flowering laterals increased gradually in buds at lower positions. The number of flowers in each inflorescence varied widely and the number of inflorescences on each fruiting lateral increases steadily from the top to the base of the main shoot.

Bradford *et al*. (2010) studied that strawberry cultivars vary greatly in the expression of remontancy in temperate climates. He evaluated flowering of two cultivars viz. *F. ananassa* cultivars and one *F. virginiana* genotype exhibiting contrasting flowering patterns in response to temperature and photoperiod. They observed differences in flowering patterns in the field between strawberry genotypes arised from the variations in temperature tolerance and different photoperiodic responses.

Surya and Rahman (2012) studied flowering and fruiting phenology in five species of *Rubus*. They observed flowers and flower buds were produced every month by *Rubus* spp., in different amount except *Rubus pyrifolius*. Furthermore, each species had a different response to the environment factors. Correlation analysis showed that maximum temperature and relative humidity influenced flower and fruit production. *Rubus fraxinifolius* and *Rubus lineatus* had more economic value due to its ability to produce fruit throughout the year.

Ashman *et al.* (2012) found that strawberry flowers were always actinomorphic, white, sometimes tinged with pink and usually 5-petalled. In some species, staminate and pistillate flowers were readily distinguished, but in others e.g. gynodioecious *Fragaria vesca* subsp. *Bracteata* the pistillate flowers had anthers and were very similar to the bisexual ones.

Hummer (2012) reported that the floral and vegetative morphology of *Fragaria* was also relatively uniform. The leaves were usually evergreen in *F. iinumae* and generally trifolioliate. Five leaflets were typical of some Chinese species, while 4 to 5 leaflets were rarely observed in *F. cascadensis*.

Selamovska (2013) reported that in strawberry differentiation of flower buds passed through 4 phases' viz., induction, initiation, differentiation and organ development of flower buds. The inner hidden changes which take place inside the bud i.e. III to VII stage were the micro-phenophase of differentiation and development of flower organs outside the bud i.e. VIII to XII stage were phenophases of differentiation. The order of rising and dynamic of growth and development of mixed buds was in correlation with their differentiation. The apical mixed bud was developed first one, after which the side mixed buds were developed. Dynamic and time of the flower bud formation was specific for each plant species.

CHAPTER 3

MATERIALS AND METHOD

The present investigation entitled "Studies on Floral Biology, Pollination and Fruit Set in Strawberry (*Fragaria* × *ananassa*) was carried out at mid-hill conditions of Uttarakhand, VCSG (College of Horticulture Bharsar) Pauri Garhwal during 2015-16.The experimental plants was located at 1900m above mean sea level where observation were recorded on the following aspects.

3.1 Site

The planting material of the strawberry selected from strawberry field of the university. The site is located at an altitude of 1900 meters above mean sea level at a Longitude of 78.99^0 E and Latitude of 30.056^0 N.

3.2 Climatic and weather

The climate of Bharsar is mild summer, higher precipitation and colder or severe cold prolonged winter. The South-east monsoon commences towards the end of June while the North-east monsoon causes occasional winter showers during November-February. During winter, snow fall is common in this region. The experimental site received average rainfall of 432.8 mm (February 2015 to June 2016) with average minimum and maximum temperature of 4.8 °C and 29 °C respectively during the period of investigation. Minimum and maximum rainfall was received during the month of December 2016 (13.5 mm) and February 2016 (13.50 mm) respectively. The minimum and maximum temperature was recorded during November 2015 (7 ^{o}C) and March 2014 (16.6 ^{o}C) respectively.

3.3 Experimental material

The present investigation entitled "Studies of Floral Biology, Pollination and Fruit Set of Strawberry (*Fragaria* × *ananasa*) Under Hilly Conditions of Uttarakhand carried out in fruit orchard, VCSG College of Horticulture, Bharsar. Twenty five healthy plants of Dilpasnd variety were selected for taking observations under the study. Other experimental material used during the field studies were hand lens, tags, butter paper bags and dissection box. Chemicals were used for different media preparation for pollen studies such as glycerol and acetocarmine.

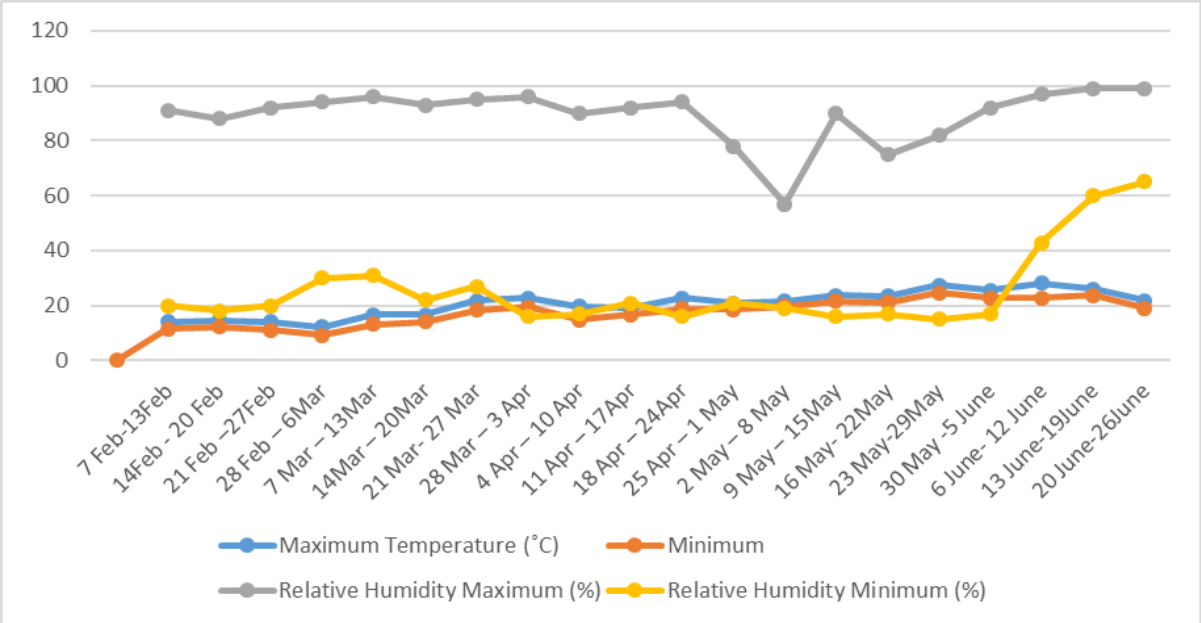

Figure 1: Weekly weather data on February to March (2015)

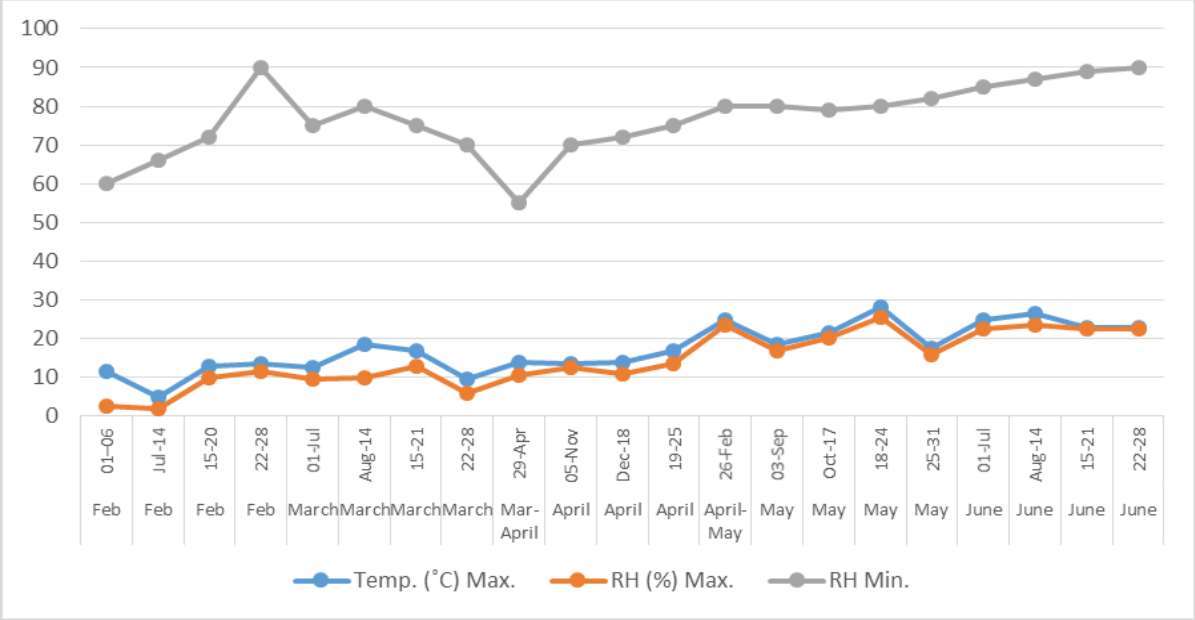

Figure 2: Weather data on February to March (2016)

3.4 Methodology

3.4.1 Floral biology

The following attributes of floral biology were studied in strawberry.

3.4.1.1 Bearing behavior

3.4.1.1.1 Flowering behavior

Five plants were selected to study the total number of inflorescence per plant. The flowers produced per inflorescence were also recorded.

3.4.1.1.2. Sex ratio

Numbers of unisexual and bisexual flowers born on current branches were counted for calculating the percentage of flowers. The percentage of flowers was computed by using the following formulae:

$$\text{Unisexual flower (\%)} = \frac{\text{Number of unisexual flowers}}{\text{Total number of flowers observed}} \times 100$$

$$\text{Bisexual flower (\%)} = \frac{\text{Number of bisexual flowers}}{\text{Total number of flowers observed}} \times 100$$

3.4.1.2 Flower bud development

For recording the floral bud development, five buds were tagged at first visual stage. Observation on size, colour and diameter of the developing buds were recorded at suitable intervals.

3.4.1.3. Time and duration of flowering

The number of freshly opened flowers in five plants was recorded every alternate day. Records on the opening of the first flower and falling of the last were maintained. The day on which more than fifty per cent of the flowers opened was considered to be the full bloom.

3.4.1.4. Floral morphology

The relative size of floral components was determined measuring the different parts of the flower with the help of a scale. This was done when the flowers has fully opened and expanded. Five flowers from each plant were taken for the study. The length and breadth of petals, length and breadth of sepals, stamens and pistils was recorded from the same number of flowers.

3.4.1.5. Anthesis

The mode of flower opening was observed from the moment the petals started unfolding till the flowers were fully opened. Five plants in which the flower were to open were tagged the previous evening in each plant. Observation for number of fully opened flowers were started at 6 am and continued upto 6 pm at a two hourly interval. All the opened flowers in each interval was marked with red ink on the petals in order to avoid

recounting. These observations were continued for five days. The period during which maximum number of flowers opened was determined.

3.4.1.6. Dehiscence

The mode of dehiscence was studied in five plants from 6 am to 6 pm for five days. Flowers in which fifty percent of anthrs had burst were taken as dehisced. Period during which maximum number of anthers dehisced was recorded. The anthers dehisced were removed from the flowers to avoid double counting.

3.4.2 Pollen studies

3.4.2.1 Pollen collection

During the peak period of flowering, floral twigs bearing copious flower buds at the balloon stage (likely to open next day) were gathered from the experimental plants on the previous evening and their cut ends were dipped in distilled water in beakers and maintained under laboratory conditions. On the succeeding days as the dehiscence of anthers was ensured, a single gentle tap on the flowers released the pollen grains easily on the petridish.

3.4.2.2 Pollen shape and size

The fresh pollen grains as collected from strawberry were used for making size measurements in different media, viz., water, acetocarmine, glycerin jelly and without any medium (dry). The size of pollen grains was measured with the help of ocular micrometer indexed against stage micrometer. The average size of 50 pollen grains under each medium was considered to arrive at the final value.

Table 3.1 Variation in shape and size of pollen grains in strawberry

Treatments	Treatments detail
T1	Water
T2	Glycerol
T3	Acetocarmine
T4	Dry condition

3.4.2.3 Pollen viability

Viability of pollen grain was studied by acetocarmine stainability test (Johansen, 1940). Acetocarmine solution was freshly prepared by taking 55 ml of water, 45 ml of glacial acetic acid and 1 gm of carmine boiled for some time and then filtered. Freshly collected pollen grains from mature anthers were placed on a sterilized slide on to which were added two drops of acetocarmine, covered with a cover slip examined under the microscope. The grains staining deeply and looking normal under microscope were counted as viable, whereas shriveled and poorly stained were considered as nonviable. Care was taken to include data from several microscopic fields to cover the pollen grains laying both at the peripheral and central regions of the cover slips.

$$\text{Pollen viability} = \frac{\text{Number of stained pollen grains}}{\text{Total number pollen grains observed}} \times 100$$

3.4.2.4 Pollen germination

Pollen germination studies were conducted in different concentration of 5, 10, 15 and 20 per-cent sucrose solution and 0.1, 0.2, 0.3 and 0.4 boric acid solution and combination of different concentration of sucrose and boric acid solution. Distilled water served as control. Slides were examined at 6 and 24 hours, after planting the pollen grains in different solution media and observations on germination of pollen grains and pollen tube length were recorded under the microscope.

For longevity study, the fresh pollen grains of the strawberry cultivar under investigation were stored in dry specimen tubes, covered with cotton plugs and maintained at room temperature.

$$\text{Pollen germination} = \frac{\text{Number of germinated pollen grains}}{\text{Total number of pollen grains observed}} \times 100$$

Table 3.2 Pollen germination treatments

Treatments	Treatments detail (%)
T_1	5 % Sucrose
T_2	10 % Sucrose
T_3	15 % Sucrose
T_4	20 % Sucrose
T_5	0.1 % Boric acid
T_6	0.2 % Boric acid
T_7	0.3% Boric acid
T_8	0.4 % Boric acid
T_9	5 %Sucrose + 0.1 %Boric acid
T_{10}	10 % Sucrose + 0.2% Boric acid
T_{11}	15 % Sucrose + 0.3 % Boric acid
T_{12}	20 % Sucrose + 0.4 % Boric acid
T_{13}	Control (Water)

3.4.3 Stigma receptivity

The stigma receptivity in the cultivars under study has been studied by the two methods, viz., visual observations and fruit-set method.

3.4.3.1 Visual observation method

Visual observations on stigma receptivity were taken two days before anthesis to two days after anthesis with the help of hand lens. A yellowish green stigma with secretion was considered to be the criterion of stigma receptivity. The stigmas looking shiny, sticky, fresh and attractive were considered to be receptive while dull, faded, non sticky and brownish stigmas were considered non-receptive.

3.4.3.2 Fruit set method

To study the receptivity of stigma by fruit set method, 5 emasculated flower buds were hand self pollinated at different ages varying as two and one day prior anthesis, on the day of anthesis and one and two days after anthesis. The pollinated buds were covered

with paper bags and tagged as usual. The fruit set was observed 21 days after pollination when ovaries started swelling.

$$\text{Fruit-set (\%)} = \frac{\text{Number of fruits set}}{\text{Total number of pollinated flowers}} \times 100$$

3.4.4 Mode of Pollination

The following methods were employed to study the mode of pollination in strawberry cultivars:

3.4.4.1 Natural pollination

Twenty five flowers were randomly tagged and their fruit set was recorded after fifteen days.

3.4.4.2 Bag self-pollination

Twenty buds were bagged one day before anthesis and the fruit set was recorded after fifteen days.

3.4.4.3 Cross pollination

Twenty five buds in the morning prior to anthesis were emasculated and pollination was made with pollen from other variety. The pollinated flowers were then bagged, tagged and labelled properly. Fruit set was recorded after fifteen days.

3.4.5 Fruit-set

3.4.5.1 Time of fruit set

The time of fruit set in the strawberry cultivars under study, five branches on the periphery of a plant were marked during flowering time. The flowers on each branch were counted. The observation on fruit set was started after one week of natural pollination. The date on which percentage of fruit set was recorded 75% or above was considered to be the data of fruit set.

3.4.5.2 Percentage of fruit set

After three weeks of pollination, fruit set in each mode of pollination was recorded and the fruit set per 100 flowers was calculated in order to get percentage of fruit set in all cultivar under study.

3.4.6 Fruit retention upto maturity

The fruits retained on all the strawberry plants were observed under different mode

of pollination and were recorded upto full maturity of the fruits.

$$\text{Fruit retention \%} = \frac{\text{Number of final fruit set}}{\text{Initial number of fruit set}} \times 100$$

3.4.7 Statistical analysis

The data recorded for the various characters under this experiment were subjected to Complete Randomized Block Design (CRD) analysis and interpretation of the data was carried out in accordance to Panse and Sukhatme (1980).

ANOVA TABLE

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Treatment	K-1	BSS	BSS/K-1(V_1)	V_1/ V_3
Error	n- K	ESS	ESS/n-K(V_2)	V_2/V_3
Total	n- 1	TSS	TSS/n-K(V_3)	

Where,

k = Treatment

n = Total no. of observation

BSS = Treatment sum of square

ESS = Error sum of square

TSS = Total sum of square

CHAPTER 4

EXPERIMENTAL RESULTS

The present research work entitled "Studies on floral biology, pollination and fruit set in Strawberry (*Fragaria* × *ananasa*) var. Dilpasand" were carried out under hilly conditions of Uttarakhand, College of Horticulture, VCSG Uttarakhand University of Horticulture or Forestry, Bharsar, Pauri Garhwal during 2015- 2016. The results obtained are presented as under:

4.1 Floral biology

4.1.1 Bearing behavior

4.1.1.1 Flowering habit:

The flower terminating the main axis of inflorescence was called 'primary', those terminating the branches were secondary, tertiary and so on (Plate 1). A young plant consists of a short primary axis, bearing leaves and leaf initials in spiral succession and terminated by a vegetative growing point. The secondary crown-extension axis so formed later terminated in a "second order" inflorescence; any further extension growth again arose from the axillary bud immediately below. This formed a tertiary crown extension axis, which in turn ended in a third orders inflorescence, and sometimes further growth produced a further order inflorescence. The inflorescence of strawberry under study was observed to be of cymose type and was terminal with sympodial growth habit. At each node of the inflorescence a bract replaces the leaf of the vegetative stem, while the bud in the axil of each bract develops into a branch of the inflorescence. The flower terminating the main axis is called the 'primary flowers 'those was terminating the branches 'secondary flowers' and those terminating the branches of the secondary ones, the tertiary, and so on. Strawberry plants under study differ in the number of inflorescences per plant and the average number of flowers per inflorescence. It produces 2 - 3 inflorescences per plant with 10 – 25 flowers per plant.

4.1.1.2 Percentage of flowering

In strawberry the flowers were mainly borne on current shoots. The flowering percentage was observed to be about 96% in all the plants (Table 4.1). Around fifteen to twenty five flowers are produced on the primary shoot.

Table 4.1 Percentage of flowering per shoot in strawberry

S.No.	Number of inflorescence	Number of buds	Number of flowers	Percentage of flowers
1	3	15	14	90
2	3	17	17	100
3	3	11	10	90
4	3	15	15	100
5	3	19	19	100
Average	**3**	**15.4**	**9.6**	**96**

4.1.1.2 Flower bud development

4.1.1.2.1 Stages of bud development

Starting from the smallest detectable floral bud the whole period of bud development till flower opening was divided into eight distinct stages. The observation with regard to the bud development stages in strawberry cultivars are shown in (Table 4.2). The chronology of bud development stages has been described as follows. The total period of bud development was divided into eight stages.

Stage I: Flower buds at this stage were just visible to the naked eye, when minutely observed. They were delicate, greenish, roughly conical and highly pubescent.

Stage II: The buds take 2 to 4 days to enter this stage. Buds appear to be conical to oval and slightly pubescent. The buds were slightly bigger than those in stage one.

Stage III: It takes another two to three days to enter this stage. The buds were plump and pubescent. This stage was distinguished by the appearance of purplish tinge.

Stage IV: The buds require 2 to 4 days to enter this stage. It was distinguished by the lobes of the epicalyx which start separating out and sepals were visible at the top of the bud. Margin of the epicalyx have a purplish tinge.

Table 4.2 Chronology of bud development stages from its emergence to full bloom

S. No.	Days required for passing one stage to next							
	I-II	**II-III**	**III-IV**	**IV-V**	**V-VI**	**VI-VII**	**VII-VIII**	**Total days required**
1	3	2	3	4	4	1	2 hours	17
2	4	2	2	4	4	2	2 hours	18
3	3	3	3	3	4	2	$2\frac{1}{2}$ hours	18
4	3	3	2	4	3	1	$2\frac{1}{2}$ hours	16
5	4	2	3	3	2	2	$2\frac{1}{2}$ hours	16
Average	**3.4**	**2.4**	**2.6**	**3.6**	**3.4**	**1.6**	**2 hours 3minutes**	**17**

Stages V: It takes another 2 to 4 days to enter this stage. By now the buds acquire a more roundish and full shaped. In this stage the lobes of the epicalyx separate out and were erect.

Stage VI: Again it takes 2 to 4 days for buds to enter this stage. This stage was distinguished by the disappearance of purple coloration and the distinction of the sepals which give room to the producing corolla.

Stage VII: The buds take another 1 to 2 days for the buds to enter this stage. The corolla had started opening. The pistils and stamens were also visible from the top of the bud. The lobes of the calyx and epicalyx have parted. Movements of honey bees around the buds become more frequent and noticeable.

Stage VIII: To reach this stage the buds take only two to two and half hour from preceding one. This is the full bloom stage depicting an anthesized flower exposing the various whorls and reproductive parts.

It is clear that as the development of the flower bud progresses less time is required to pass from one stage to the next. This indicates that development is more rapid as the bud approaches maturity. The total time taken for the complete development of the bud varies from 16 to 18 days in the variety under study.

4.1.1.2.2 Bud growth behavior

Data presented in Table 4.3 indicate that in the initial stages, there was a slow growth of buds in all the aspects, viz., size and shape but after 10 days, there was recorded a fast growth. However, during the later period of bud development i.e. fewer days prior to the

anthesis, the bud growth in length was little faster than radial growth. It took 16-20 days for reached from initial stage to anthesis.

Table 4.3 Bud growth behavior at different stages of development

Stages of development	Size of bud (cm)	
	Length	Width
I	0.3	0.2
II	0.5	0.3
III	0.9	0.5
IV	1.1	0.5
V	1.5	0.7
VI	1.6	0.7
VII	1.6	0.7
VIII	1.9	0.7

4.1.1.3 Time and duration of flowering

Under Bharsar condition the strawberry plants under study were found to flower regularly once a year in February to June. With total duration of flowering 90 to 95 days and peak period was recorded 20 to 36 days after first flower apearance (Table 4.4).

Table 4.4 Time and duration of flowering in strawberry

Beginning flowering	Peak period of flowering	End of flowering	Duration of full blooming (days)	Duration of flowering period (days)
05/03/2015	14/03/2015 to 19/04/2015	07/06/2015	36	94
05/03/2015	29/03/2015 to 01/05/2015	11/06/2015	33	89
09/03/2015	25/03/2015 to 20/05/2015	10/06/2015	26	94
09/03/2015	31/03/2015 to 03/05/2015	09/06/2015	34	94
11/03/201	23/03/2015 to 12/04/2015	08/06/2015	20	90

4.1.1.4 Flowers and its organization

Freshly opened flowers of strawberry cultivars were collected for visual observation and size measurement of their parts. The data thus, obtained are presented in Table 4.5.

Flower: A typical flower of strawberry was usually hypogynous and was pentamerous with regard to all floral parts except carpels. Flowers were regular, bisexual, rosaceous the receptacle was hollowed and cup shaped. Number and size of different floral structures are given in Table 4.5.

(i) Calyx: Sepals 5, adnate to the receptacle, lobes free, polysepalous, medium sized, pointed apices, pubescent, reflexed, persistent with 5 epicalyx, narrow pointed apices, which was not distinguished easily.

(ii) Corolla: Petals 5, free, usually imbricate alternating with the sepals, usually white, polypetalous, large, broad and obovate with round apices.

(iii) Androecium: Stamens many, 20 to 22 in number, incurred in bud, arranged in three whorls in cyclic order, fine hairs at the base of the filament, anthers yellow, plump dehiscing by two longitudinal sutures. The height stamens were recorded about 0.4 cm.

(iv) Gynoecium: Carpels, 90 to 120 in number, numerous, style slender, obliquely attached, very fine hairs around the base of the carpels; stigma small knob shaped.

Table 4.5 Dimension of different flower parts

Number flowers	Calyx			Corolla			Androecium		Gynoecium	
	Average Number	Size (cm)		Average number	Size (cm)		Average number	Size (cm)	Average number	Size (cm)
		Length	Width		Length	Width		Length		Length
5	5	0.87	0.42	5	0.92	0.86	22.8	0.38	107.2	0.14

Table 4.6 Time of anthesis

Date of observation	Percentage of flowers opened at different time interval								Temperature (ºC)		Humidity (%)	
	Total no. of flowers observed	4- 6 am	6-8 am	8-10 am	10 am - 12 noon	12-2 pm	2-4 pm	4-6 pm	Max.	Min.	Max.	Min.
27/04/2016	20	5	10	20	40	25	0	0	23	16	65	60
29/04/2016	20	5	15	15	45	15	5	0	23	16	65	60
01/05/2016	20	0	10	25	30	20	10	0	23	16	65	60
03/05/2016	20	5	15	20	40	10	10	0	25	17	60	60
05/05/2016	20	0	10	20	35	20	10	0	23	16	65	60
Average	**20**	**3**	**12**	**20**	**38**	**18**	**7**	**0**	**23.4**	**16.2**	**64**	**60**

4.1.1.5 Anthesis

4.1.1.5.1 Time of anthesis

Observations on the rate of anthesis were recorded at two hours interval daily for 5 days. The results are presented in Table 4.6. It is clear from Table 4.6 that anthesis, i.e., the opening of flowers took place between 6.00 am to 6.00 pm. The rate of anthesis increased gradually from 6 am to 12 noon after which it was gradually decreased. Maximum anthesis was recorded between 6 am to 12 noon. The peak time of anthesis with 38 % flower opening was observed between 10 am to 12 noon.

4.1.1.5.2 Mode of anthesis

The process of opening of flowers in strawberry took place rather quickly. The calyx segments were noted to separate out gradually due to the inner pressure of the protruding corolla. The corolla made its appearance through the slightly split sepals at stage VI i.e. brusting stage about one to two days before full opening of the flowers. Petals opened out exposing the gynocium and anthers became visible from the top as in stage VII i.e. partial opening stage. The petals along with the sepals and the epicalyx gradually stretched out and the anthesis was complete. It took about two to two and half hours for the buds to accomplish anthesis, i.e. to reach the stage VIII (full bloom stage) from the preceding one.

4.1.1.6 Dehiscence

4.1.1.6.1 Time of dehiscence

The time of dehiscence in strawberry under study was observed for 5 days. The data regarding time of dehiscence are given in Table 4.7. The data show that in strawberry flowers anthers had maximum dehiscence was achieved at different hours. Anthers were started dehiscing around 8 am and continued upto 6 pm Optimum period of dehiscence was observed between 10 am to 2 pm. Peak period being recorded at 10 am to 12 noon. The yellow to golden yellow anthers gradually become dull and turned mudy yellow to brownish yellow in colour after dehiscence.

4.1.1.6.2 Mode of dehiscences

The stamens in strawberry flowers were arranged in three whorls. The inner most and middle whorls were having five stamens each while the outer most consist of fifteen stamens. In total there were twenty stamens in each flower, however in some cases this number was recorded up to 22 per flower. The stamens whorls were too close together to be easily differentiated from one another by naked eye. The dehiscence started, just after the full

opening of flower. It started first in outer whorls followed by middle and inner whorls. The dehiscence of anthers took place longitudinally. The pale yellow mass of pollen was visible on the anther lobes. The dehiscence of anthers in flowers of strawberry was completed in one day.

4.2 Pollen studies

4.2.1 Pollen size and shape

Freshly dehisced pollen grains looked dirty yellow in a mass to the naked eye and golden yellow when viewed under the microscope. They are sticky just after anthesis. In dry mount and glycerol almost all the pollen grains appeared to be elliptical. However the pollen grains became roundish when mounted in water and acetocarmine. Maximum length of pollen grain was observed in dry condition (155.51 µ) and glycerol (155.51 µ) which was statistically at par with T_2 (water) 137.74 µ while maximum width of pollen grain was observed in water condition (137.74 µ) followed by acetocarmine (115.52 µ). Minimum length was observed under T_4 (acetocarmine) 115.52 µ and minimum width was observed under T_1 (dry condition) 84.42 µ which was statistically at par with T3 (glycerol) 88.86 µ.

Table 4.7 Time of dehiscence

Date of observation	Percentage of anthers dehisced at hours								Temperature (ºC)		Humidity (%)	
	Average number of anthers observed	4-6 am	6-8 am	8-10 am	10 am -12 noon	12-2 pm	2-4 Pm	4-6 pm	Max.	Min.	Min.	Max.
07/05/2016	22	0	4.54	18.18	45.45	13.63	9.04	9.04	23	16	60	65
08/05/2016	22	0	4.54	13.63	40.90	18.18	18.18	4.54	23	16	60	65
09/05/2016	22	0	4.54	18.18	40.90	18.18	13.63	4.54	23	16	60	60
10/05/2016	22	0	9.09	13.63	50	18.18	4.54	4.54	25	17	60	60
11/05/2016	22	0	9.09	13.63	45.45	13.63	9.04	9.04	23	16	60	65
Average	22	**0**	**6.36**	**15.45**	**44.54**	**16.36**	**10.89**	**6.34**	**23.4**	**16.2**	**60**	**63**

Table 4.8 Pollen size in different media

Treatment	Length	Width
T_1 Dry condition	155.51 ± 11.75	84.42 ± 4.44
T_2 Water condition	137.74 ± 4.44	137.74 ± 4.44
T_3 Glycerol	155.51 ± 4.44	88.86 ± 4.44
T_4 Acetocarmine	115.52 ± 4.44	115.52 ± 4.44
SE(d)	9.93	6.28
C.D. (0.05)	23.26	14.71

µ= micron (unit of pollen tube length

4.2.2 Pollen viability

The viability of pollen grains in strawberry cultivar under study was high. The fresh pollen grains show 100% viability on the day of flower opening (anthesis).

4.2.3 Pollen germination

The observation on pollen germination of strawberry cultivars under study recorded in 5, 10, 15 and 20 per cent sucrose solution and 0.1, 0.2, 0.3 and 0.4 per cent boric acid solution either alone or in combination at room temperature.

4.2.3.1 Pollen germination and pollen tube length at 6 hours

The data on pollen germination and pollen tube length in strawberry (*Fragaria* × *ananasa*) is presented in Table 4.9 and Table 4.10. The data revealed that the maximum pollen germination percentage (77.42%) was recorded with T_{12} (20% sucrose solution + 0.4% Boric acid at 6 hours) which were statistically at par with treatment T_{11} recording 69.98% germination while T_9 (5% sucrose solution + 0.1% boric acid) with 16.40% pollen germination show the lowest pollen germination. The maximum pollen tube length (41.76 µ) was recorded with T_{12} (25% sucrose solution + 0.4% Boric acid at 6 hours) followed by T_8 (0.4% boric acid) and T_{11} (15% sucrose solution + 0.3% boric acid) which gave 34.65µ long pollen tube.

4.2.3.2 Pollen germination and pollen tube length at 24 hours

After 24 hours of slide preparation (Table 4.9 and Table 4.10) it was observed that the increasing concentration of sucrose and boric acid either single or on combination increase the pollen germination and pollen tube length. T_{12} (20% sucrose solution + 0.4% boric acid)

Table 4.9 Pollen germination at different time of incubation

Treatment	Pollen germination (6 hours) (%) ± SE(m)	Pollen germination (24 hours) (%) ± SE(m)
T_1- 5% sucrose solution	0.00 ± 0.00	39.35 ± 1.96
T_2- 10% sucrose solution	43.03* ± 0.68	52.66* ± 1.45
T_3- 15% sucrose solution	48.32 *± 1.19	76.27* ± 0.00
T_4- 20% sucrose solution	60.12* ± 8.91	81.18* ± 2.23
T_5- 0.1% boric acid	0.00* ± 0.00	39.82 ± 3.70
T_6- 0.2% boric acid	40.50* ± 5.34	46.34 ± 2.46
T_7- 0.3% boric acid	46.93* ± 5.41	64.13* ± 1.46
T_8- 0.4% boric acid	49.55* ± 3.53	79.15* ± 3.05
T_9- 5% sucrose solution + 0.1% boric acid	16.40 ± 5.47	48.13 ± 8.07
T_{10}- 10% sucrose solution + 0.2% boric acid	53.91* ± 2.31	64.60* ± 3.38
T_{11}- 15% sucrose solution + 0.3% boric acid	69.98* ± 4.38	83.19* ± 5.23
T_{12}- 20% sucrose solution + 0.4% boric acid	77.42* ± 4.93	94.34* ± 1.12
T_{13}- (control) Water	0.00 ± 0.00	0.00 ± 0.00
SE(d)	5.95	4.76
CD (0.05)	12.30	9.85

Table 4.10 Pollen tube length at different time of incubation

Treatment	Pollen tube length (6 hours) (µ) ± SE(m)	Pollen tube length (24 hours) (µ) ± SE(m)
T_1- 5% sucrose solution	0.00 ± 0.00	19.55 ± 3.20
T_2- 10% sucrose solution	20.43* ± 2.35	26.65* ± 0.00
T_3- 15% sucrose solution	25.77* ± 3.20	35.54* ± 0.88
T_4- 20% sucrose solution	31.10* ± 0.88	38.21* ± 0.88
T_5- 0.1% boric acid	0.00 ± 0.00	19.54 ± 2.35
T_6- 0.2% boric acid	22.21* ± 1.77	25.76* ± 0.88
T_7- 0.3% boric acid	31.10* ± 1.77	33.76* ± 1.77
T_8- 0.4% boric acid	34.65* ± 1.53	43.21* ± 1.63
T_9- 5% sucrose solution + 0.1% boric acid	10.66 ± 2.66	33.76* ± 0.88
T_{10}- 10% sucrose solution + 0.2% boric acid	28.43* ± 1.78	35.54* ± 0.88
T_{11}- 15% sucrose solution + 0.3% boric acid	34.65* ± 1.53	48.87* ± 4.94
T_{12}- 20% sucrose solution + 0.4% boric acid	41.76* ± 1.77	59.54* ± 2.35
T_{13}- (control) Water	0.000 ± 0.00	0.00 ± 0.00
SE(d)	2.92	2.51
CD (0.05)	5.19	6.04

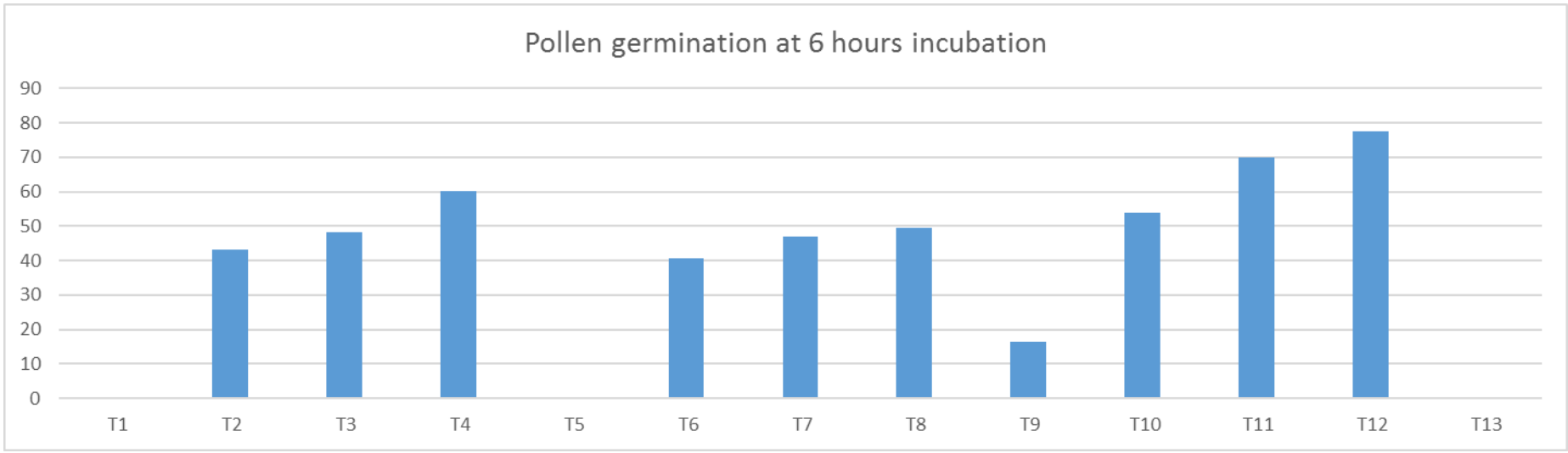

Figure 3: Percentage of pollen germination at 6 hours incubation

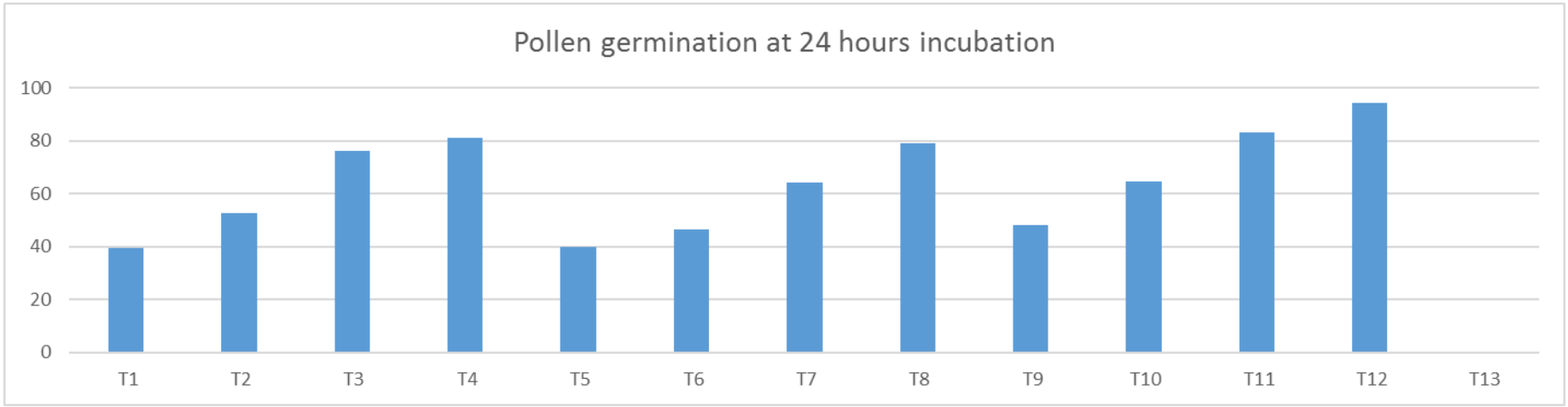

Figure 4: Percentage of pollen germination at 24 hours incubation

with 94.34% pollen germination and 59.54µ pollen tube length obtained first rank followed by T_{11} (15% sucrose solution + 0.3% boric acid) which gave 83.19% pollen germination and 48.87µ long pollen tube whereas the minimum pollen germination (39.35%) was recorded with 5% sucrose solution (T_1) which was statistically at par with T_5 (39.82%), T_6 (46.34%) and T_9 (48.13%) while the shortest pollen tube (19.54µ) was observed under 0.1% boric acid treatment which was statistically at par with T_1 (19.55µ).

4.2.4 Pollen longevity

The longevity of pollen grains stored under room conditions have been presented in Table 4.11 which indicate that after 4 days of storage, the pollen grains were quite normal and showed 60.34% viability. But after that the longevity of pollen decreased rapidly and after 6 days of storage, the viability dropped to nil.

Table 4.11 Pollen longevity

Days of Interval	Total pollen grains	Pollen grains stained	Pollen viability (with acetocarmine)
I day	84.33	84.33	100%
III day	28	21	75%
V day	58	35	60.34%
VII day	54	18	33.33%
IX day	36	0	0%

4.3 Stigma receptivity

4.3.1 Visual observation

In order to study stigma receptivity by visual observation stigmas of different age group viz., two day and one day before anthesis, on the day of anthesis and one day and two day after anthesis were recorded with the help of a hand lens. Stigma which were plump and shiny with stigmatic secretion were considered to be receptive while those having dull brownish appearance and lacking in secretions were considered to be non receptive.

Two days before anthesis: The stigma was green and very thin structure of ovary was present, dark cream color, less shiny and style length was also short.

One day before anthesis: Dark cream color, starting to appearance of shininess, style was healthy.

On the day of anthesis: On the day of anthesis stigma was turned into brownish color, it was very shiny and sticky with more stigmatic secretion.

One day after anthesis: Ovary size increased, brown colored stigma, stigmatic surface bilobed.

Two days after anthesis: Style constriction at the middle portion and shininess dries up.

4.3.2 Fruit set method

To ascertain stigma receptivity by fruit set method flower buds of different age group were emasculated and pollinated with fresh pollen. It is evident from Table13 that a fruit set was observed in two day before anthesis (60%), (80%) was recorded when stigma were pollinated one day before anthesis while on the day of anthesis the fruit set percentage was observed (100%). It is further observed from the table that receptivity was almost equally good on the day of anthesis.

Table 4.12 Stigma receptivity by fruit set method

Age of stigma	Number of buds pollinated	Number of fruit set	Percentage of fruit set
Two days before anthesis	5	3	60 %
One day before anthesis	5	4	80 %
Day of anthesis	5	5	100 %
One day after anthesis	5	3	60 %
Two days after anthesis	5	1	20 %

4.4 Mode of pollination

4.4.1 Self pollination

To determine the extent of self fruitfulness, selfing by bagging was done and fruit were assessed. The study showed that Dilpasand variety of strawberry set 64 % fruits (Table 4.13).

4.4.2 Natural pollination

Under open pollination, average fruit set was 96.00 % (Table 4.13).

4.4.3 Cross pollination

Under cross pollination, Dilpasand cultivar is crossed with the Chandler variety of strawberry and the average fruit set was recorded 44%.

Table 4.13 Mode of pollination

Mode of pollination	Number of flower pollinated	Number of fruit set	Percentage of fruit set (%)
Self pollination	25	18	64.00 %
Natural pollination	25	22	88.00 %
Cross pollination	25	11	44.00 %

4.5 Fruit set

4.5.1 Time of fruit set

Observation on the time of fruit set revealed that the variety of strawberry under study set fruits between first weeks of May to last week of June 2016. On an average the number of days from peak flowering to fruit set in strawberry plants was ranged between 20 to 30 days.

4.5.2 Percentage of fruit set

The data on percentage of fruit set under different modes of pollinations presented in Table 4.13. Maximum fruit set observed under the open pollination (88%) followed by 64% fruit set in self-pollination 44% and fruit set was observed in cross pollination.

4.6 Fruit retention upto maturity

In the present investigation it was found that in the strawberry cultivar under study 72% fruits were retained at the full maturity stage.

Table 4.14 Extent of fruit retention upto maturity in strawberry under natural pollination

Number of flowers per plant	Initial fruit set	Initial fruit set (%)	Fruit retention percentage
25	22	88	72

CHAPTER 5

DISCUSSION

The present investigation on the Study of floral biology, pollination and fruit set in Strawberry (*Fragaria* × *ananasa*) var. Dilpasand was carried out with respect to their flowering habit and duration, pollen characteristics and fruit under different modes of pollination. The results of the present studies are discussed below:

Under the study strawberry plants were generally low perennial creeping herb. Strawberry plants were generally 20 cm in hight. Flowering starts in the end of February and continuous upto the end of June in one continuous flush. The inflorescence was cymose type. Flowers are small or large, white in colour, in corymbose racemes on slender peduncles perfect (having both stamens and pistils) hypogynous, typically pentamerous with regard to all parts except the carpals. Guttridge (1952) found that in the Royal Sovereign the number of inflorescences varied between 2 to 3 percent crown. He further pointed out that the number of inflorescence initiated each year by each plant might be expected to depend upon the duration of the active growth period. Lambertype (1863) reported a direct correlation of the size of the inflorescence and the vigour of the plant in strawberry. Gardner (1923) has shown that the more vigorous plants of the cultivar Dunlap produced larger flower cluster than did the weaker ones. Ali (1962) and Chauhan (1966) have also reported one bloom period in different cultivars of strawberry. Waldo (1930), however, reported that the variety progressive, and ever bearing strawberry fruited in three flushes in the spring, in summer and in the fall until freezing weather occurred. This habit of continuous bearing seems to be the result of certain environmental conditions in some and due to genetic characterstics in others.

Eight stages of flower bud development were observed in strawberry under study. The total time required for flower bud to reach the anthesis was 16 to 20 days in strawberry plants. The growth of flower buds in strawberry cultivars under present investigation showed slow growth for initial days. The floral bud of strawberry was found to pass through eight distinct stages in all the cultivars under study. Cultivar under study took 16 days to develop from first visible stage to the full bloom. The difference in flower bud development period may be due to the genetic makeup of the individuals, which appears to be a principle factors like in controlling flower bud development. Tamura *et al.* (1987)

reported seven bud development stages in apple. He suggested that the diameter of flower primordial was a suitable indicator of the stage of flower bud development. Asada (1987) reported that the morphological development of flower bud in early spring with various apple cultivars that L/D ratio (length/diameter) was similar for all the cultivars rising from 0.25 at dormancy to 0.65 at flowering.

In strawberry plants the flowering started from last week of February to June and total period was recorded to be about 90 to 100 days. As per the observation, the flowering in strawberry under hilly conditions of Bharsar commences between the last weeks of February to June with peak period 18-20 days after opening of first flower. Flowering season, its beginning, peak, and end varied from variety to variety. Strawberry variety which took under study was the first to bloom on 5.3.2015. Desai (1963) has reported that the first flower of strawberry appeared in January and the fruit matured in about three weeks. Ali (1962) and Chauhan (1966) have reported that flowering season varies not only from place to place but also from year to year. This difference can be attributed to weather conditions, time of planting and cultural practices.

The flowers in strwberry cultivars were observed as hermaphrodite, actinomorhic, bracteolate, hypogynous and white in color. The number of petals and sepals were five. The average numbers of pistils were 90 to 120 and stamens were 20 to 22. Ashman *et al.* (2012) found that strawberry flowers were always actinomorphic, white, sometimes tinged with pink and usually 5-petalled. In some species, staminate and pistillate flowers were readily distinguished, but in others e.g. gynodioecious *Fragaria vesca* subsp. *bracteata* the pistillate flowers had anthers and were very similar to the bisexual ones. Strawberry flowers under study were observed to produce only hermaphrodite flowers. No pistillate and staminate flowers were observed. However, occurrence of pistillate and staminate flowers has been reported by Darrow and Waldo (1935). Primary flowers were observed to bloom first of all followed by secondary tertiary and quaternary respectively. Haskell et al. (1954) reported that stamen number in octaploid strawberries is a genetically controlled character and further pointed out that the diploid strawberries have a mode at 20, whereas octaploids have a mode at 29. The basic number is thus close to a multiple of 5 for lower values of each series, but there is a tendency to lose a stamen when the multiple of 5 rises above 5. However in the cultivar Duchesne the mode is 21 which is one more than the basic multiple of 5. Miller (1807) has reported that European strawberries have generally

four, stamens to each petal, but American types have five or six; so that when the latter have the regular number of petals the stamen numbers varies from 25 to 30; but when they have 7 petals the number of stamens varies from 35 to 42.

Observation on anthesis were recorded at two hours interval from 6 am to 6 pm from April 27 to May. It was seen that the process of anthesis was spread over a period of 12 hours commencing around 6 am and ceasing around 6 pm; peak period being achieved between 8 am to 12 noon. The low rate of anthesis was recorded in morning hours. The maximum anthesis was observed between 10.00 am to 12.00 pm. Highest mean percentage of anthesis (38%) was recorded between 10.00 am to 12.00 pm. The percentage of anthesis increased gradually from 8.00 am to 2.00 pm after which it declined gradually up to 6.00 pm. According to the Kumar (1998) the percentage anthesis increased gradually from 8:00 am to 2:00 pm., after which it decreased in all the cultivars of apple. While Sharma (1970) reported that the anthesis occurred between 6.00 am to 6.00 pm with gradual increase up to 12.00 noon and then decreased slowly which ended by 6.00 pm. in apple cultivars.

The rate of anther dehiscence was also found to be a continuous process, maximum dehiscence being achieved around 12 noon. The dehiscence started just after the full opening of the flower, occurring first in anthers on outer whorls followed by those on middle and inner whorls respectively. Further dehiscence started after opening of flower in all the plants studied. The peak period of dehiscence was recorded between 10.00 am to 12.00 noon (44.54%), followed by (16.36%) between 12.00 noon to 2.00 pm. The dehiscence almost completed between 4.00 pm to 6.00 pm. It was observed that almost all the anthers of a flower had dehisced on the day of anthesis. Ali (1962) and Chauhan (1966) observed similar type of dehiscence in different strawberry cultivars. Bright sunny weather tended to accelerate the process of dehiscence and conversely dull cloudy and humid weather slowed down the process.

The pollen grains of strawberry was observed to be elliptical in dry mount and in glycerol. Further the pollen grains were observed to assume different shapes when mounted under different media, being roundish in water and acetocarmine. Maximum length of pollen grain was observed in dry condition (155.51 µ) and glycerol (155.51 µ) while maximum width of pollen grain was observed in water condition (137.74 µ) followed by acetocarmine (115.52 µ). Wedehouse (1935) and Ali (1962) are of the view

that it is the effect of the stain which brings about change in the shape of the pollen grains. Ali (1962), Chauhan (1966) and Rajput (1967) observed that the shape of the pollen grains in dry state was elliptical. While the shape of the pollen grains was observed to be roundish when mounted in 2% acetocarmine.

In the present investigation, pollen grain viability ranged between 100%. Rajput and Singh (1967) also observed a very high degree of stainability in strawberry varieties. Pollen viability was found to vary from plant to plant, in the flowers of the same inflorescence and even within the anthers of the same flower. The inflorescence later in the season had a higher percentage of viable pollen grains. Otterbacher *et al.* (1983) showed that high temperature resulted in rapid loss of viability of raspberry pollen. Similar result also found by Asma (2008) who reported that the pollen viability and germination ratios were determined for eight apricot cultivars. The results indicated that viable, semi viable and dead pollen rates differed among cultivars, where Roksana had the least amount of viable pollen (41.50 %).

Amongst the four concentration of sucrose solution studied, best pollen grain germination was obtained in 20% sucrose solution + 0.4 % boric acid solution which ranged from 77.42 to 94.34 %. The best pollen tube length was observed with 20% sucrose + 0.4% boric acid solution which ranged from 41.76 µ to 59.54 µ. Similar observations were taken by Wertheim (1996) who reported that 13 to 89 per cent pollen germination took place in different apple cultivars in a solution containing 15 per cent sucrose + 15 ppm boric acid + 150 ppm calcium nitrate. Kumar (1988) reported that the sucrose solution of 9 to 10 per cent concentration was the most effective for pollen germination of apple cultivars. Abdel (1999) reported 73.30 to 86.10 per cent pollen germination in 15 per cent sucrose solution in three apple cultivars. The best pollen tube length was observed with 25% sucrose + 0.4% boric acid solution which ranged from 26.66 µ to 284.37µ. According to Rawat *et al*. (2003) the pollen grains of peach were large, equitriangular, tricolpoate with thick exine. The highest pollen germination (83.78%) and pollen tube length (1259.01µ) were recorded in 10% sucrose solution.

In order to study stigma receptivity by visual observation, stigmas of different age group viz., two day and one day before anthesis, on the day of anthesis and one day and two day after anthesis were recorded with the help of a hand lens. On the day of anthesis

the stigma receptivity occurred high as compared to the one and two days prior and after anthesis. In Dilpasand, the stigma remained receptive even two day after anthesis. Darrow (1937) has also reported that stigma was highly receptive on the day of anthesis. Hopper (1918) however has reported that in strawberry the anthers mature later than the stigma.

Chauhan (1966) reported similar findings in the cultivars Pusa Early Dwarf and Kalimpong Local under Delhi condition.

In pollination study natural pollination gave 88 percent fruit set whereas self pollination gave 64 percent fruit set. Cross pollination give the lowest fruit set of 44 percent. Almost similar observation has been reported by Chauhan (1966). Rajput and Singh (1967) reported that the cross pollination resulted in the highest percentage of fruit set and self pollination resulted in the lowest fruit set in strawberry cultivars.

Percentage fruit set under self pollination, and natural pollination was 64% and 88.00% respectively. The time of fruit set revealed that all the plant under study set fruits between first weeks of May to last week of June 2016. Valleau (1923) reported that 10.6 percent primary flowers in the clusters failed to set or setting imperfectly, whereas secondary tertiary and quarternary, 20.9 percent, 36.7 percent and 50.6 percent flowers respectively failed to set fruit.

Fruit retention upto maturity in open pollination was 72%. Bist (1985) obtained as much as 22.40 % fruit retention upto maturity under cross pol lination in apple cultivar. Further, 3.87 % and 0.49 % fruit retention was recorded under hand self pollination and selfing by bagging.

CHAPTER 6

SUMMARY AND CONCLUSION

Strawberry have their own importance, because of high nutritive value, vitamin C content and suitability to various products and uses. A survey of literature has revealed that various aspects of floral biology, pollination and fruit set are the parameters which are most important pre-requisites for any improvement and hybridization programme has yet not received much attention in strawberry fruits under temperate conditions in the hills. The hills and valley areas of Uttarakhand state offer suitable climate for growing strawberry fruits and thus, there seems to be a big scope of these fruits. The present investigation on the above aspects has been carried out under mid hill conditions for strawberry at V.C.S.G College of Horticulture, Bharsar, Pauri Garhwal, U.K. The salient finding of the study are being summarized in the following paragraphs:

6.1 Floral biology

6.1.1 Strawberry varieties differed in the number of inflorescence per plant and in the average number of flowers per plant. Growth was observed to be sympodial and inflorescences were formed terminally. Flowers were born in cymose clusters in all the varieties.

6.1.2 A typical flower of strawberry was pentamerous with regard to all the floral parts except the carpels. The size of the flower was variable; the primary flowers being the largest followed by secondary tertiary and so on. All the flowers were hermaphrodite. The number of floral parts was observed to be higher in the primary flowers than the secondary and tertiary flowers.

6.1.3 The floral bud was observed to pass through eight distinct stages taking a total of 16 days to develop from first visible stage to the full bloom.

6.1.4 The flower of strawberry is hermaphrodite, complete, perfect, and hypogynous. The average size of flowers are (length × diameter) 1.9 × 0.7 cm and basically made up of four concentric rings of structure. The outer ring of modified leaves called sepals which are green in colour and 5 in numbers. Inside the sepals is another ring of modified leaves called petals which are often white in colour. This layer is known as the corolla which are also 5 in numbers. Within the corolla are more stamens containing pollen (20 to 22), which are the male reproductive structures. In the very centre of the flower are the female reproductive organs which are known as pistil, which are also more in numbers (90 to

120). The female parts of a flower consist of an ovary, which contains one or more ovules, a style and the stigma. The ovary is at the base of the flower.

6.1.5 The period of anthesis varied from 6 am to 6 pm with the peak period of anthesis (38%) having reached between 10 am to 12 noon.

6.1.6 The dehiscence started just after complete anthesis. The anther lobes marginally bursting generally from top to base and single anther required 20- 25 minutes to dehisce completely. The major dehiscence period of the day was recorded between 10 am to 4 pm. The highest number of anthers (44.54%) dehisced between 10 am to 12 noon. Dehiscence complete in one day.

6.2 Pollen studies

6.2.1 Amongst different media tested, maximum length of pollen grain was observed in dry condition (155.51 µ) and glycerol (155.51 µ) while maximum width of pollen grain was observed in water condition (137.74 µ) followed by acetocarmine (115.52 µ). The shape of pollen grains in glyccerol and dry conditions were oblong and in acetocarmine and water pollen grains looked round in shape. The pollen viability was recorded 100% through acetocarmine test.

6.2.2 The highest pollen germination percentage 94.34% and maximum pollen tube length 59.54µwas recorded with T_{12} (20% sucrose solution + 0.4 % boric acid solution). The pollen was observed viable up to seven days with 33.33% viability, which decreased rapidly and after one day of storage it remained 0%. The viability was decreased rapidly and after 9 days of storage, the germination percentage totally declined.

6.3 Stigma receptivity

The stigma continued to be receptive from two days prior to two days after anthesis. However, the best receptivity of stigma (100%) has been witnessed on the day of anthesis by the fruit set method.

6.4 Mode of pollination and fruit set

Among the three modes of pollination, viz., self pollination, natural pollination and cross pollination the maximum fruit set (88.00%) has been recorded under natural pollination, followed by self pollination (64.00%).

6.5 Fruit retention upto maturity

Fruit retention upto maturity in open pollination was observed 72%. Which was observed after final fruit set to maturity of fruits.

Conclusion

In present study, under hilly conditions of Uttarakhand, strawberry flowers pass through eight distint stages taking a total of 16 days to develop from visible stage to full bloom. Time and duration of flowering was varies from 5th March to 11th June and peak anthesis of flower bud varies from 10am – 12 noon. The anthers dehiscence was observed after anthesis the peak period of anthers dehisced 10 am to 12 noon. Stigma receptivity was highest on the day of anthesis. In Strawberry plants the more fruit set occurred via natural pollination. The maximum length of pollen grain was observed in dry condition and glycerol while maximum width of pollen grain was observed in water condition and acetocarmine condition. The pollen viability was recorded 100% on the day of anthesis. The highest pollen germination percentage and maximum pollen tube length was recorded with T_{12} (20% sucrose solution + 0.4 % boric acid solution). From the above observation we conclude that, under hilly conditions of Uttarakhand, to do the breeding work and production of strawberry, February - June month is more suitable. The above study gave the estimate of time and duration of various flowering stages. The above information can be utilized in the future breeding programmes that involve extensive crossing works. This research will serve as a vital step in the developments of improved genotypes of strawberry with commercial potential.

CHAPTER 7

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Appendices

Appendix 1: Meteorological weather data February to June (2015) at Bharsar

Month	Maximum Temperature (˚C)	Minimum Temperature (˚C)	Relative Humidity Maximum (%)	Relative Humidity Minimum (%)
7 Feb-13Feb	14.16	11.58	91	20
14Feb - 20 Feb	14.50	12.20	88	18
21 Feb –27Feb	14.20	11.00	92	20
28 Feb – 6Mar	12.25	9.25	94	30
7 Mar – 13Mar	16.60	13.30	96	31
14Mar – 20Mar	16.75	14.08	93	22
21 Mar- 27 Mar	21.75	18.33	95	27
28 Mar – 3 Apr	22.87	19.50	96	16
4 Apr – 10 Apr	19.75	14.75	90	17
11 Apr – 17Apr	19.10	16.70	92	21
18 Apr – 24Apr	22.75	18.88	94	16
25 Apr – 1 May	21.00	18.50	78	21
2 May – 8 May	21.55	19.75	57	19
9 May – 15May	23.75	21.67	90	16
16 May- 22May	23.58	21.25	75	17
23 May-29May	27.42	24.67	82	15
30 May -5 June	25.50	22.67	92	17
6 June- 12 June	28.16	22.69	97	43
13 June-19June	26.00	23.75	99	60
20 June-26June	21.75	19.08	99	65

Appendix 2: Meteorological weather data February to June (2016) at Bharsar

Week no. and month	Temp. Min.	Temp. (˚C) Max.	RH (%) Max.	RH Min.
Feb	01–06	11.5	2.5	60
Feb	07-14	5.0	2.0	66
Feb	15-20	13.0	10.0	72
Feb	22-28	13.5	11.5	90
March	01-07	12.5	9.5	75
March	08-14	18.5	10.0	80
March	15-21	17.0	13.0	75
March	22-28	9.5	6.0	70
Mar-April	29-04	13.8	10.5	55
April	05-11	13.5	12.5	70
April	12-18	14.0	11.0	72
April	19-25	17.0	13.5	75
April-May	26-02	25.0	23.5	80
May	03-09	18.5	17.0	80
May	10-17	21.5	20.2	79
May	18-24	28.0	25.5	80
May	25-31	17.5	16.0	82
June	01-07	25.0	22.5	85
June	08-14	26.5	23.5	87
June	15-21	23.0	22.5	89
June	22-28	23.0	22.5	90

Appendix 3: ANOVA Table for pollen length

SV	DF	SS	MSS	F cal	SV
Treatment	3	3,242.866	1,080.955	7.300	0.01118
Error	8	1,184.584	148.073		
Total	11	4,427.450			
CD (0.05) = 23.26	**CV = 8.62**				
SE(m) = 7.02					

Appendix 4: ANOVA Table for pollen width

SV	DF	SS	MSS	F cal	SV
Treatment	3	5,567.611	1,855.870	31.334	0.00009
Error	8	473.829	59.229		
Total	11	6,041.441			
CD (0.05) = 14.71	**CV = 7.21**				
SE(m) = 4.44					

Appendix 5: ANOVA Table for 6 hours pollen germination

SV	DF	SS	MSS	F cal	SV
Treatment	12	25,374.404	2,114.534	39.746	0.00000
Error	26	1,383.219	53.201		
Total	38	26,757.624			
CD (0.05) = 12.30	**CV = 18.73**				
SE(m) = 4.21					

Appendix 6: ANOVA Table for 24 hours pollen germination

SV	DF	SS	MSS	F cal	SV
Treatment	12	22,928.778	1,910.732	56.089	0.00000
Error	26	885.712	34.066		
Total	38	23,814.490			
CD (0.05) = 9.85	**CV = 9.86**				
SE(m) = 3.37					

Appendix 7: ANOVA Table for 6 hours pollen tube length

SV	DF	SS	MSS	F cal	SV
Treatment	12	7,540.295	628.358	66.286	0.00000
Error	26	246.468	9.480		
Total	38	7,786.762			
CD (0.05) = 5.19	**CV = 14.25**				
SE(m) = 1.77					

Appendix 8: ANOVA Table for 24 hours pollen tube length

SV	DF	SS	MSS	F cal	SV
Treatment	12	7,917.959	659.830	51.444	0.00000
Error	26	333.479	12.826		
Total	38	8,251.438			
CD (0.05) = 6.04	**CV = 11.08**				
SE(m) = 2.06					

ABSTRACT

Name of the student: Madhuri Kandwal **ID No.**: 14104

Year of admission: 2014 **Degree**: MSc. Horticulture (Fruit Science)

Major Field: Fruit Science **Department**: Fruit Science

Minor Field: Genetics and Plant Breeding

Title of Thesis: **"Studies on floral biology, pollination and fruit set in Strawberry (*Fragaria* × *ananasa* L.) under hilly conditions of Uttarakhand"**

The present investigations entitled "Studies on floral biology, pollination and fruit set in Strawberry (*Fragaria* × *ananasa*) under hilly conditions of Uttarakhand" was carried out at College of Horticulture, Uttarakhand University of Horticulture and Forestry, Bharsar, during 2015-1016. The different parameters for floral biology, pollination and fruit set was recorded on the basis of time period.

It was observed that the total span of flower bud development from bud emergence to the anthesis had eight different stages. The time required from flower bud development to reach anthesis was 16 days. The period of anthesis varied from 6 am to 6 pm with the peak period of anthesis (38%) having reached between 10 am to 12 noon. The major dehiscence period of the day was recorded between 10 am to 4 pm. The highest number of anthers (44.54%) dehisced between 10 am to 12 noon. Amongst different media tested, the average size of pollens (length × width) was maximum 155.52 × 88.86µ in glycerol conditions. The highest pollen germination percentage 94.34% and maximum pollen tube length 59.54µ was recorded with T_{12} (20% sucrose solution + 0.4 % boric acid solution). Best receptivity of stigma (100%) had witnessed on the day of anthesis by the fruit set method and the stigma receptivity continued upto one week. The maximum fruit set (88.00%) has been recorded under natural pollination, followed by self pollination (64.00%). The fruit retention upto maturity in case of natural pollination was 72%.

Hence, the studies indicated that the best time and duration of strawberry for production and breeding programme is last week of February to last week of June under hilly condition of Uttarakhand.

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सारांश

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प्रवेश का समय और वर्ष - 2014 **उपाधि - औद्यानिकी (फल विज्ञान)**

मुख्य विज्ञान - फल विज्ञान **विभाग - फल विज्ञान**

लघु विषय- आनुवांशिकता एवं पादप प्रजनन

शोध शीर्षक - "उत्तराखंड की पर्वतीय परिस्थितियो में स्ट्रॉबेरी (फ्रेगेरिया × अनानासा) के पुष्प जीव विज्ञान परागण एवं फल स्थापन का अध्ययन"

वर्तमान शोध शीर्षक "उत्तराखंड की पर्वतीय परिस्थितियों में स्ट्रॉबेरी (फ्रेगेरिया अनेनासा) के पुष्प जीव विज्ञान परागण एवं फल स्थापन का अध्ययन", औद्यानिकी महाविद्यालय, वी. च. सिं. ग. उत्तराखंड औद्यानिकी एवं वानिकी विश्वविद्यालय, भरसार के फल बगीचा प्रखंड में, फरवरी माह से जून माह 2016 तक किया गया, पुष्प आकारिकी परागण व फलन के विभिन्न पहलुओं का अध्ययन समय समय पर किया गया है। वर्तमान शोध कार्य का पारिणाम यह दर्शाता है कि स्ट्रॉबेरी के पुष्पों में पुष्प कलिका का विकास 8 विभिन्न चरणों में हुआ तथा पुष्प कलिका के सम्पूर्ण विकास में कुल 16 दिन के समय की आवश्यकता हुई। पुष्प खिलने का समय प्रात: 6 बजे से सांय 6 बजे तक देखा गया एवं पुष्प खिलने का शिखर समय प्रात: 10 बजे से दोपहर 12 बजे तक (38%) दर्ज किया गया। सबसे ज्यादा परागकोश स्फुटन (44.54%) भी प्रात: 10 बजे से दोपहर 12 बजे के बीच दर्ज किया गया। विभिन्न माध्यमों में परागकणों का आकार अध्ययन करने पर पाया गया कि परागकणों का सर्वाधिक आकार (लम्बाई × चौड़ाई) (155.52μ × 88.86μ) ग्लिसरोल माध्यम में दर्ज किया गया। परागणों का सर्वाधिक अंकुरण (94.34%) तथा परागनली की अधिकतम लम्बाई (59.54μ), T_{12} (20% सुक्रोज विलयन + 0.4% बोरिक अम्ल विलयन) में पायी गयी। वर्तमान शोध कार्य के परिणामों से यह प्रदर्शित होता है कि वर्तिकाग्र की ग्रहणशीलता पुष्प खिलने के दिन सर्वाधिक होती है, शोध के दौरान पाया गया कि पुष्प खिलने के दिन परागण से सर्वाधिक फल (100%) स्थापित हुए। साथ ही यह पाया गया कि प्राकृतिक परागण के द्वारा सर्वाधिक फल स्थापित (88%) हुए जबकि इसकी तुलना में स्वपरागण से 64% फल स्थापित हुए। प्राकृतिक परागण से फल की परिपक्वता तक फल अवधारण 72% दर्ज किया गया।

वर्तमान शोध के परिणामों से यह निष्कर्ष निकलता है कि पर्वतीय क्षेत्रों में स्ट्रॉबेरी फल की नयी प्रजाति तैयार करने हेतु प्रजनन कार्य का उचित समय फरवरी माह का अंतिम सप्ताह है।

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Whether sponsored by some state/ Central Govt./Univ./SAARC : No

Scholarship/ Stipend/ Fellowship, any other financial assistance received during the study period : No

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